AMRITA
VISHWA VIDYAPEETHAM
DEEMED TO BE UNIVERSITY

15CSE312
COMPUTER NETWORKS
3-0-0 3

Chapter 4: Network Layer

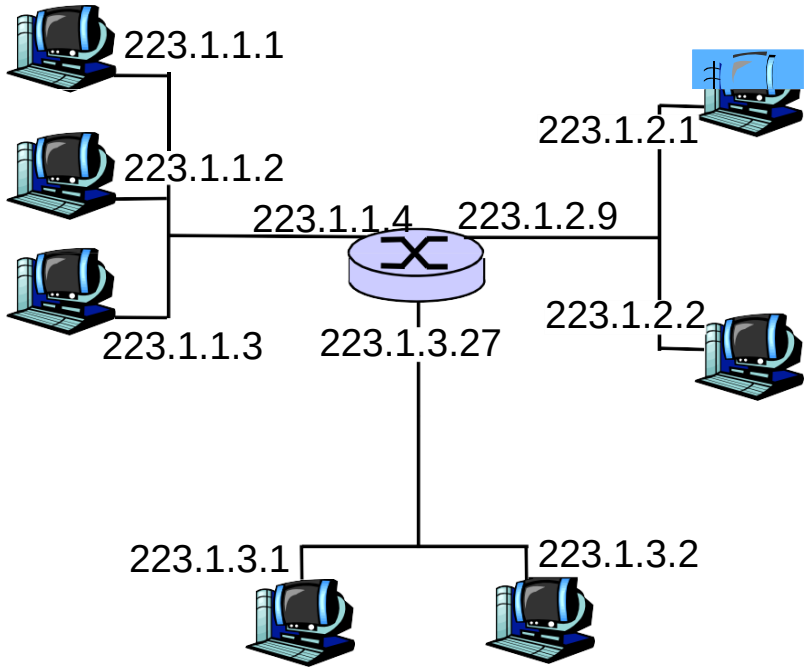
- IPV4 (revisit)
- Static IP/Dynamic IP
- DHCP
- NAT
- ICMP

Chapter 4: Network Layer

- 4. 1 Introduction
- 4.2 Virtual circuit and datagram networks
- 4.3 What's inside a router
- 4.4 IP: Internet Protocol
  - Datagram format
  - IPv4 addressing
  - ICMP
  - IPv6
- 4.5 Routing algorithms
  - Link state
  - Distance Vector
  - Hierarchical routing
- 4.6 Routing in the Internet
  - RIP
  - OSPF
  - BGP
- 4.7 Broadcast and multicast routing

IP Addressing: introduction

- IP address: 32-bit identifier for host, router *interface*
- *interface:* connection between host/router and physical link
  - router's typically have multiple interfaces
  - host typically has one or more interface
  - IP addresses associated with each interface

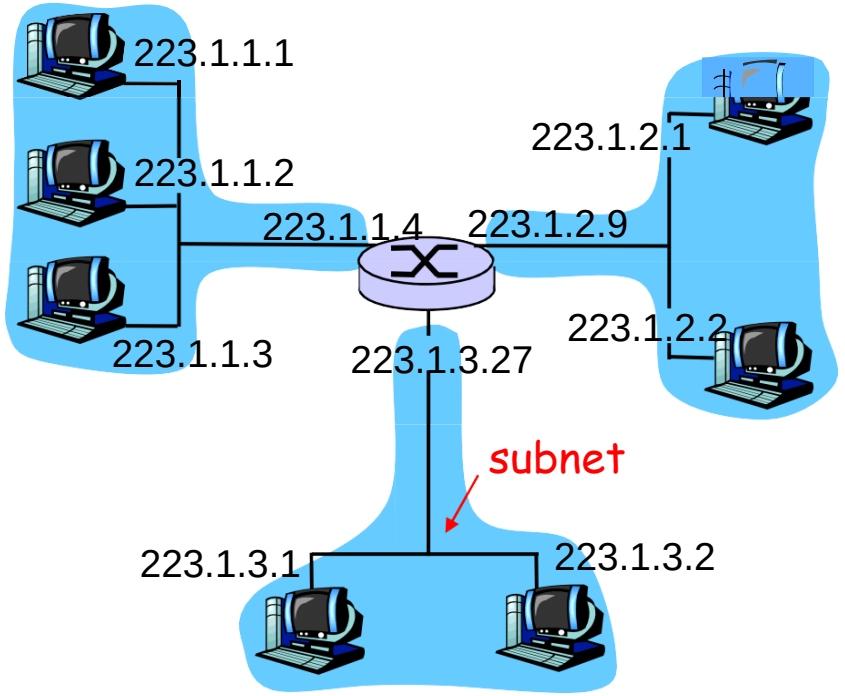


223.1.1.1 = 11011111 00000001 00000001 00000001

223 1 1 1

Subnets

- IP address:
  - subnet part (high order bits)
  - host part (low order bits)
- *What's a subnet ?*
  - device interfaces with same subnet part of IP address
  - can physically reach each other without intervening router

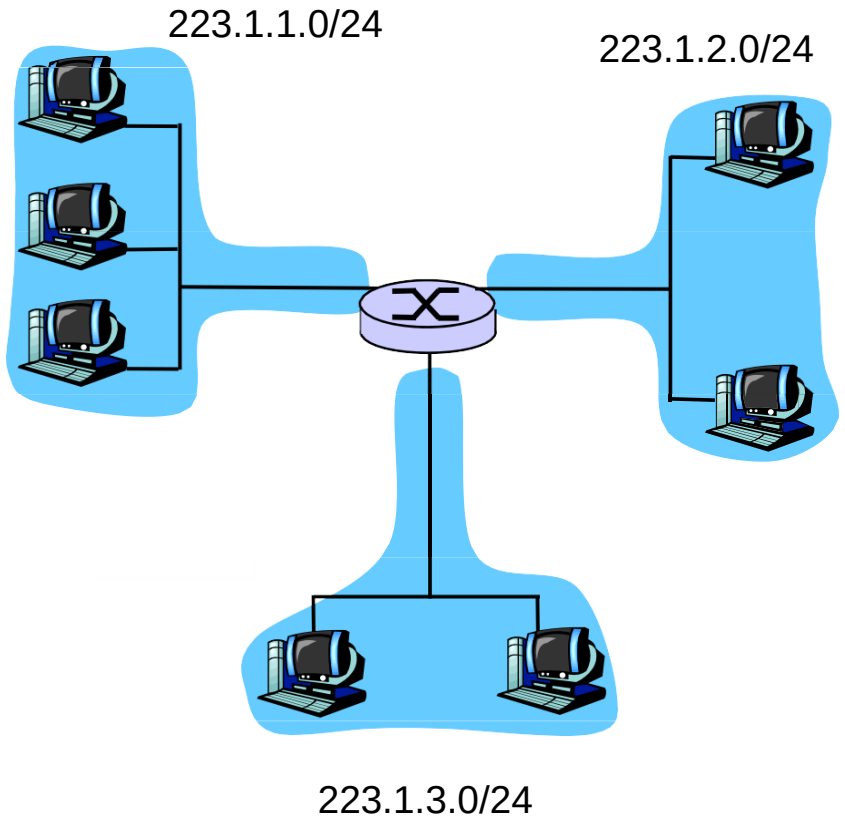


network consisting of 3 subnets

Subnets

Recipe

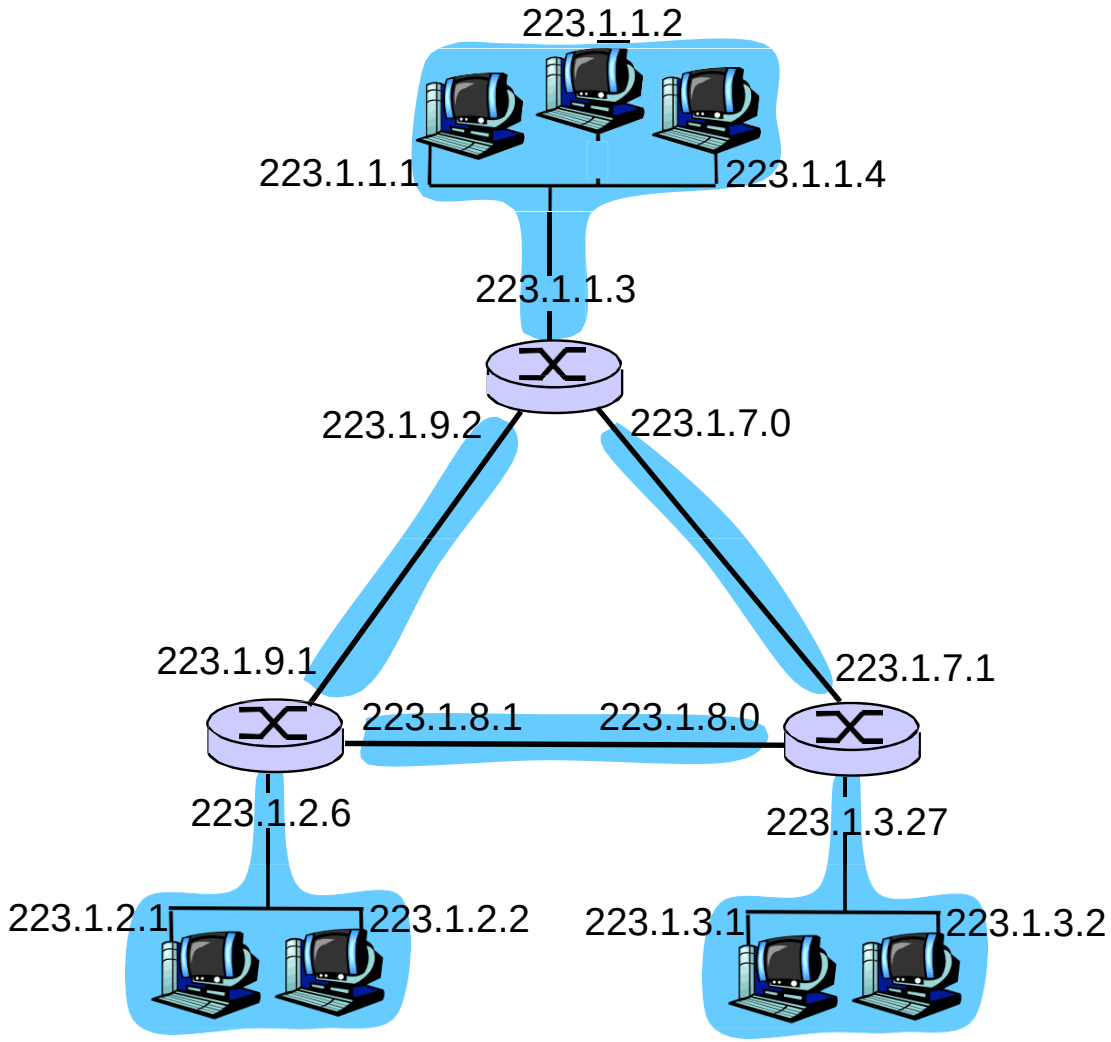
- To determine the subnets, detach each interface from its host or router, creating islands of isolated networks. Each isolated network is called a subnet.



Subnet mask: /24

Subnets

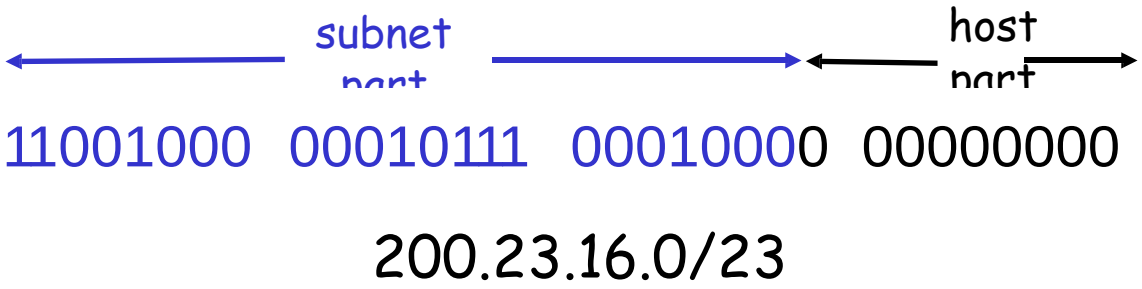
How many?



IP addressing: CIDR

CIDR: Classless InterDomain Routing

- subnet portion of address of arbitrary length
- address format: a.b.c.d/x, where x is # bits in subnet portion of address

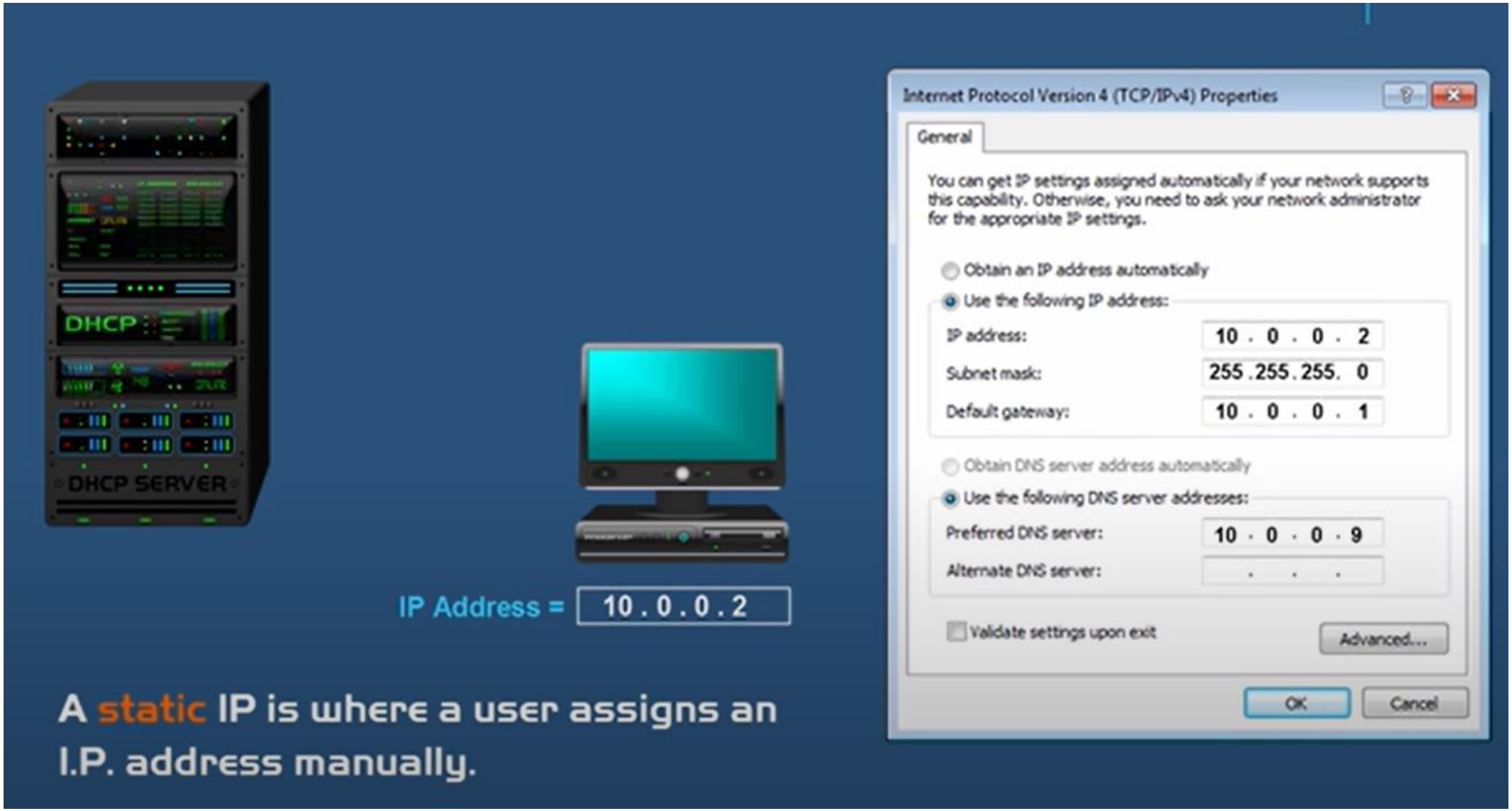


IP addresses: how to get one?

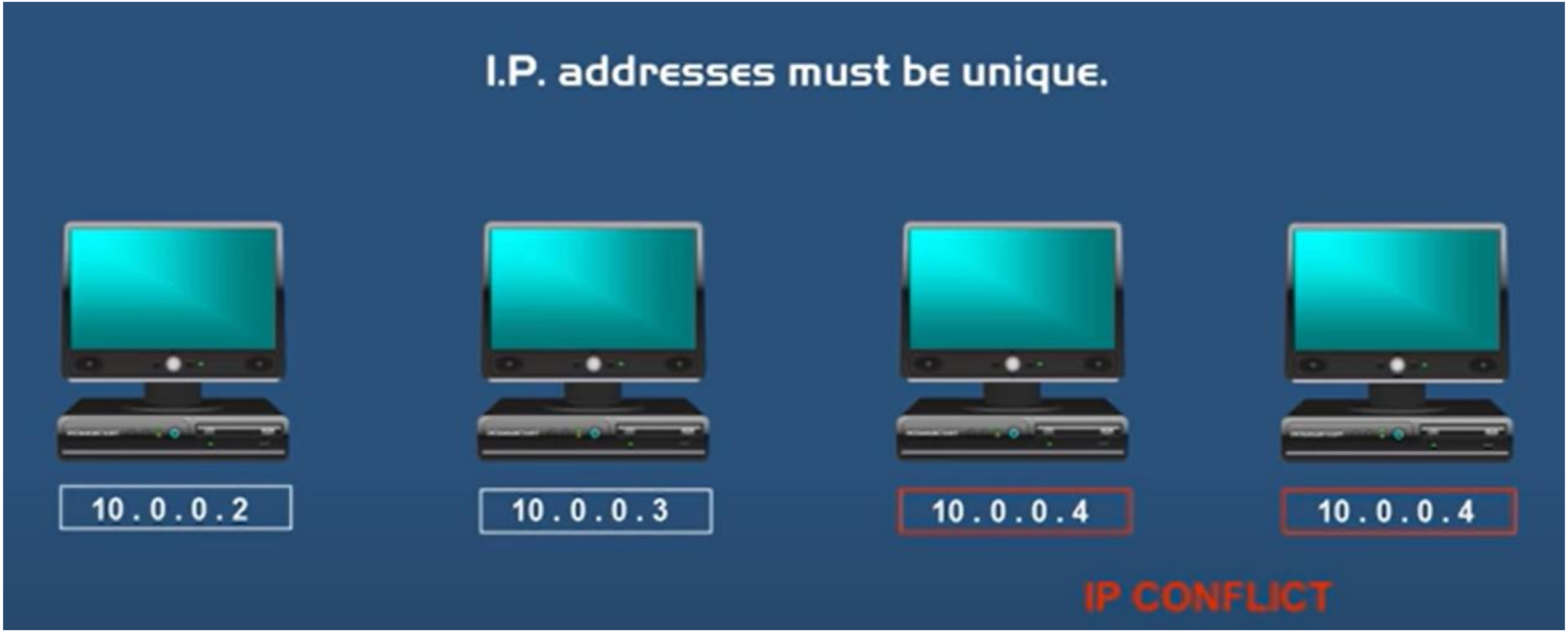
Q: How does a *host* get IP address?

- hard-coded by system admin in a file
  - Windows: control-panel->network->configuration->tcp/ip->properties
  - UNIX: /etc/rc.config
- DHCP: Dynamic Host Configuration Protocol: dynamically get address from as server
  - "plug-and-play"

Static IP


DHCP
DHCP SERVER
IP Address = 10 . 0 . 0 . 2
A static IP is where a user assigns an I.P. address manually.
Internet Protocol Version 4 (TCP/IPv4) Properties
General
You can get IP settings assigned automatically if your network supports this capability. Otherwise, you need to ask your network administrator for the appropriate IP settings.
Obtain an IP address automatically
Use the following IP address:
IP address: 10 . 0 . 0 . 2
Subnet mask: 255 . 255 . 255 . 0
Default gateway: 10 . 0 . 0 . 1
Obtain DNS server address automatically
Use the following DNS server addresses:
Preferred DNS server: 10 . 0 . 0 . 9
Alternate DNS server:
Validate settings upon exit
Advanced...
OK
Cancel

Static IP


I.P. addresses must be unique.
10 . 0 . 0 . 2
10 . 0 . 0 . 3
10 . 0 . 0 . 4
10 . 0 . 0 . 4
IP CONFLICT

DHCP: Dynamic Host Configuration Protocol

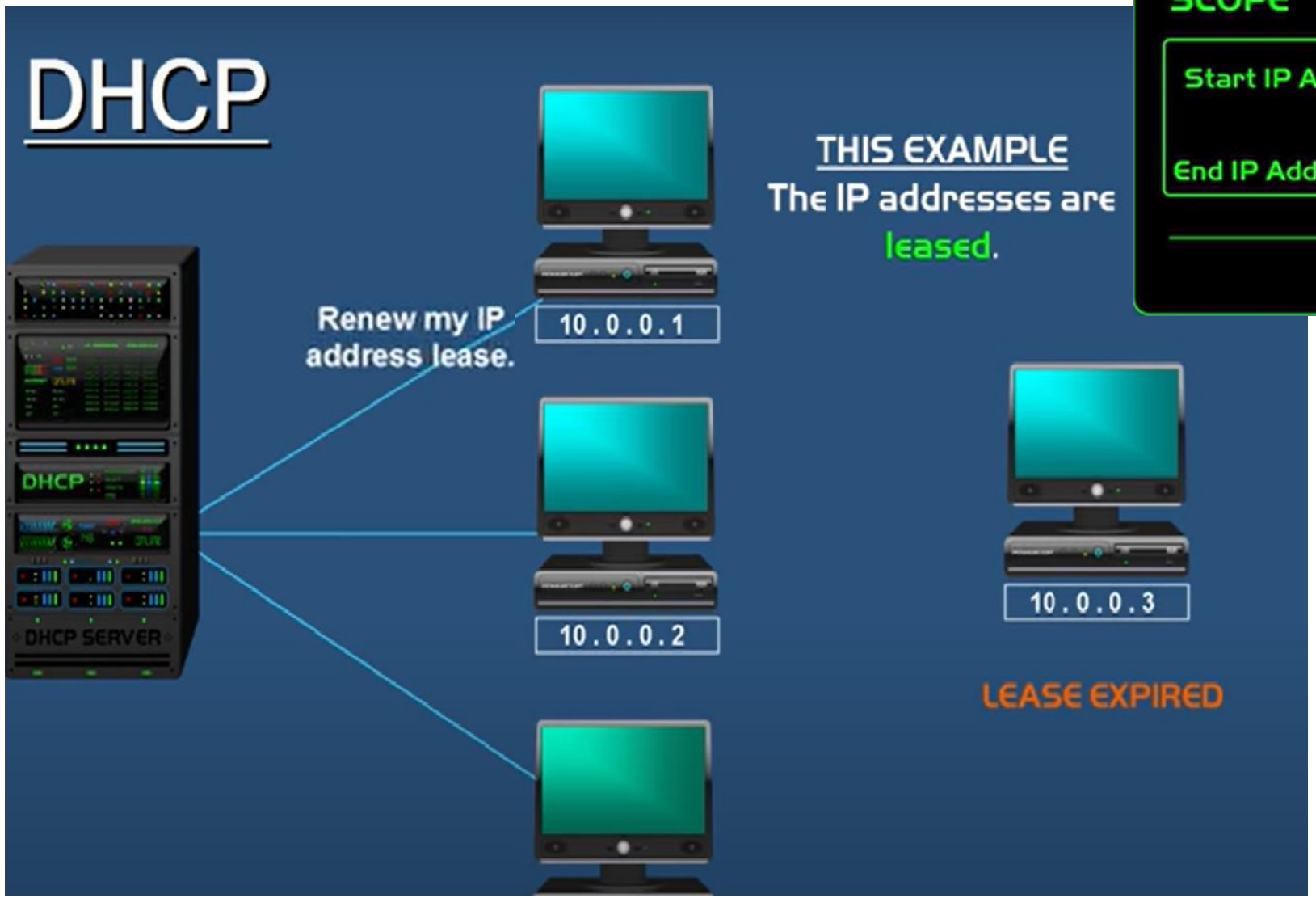
IP Address =

A dynamic IP is where a computer gets an I.P. address from a DHCP server.

A DHCP server automatically assigns a computer an:

- I.P. address
- Subnet mask
- Default gateway
- DNS server

DHCP: Dynamic Host Configuration Protocol



DHCP SETTINGS

SCOPE

Start IP Address	10 . 0 . 0 . 1
End IP Address	10 . 0 . 0 . 3

DHCP SETTINGS

ADDRESS RESERVATION

IP Address	Device Name	MAC Address
10.0.0.1	MY-PC	00:17:30:46:72:04

A reservation ensures that a specific computer or device will always be given the same I.P. address.

DHCP: Dynamic Host Configuration Protocol

DHCP is useful in residential ISP access networks. Consider, for example, a residential ISP that has 2,000 customers, but no more than 400 customers are ever online at the same time. In this case, rather than needing a block of 2,048 addresses, a DHCP server that assigns addresses dynamically needs only a block of 512 addresses (for example, a block of the form a.b.c.d/23). As the hosts join and leave, the DHCP server needs to update its list of available IP addresses. Each time a host joins, the DHCP server allocates an arbitrary address from its current pool of available addresses; each time a host leaves, its address is returned to the pool

A student who carries a laptop from a dormitory room to a library to a classroom. It is likely that in each location, the student will be connecting into a new subnet and hence will need a new IP address at each location. DHCP is ideally suited to this situation, as there are many users coming and going, and addresses are needed for only a limited amount of time.

DHCP: Dynamic Host Configuration Protocol-**plug-and-play protocol**

DHCP: Dynamic Host Configuration Protocol

Goal: allow host to *dynamically* obtain its IP address from network server when it joins network

- Can renew its lease on address in use
- Allows reuse of addresses (only hold address while connected an "on")
- Support for mobile users who want to join network (more shortly)

DHCP overview:

- host broadcasts "DHCP discover" msg [optional]
- DHCP server responds with "DHCP offer" msg [optional]
- host requests IP address: "DHCP request" msg
- DHCP server sends address: "DHCP ack" msg

DHCP client-server scenario

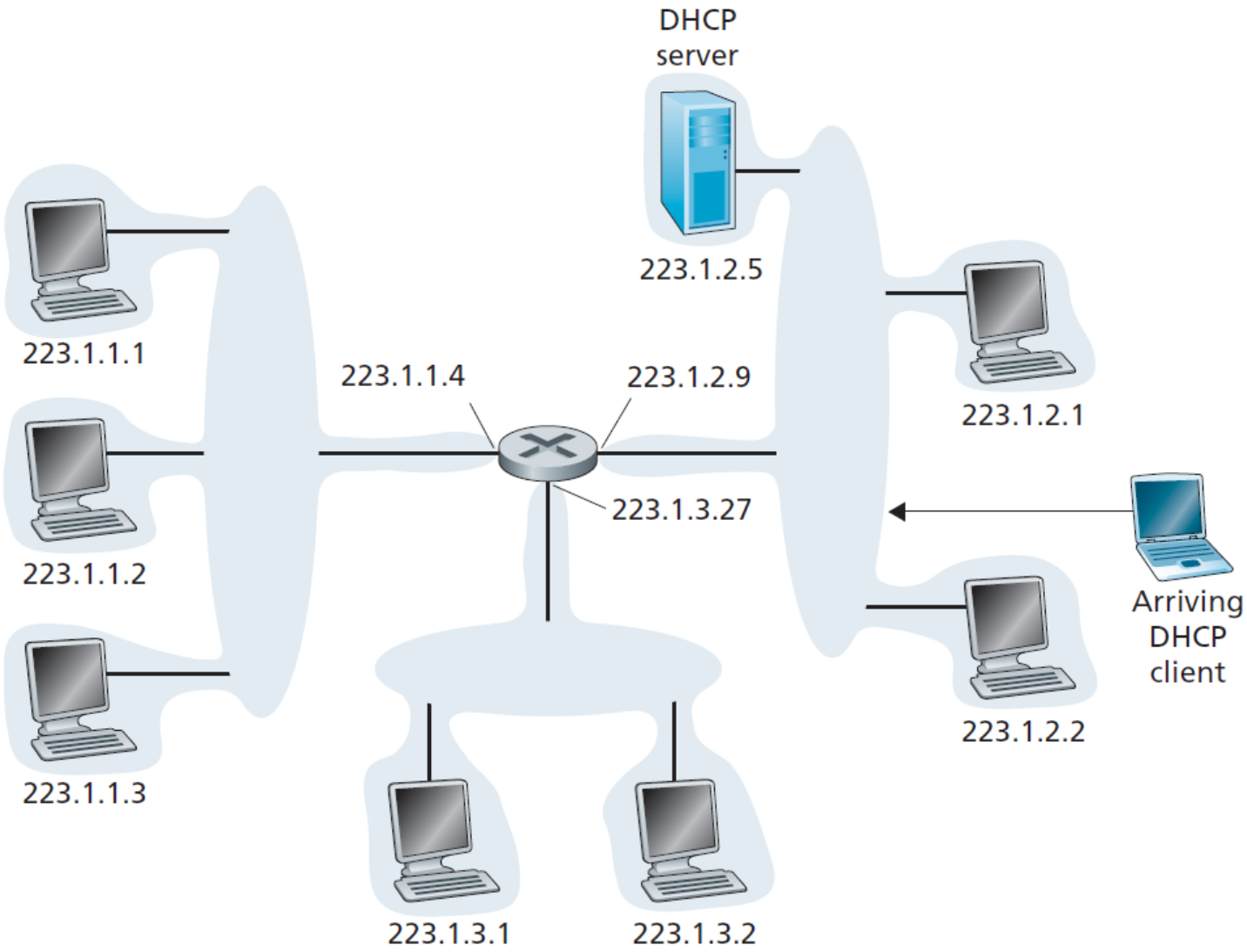
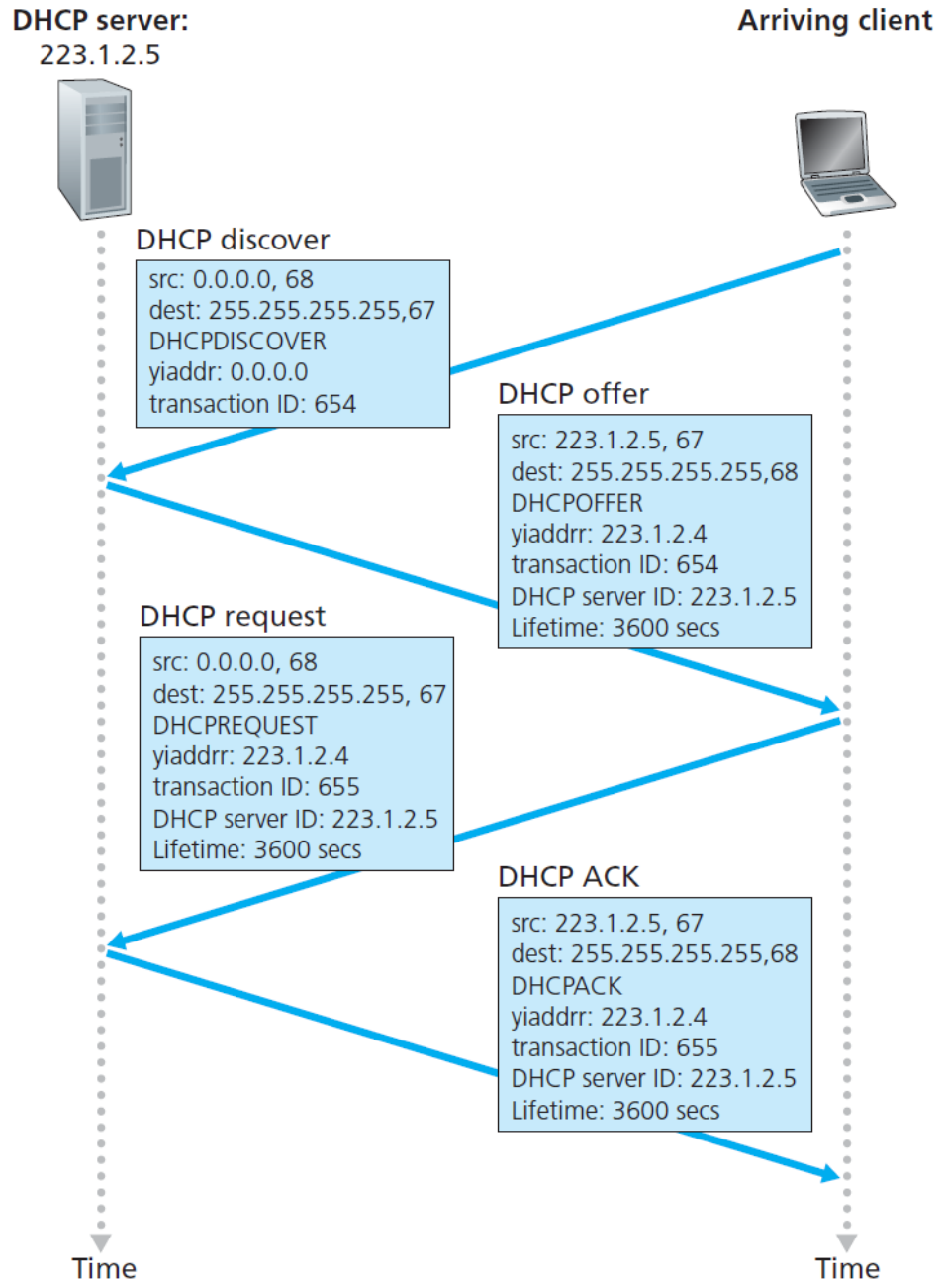


Figure 4.20 ♦ DHCP client-server scenario



4.21 ♦ DHCP client-server interaction

DHCP client-server interaction

DHCP server discovery. The first task of a newly arriving host is to find a DHCPserver with which to interact. This is done using a **DHCP discover message**, which a client sends within a UDP packet to port 67. The UDP packet is encapsulated in an IP datagram. the DHCP client creates an IP datagram containing its DHCP discover message along with the broadcast destination IP address of 255.255.255.255 and a "this host" source IP address of 0.0.0.0. The DHCP client passes the IP datagram to the link layer, which then broadcasts this frame to all nodes attached to the subnet

DHCP server offer(s). A DHCP server receiving a DHCP discover message responds to the client with a DHCP offer message that is broadcast to all nodes on the subnet, again using the IP broadcast address of 255.255.255.255 . Since several DHCP servers can be present on the subnet, the client may find itself in the enviable position of being able to choose from among several offers. Each server offer message contains the transaction ID of the received discover message, the proposed IP address for the client, the network mask, and an IP address lease time—the amount of time for which the IP address will be valid. It is common for the server to set the lease time to several hours or days

DHCP request. The newly arriving client will choose from among one or more server offers and respond to its selected offer with a **DHCP request message**, echoing back the configuration parameters.

DHCP ACK. The server responds to the DHCP request message with a DHCP ACK message, confirming the requested parameters.

Once the client receives the DHCP ACK, the interaction is complete and the client can use the DHCP-allocated IP address for the lease duration

DHCP: more than IP address

DHCP can return more than just allocated IP address on subnet:

- address of first-hop router for client
- name and IP address of DNS sever
- network mask (indicating network versus host portion of address)

IP addressing: the last word…

Q: How does an ISP get block of addresses?

A: ICANN: Internet Corporation for Assigned Names and Numbers

- allocates addresses
- manages DNS
- assigns domain names, resolves disputes

NAT: Network Address Translation

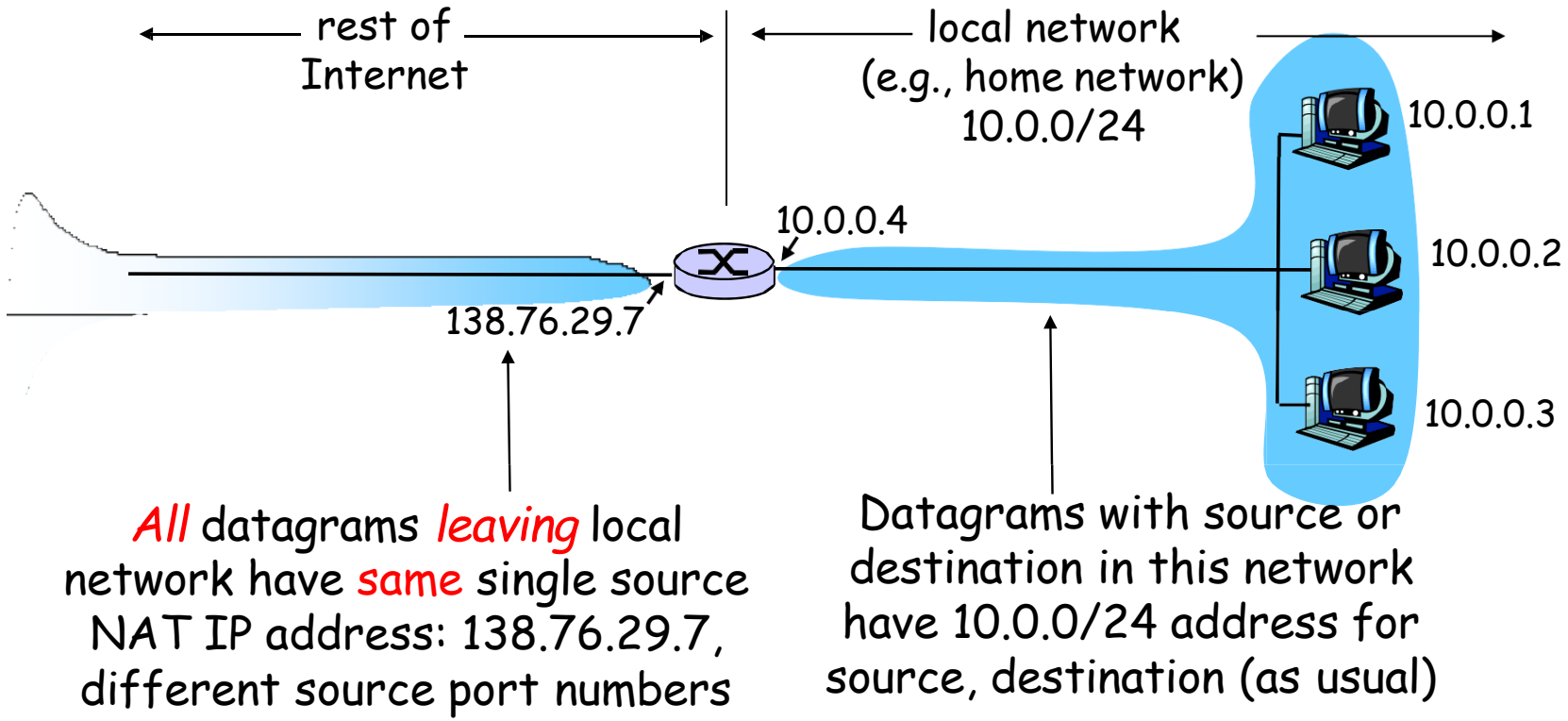
What is NAT?

Network Address Translation (NAT) is designed for IP address conservation(lack of IP addresses due to large vast amount of growing IT technology relying on IP addresses). It enables private IP networks that use unregistered IP addresses to connect to the Internet. NAT operates on a router, usually connecting two networks together, and translates the private (not globally unique) addresses in the internal network into legal addresses, before packets are forwarded to another network. NAT resulted in two types of IP addresses, public and private. A range of private addresses were introduced, which anyone could use, as long as these were kept private within the network and not routed on the internet. As part of this capability, NAT can be configured to advertise only one address for the entire network to the outside world. This provides additional security by effectively hiding the entire internal network behind that address. NAT offers the dual functions of security and address conservation and is typically implemented in remote-access environments.

Network Address Translation allows a single device, such as a router, to act as an agent between the Internet (or public network) and a local network (or private network), which means that only a single unique IP address is required to represent an entire group of computers to anything outside their network

The NAT-enabled router does not look like a router to the outside world. Instead the NAT router behaves to the outside world as a single device with a single IP address.

NAT: Network Address Translation



The router gets its address from the ISP's DHCP server, and the router runs a DHCP server to provide addresses to computers within the NAT-DHCP-router-controlled home network's address space.)

NAT translation table at the NAT router, will help in knowing the internal host to which it should forward a given Datagram.
To include port numbers as well as IP addresses in the table entries

All traffic leaving the home router for the larger Internet has a source IP address of 138.76.29.7, and all traffic entering the home router must have a destination address of 138.76.29.7

NAT: Network Address Translation

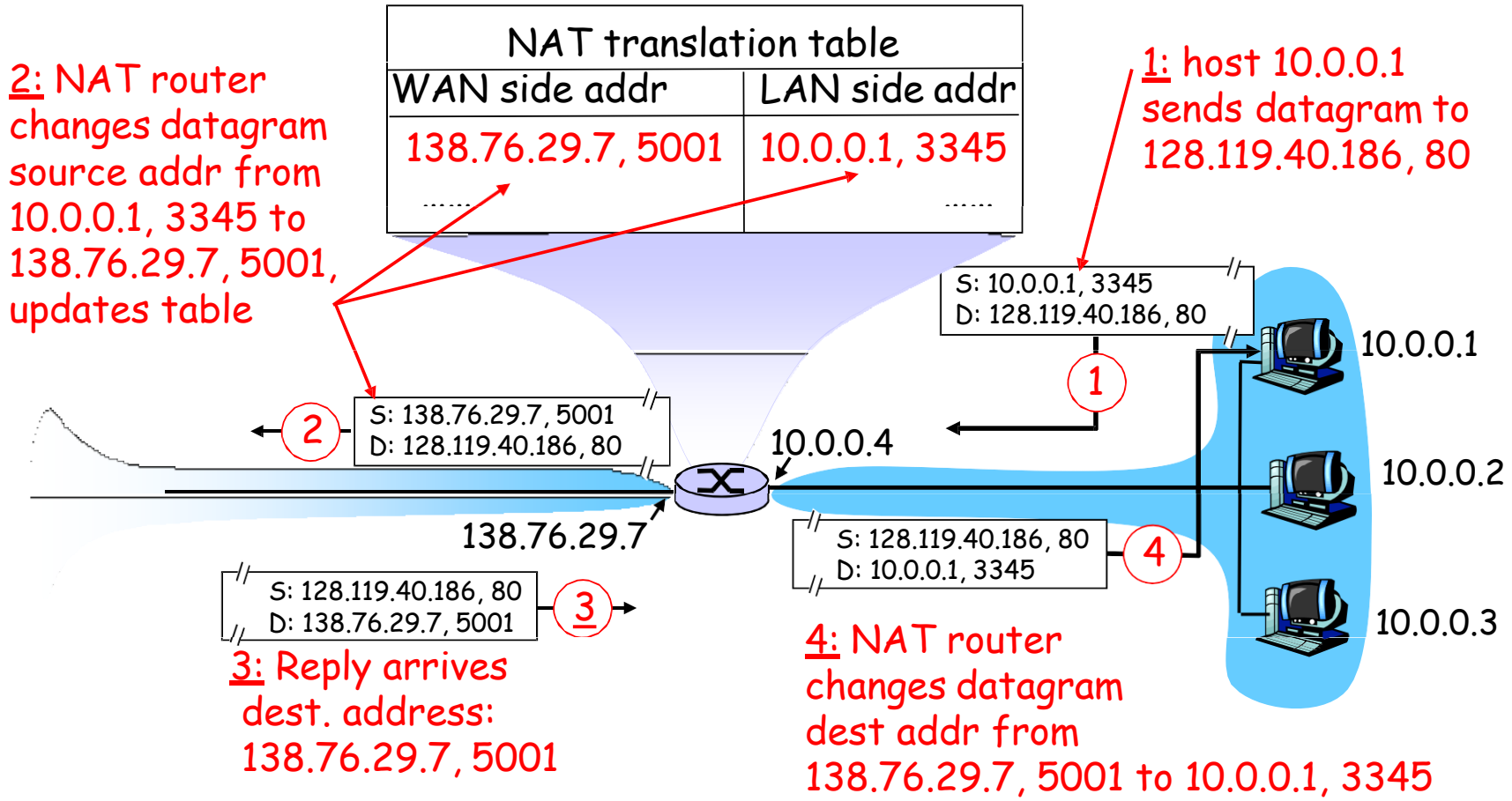
- Motivation: local network uses just one IP address as far as outside world is concerned:
  - range of addresses not needed from ISP: just one IP address for all devices
  - can change addresses of devices in local network without notifying outside world
  - can change ISP without changing addresses of devices in local network
  - devices inside local net not explicitly addressable, visible by outside world (a security plus).

NAT: Network Address Translation

Implementation: NAT router must:

- *outgoing datagrams: replace* (source IP address, port #) of every outgoing datagram to (NAT IP address, new port #)
  - . . . remote clients/servers will respond using (NAT IP address, new port #) as destination addr.
- *remember (in NAT translation table)* every (source IP address, port #) to (NAT IP address, new port #) translation pair
- *incoming datagrams replac* (NAT IP address, new port #) in dest fields of every incoming datagram with corresponding (source IP address, port #) stored in NAT table

NAT: Network Address Translation



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  - ICMP
  - IPv6
- 4.5 Routing algorithms
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- 4.6 Routing in the Internet
  - RIP
  - OSPF
  - BGP
- 4.7 Broadcast and multicast routing

ICMP: Internet Control Message Protocol

ICMP, specified in [RFC 792], is used by hosts and routers to communicate network- layer information to each other. The most typical use of ICMP is for error reporting.
For example, when running a Telnet, FTP, or HTTP session, you may have encountered an error message such as "Destination network unreachable." This message had its origins in ICMP. At some point, an IP router was unable to find a path to the host specified in your Telnet, FTP, or HTTP application. That router created and sent a type-3 ICMP message to your host indicating the error.
ICMP sends control messages such as *destination network unreachable*, *source route failed*, and *source quench*. It uses a data packet structure with an 8-byte header and variable-size data section.
Ping is a utility which uses ICMP messages to report back information on network connectivity and the speed of data relay between a host and a destination computer

ICMP is often considered part of IP but architecturally it lies just above IP, as ICMP messages are carried inside IP datagrams

ICMP messages have a type and a code field, and contain the header and the first 8 bytes of the IP datagram that caused the ICMP message to be generated in the first place

ICMP: Internet Control Message Protocol

- used by hosts & routers to communicate network-level information
  - error reporting: unreachable host, network, port, protocol
  - echo request/reply (used by ping)
- network-layer "above" IP:
  - ICMP msgs carried in IP datagrams
- ICMP message: type, code plus first 8 bytes of IP datagram causing error

Type	Code	description
0	0	echo reply (ping)
3	0	dest. network unreachable
3	1	dest host unreachable
3	2	dest protocol unreachable
3	3	dest port unreachable
3	6	dest network unknown
3	7	dest host unknown
4	0	source quench (congestion control - not used)
8	0	echo request (ping)
9	0	route advertisement
10	0	router discovery
11	0	TTL expired
12	0	bad IP header

Traceroute and ICMP

- Source sends series of UDP segments to dest
  - First has TTL =1
  - Second has TTL=2, etc.
  - Unlikely port number
- When nth datagram arrives to nth router:
  - Router discards datagram
  - And sends to source a ICMP message (type 11, code 0)
  - Message includes name of router& IP address
- When ICMP message arrives, source calculates RTT
- Traceroute does this 3 times

Stopping criterion

- UDP segment eventually arrives at destination host
- Destination returns ICMP "host unreachable" packet (type 3, code 3)
- When source gets this ICMP, stops.

Traceroute is a network diagnostic tool used to track in real-time the pathway taken by a packet on an IP network from source to destination, reporting the IP addresses of all the routers it pinged in between. **Traceroute** also records the time taken for each hop the packet makes during its **route** to the destination.

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IPv6

A successor to IPv4- IPv6

A prime motivation for the effort to develop a successor to the IPv4 protocol was the realization that the 32-bit IP address space was beginning to be used up, with new subnets and IP nodes being attached to the Internet (and being allocated unique IP addresses) at a breathtaking rate. To respond to this need for a large IP address space, a new IP protocol, IPv6, was developed. The designers of IPv6 also took this opportunity to tweak and augment other aspects of IPv4, based on the accumulated operational experience with IPv4.

- Initial motivation: 32-bit address space soon to be completely allocated.
- Additional motivation:
  - header format helps speed processing/forwarding
  - header changes to facilitate QoS
  - fixed-length 40 byte header
  - no fragmentation allowed

IPv6 Header (Cont)

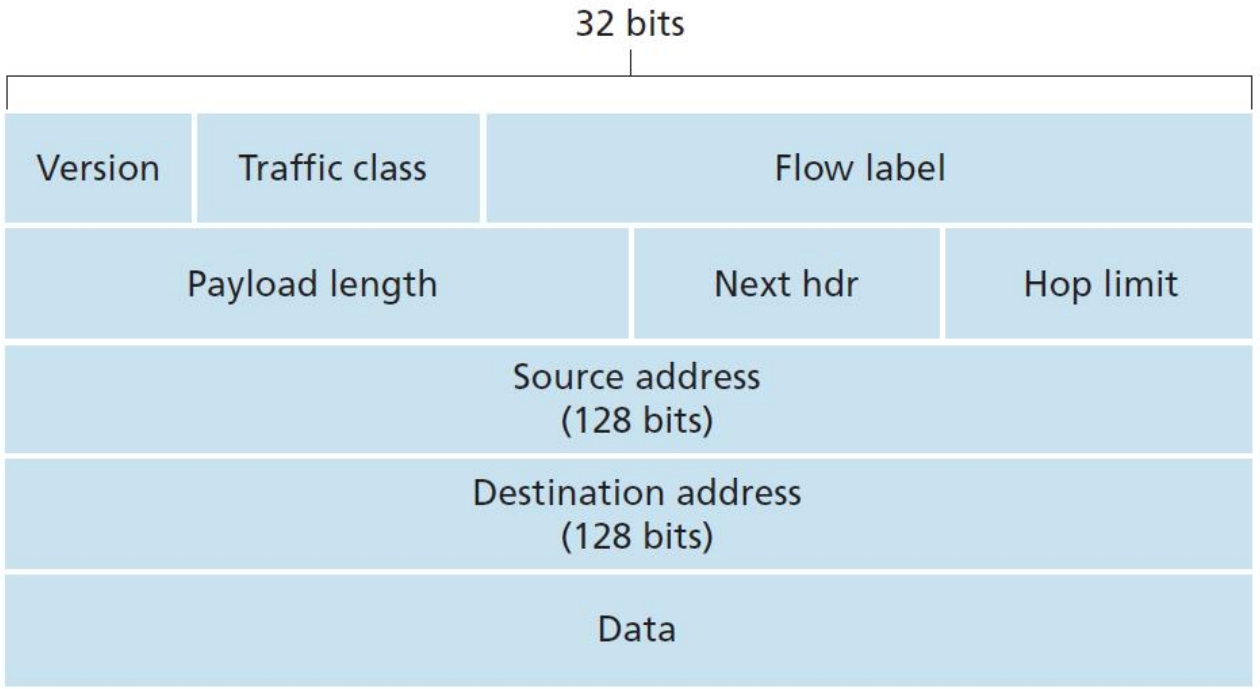


Figure 4.24 ♦ IPv6 datagram format

Priority: identify priority among datagrams in flow

Flow Label: identify datagrams in same "flow." (concept of"flow" not well defined).

Next header identify upper layer protocol for data

- *Checksum:* removed entirely to reduce processing time at each hop
- *Options:* allowed, but outside of header, indicated by "Next Header" field

Fixed 40 byte header

IPV6 Header

Version. This 4-bit field identifies the IP version number. Not surprisingly, IPv6 carries a value of 6 in this field.

Traffic class. This 8-bit field is similar in spirit to the TOS field we saw in IPv4

Flow label., this 20-bit field is used to identify a flow of datagrams.

Payload length. This 16-bit value is treated as an unsigned integer giving the number of bytes in the IPv6 datagram following the fixed-length, 40-byte datagram header.

Next header. This field identifies the protocol to which the contents (data field) of this datagram will be delivered (for example, to TCP or UDP). The field uses
the same values as the protocol field in the IPv4 header

Hop limit. The contents of this field are decremented by one by each router that forwards the datagram. If the hop limit count reaches zero, the datagram is discarded.

Source and destination addresses. The various formats of the IPv6 128-bit address are described in RFC 4291

Data. This is the payload portion of the IPv6 datagram. When the datagram reaches its destination, the payload will be removed from the IP datagram and passed on to the protocol specified in the next header field.

Other Changes from IPv4

Expanded addressing capabilities. *IPv6 increases the size of the IP address from 32 to 128 bits. This ensures that the world won't run out of IP addresses.*

A streamlined 40-byte header.:*A number of IPv4 fields have been dropped or made optional. The resulting 40-byte fixed-length header allows for faster processing of the IP datagram*

Flow labeling and priority: *"labeling of packets belonging to particular flows for which the sender requests special handling, such as a nondefault quality of service or real-time service."*

audio and video transmission might likely be treated as a flow. On the other hand, the more traditional applications, such as file transfer and e-mail, might not be treated as flows

Base Header	Extension Header	.....	Extension Header	Data

Extension Headers

1) Routing Header(43)
2) Hope by Hope option(0)
3) Fragment Header (44)
4) authentication Header(51)
5) Destination option (60)
6) Encapsulation Security (50)

Removed in IPv6

Fragmentation/Reassembly. IPv6 does not allow for fragmentation and reassembly at intermediate routers; these operations can be performed only by the source and destination. If an IPv6 datagram received by a router is too large to be forwarded over the outgoing link, the router simply drops the datagram and sends a "Packet Too Big" ICMP error message (see below) back to the sender. The sender can then resend the data, using a smaller IP datagram size. Fragmentation and reassembly is a time-consuming operation; removing this functionality from the routers and placing it squarely in the end systems considerably speeds up IP forwarding within the network

Header checksum. Because the transport-layer (for example, TCP and UDP) and link-layer (for example, Ethernet) protocols in the Internet layers perform checksumming, the designers of IP probably felt that this functionality was sufficiently redundant in the network layer that it could be removed.

Options. An options field is no longer a part of the standard IP header. However, it has not gone away. Instead, the options field is one of the possible next headers pointed to from within the IPv6 header. That is, just as TCP or UDP protocol headers can be the next header within an IP packet, so too can an options field. The removal of the options field results in a fixed-length, 40- byte IP header.

Transition From IPv4 To IPv6

How will the public Internet, which is based on IPv4, be transitioned to IPv6?

- Not all routers can be upgraded simultaneous
  - no "flag days"
  - How will the network operate with mixed IPv4 and IPv6 routers?
- *Tunneling:* IPv6 carried as payload in IPv4 datagram among IPv4 routers

The problem is that while new IPv6-capable systems can be made backwardcompatible, that is, can send, route, and receive IPv4 datagrams, already deployed IPv4-capable systems are not capable of handling IPv6 datagrams

Integrating IPv6 hosts and routers into an IPv4 world

RFC 4213 describes two approaches (which can be used either alone or together) for gradually integrating IPv6 hosts and routers into an IPv4 world (with the long-term goal, of course, of having all IPv4 nodes eventually transition
to IPv6)

- *dual-stack approach*
- *tunneling*

Dual Stack Approach

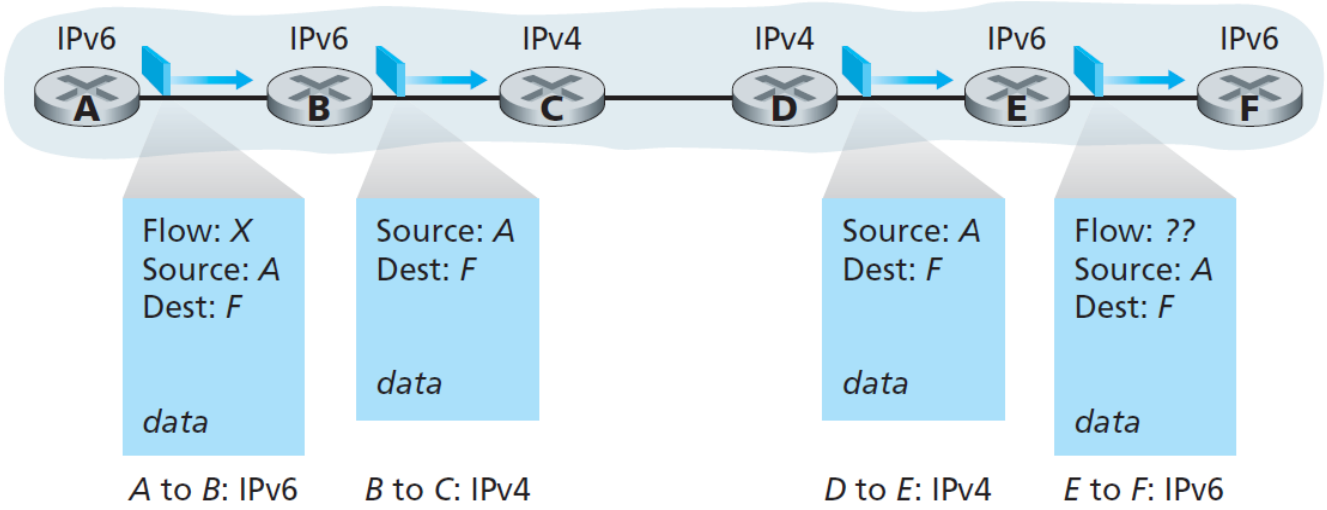
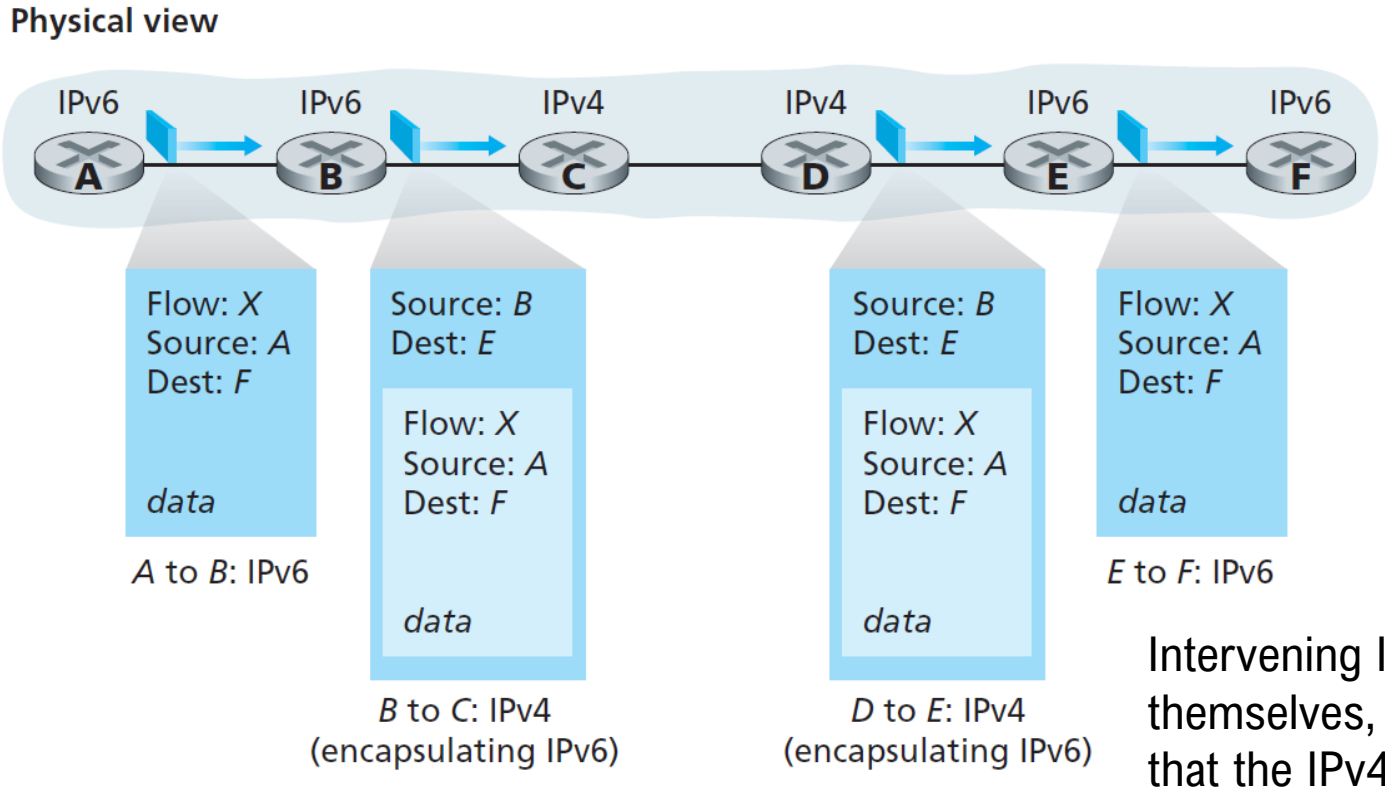


Figure 4.25 ♦ A dual-stack approach

- Nodes A and B can exchange an IPv6 datagram.
- Node B must create an IPv4 datagram to send to C. The information in the fields of IPv6 se fields will be lost.
- Thus, even though E and F can exchange IPv6 datagrams, the arriving IPv4 datagrams at E from D do not contain all of the fields that were in the original IPv6 datagram sent from A.

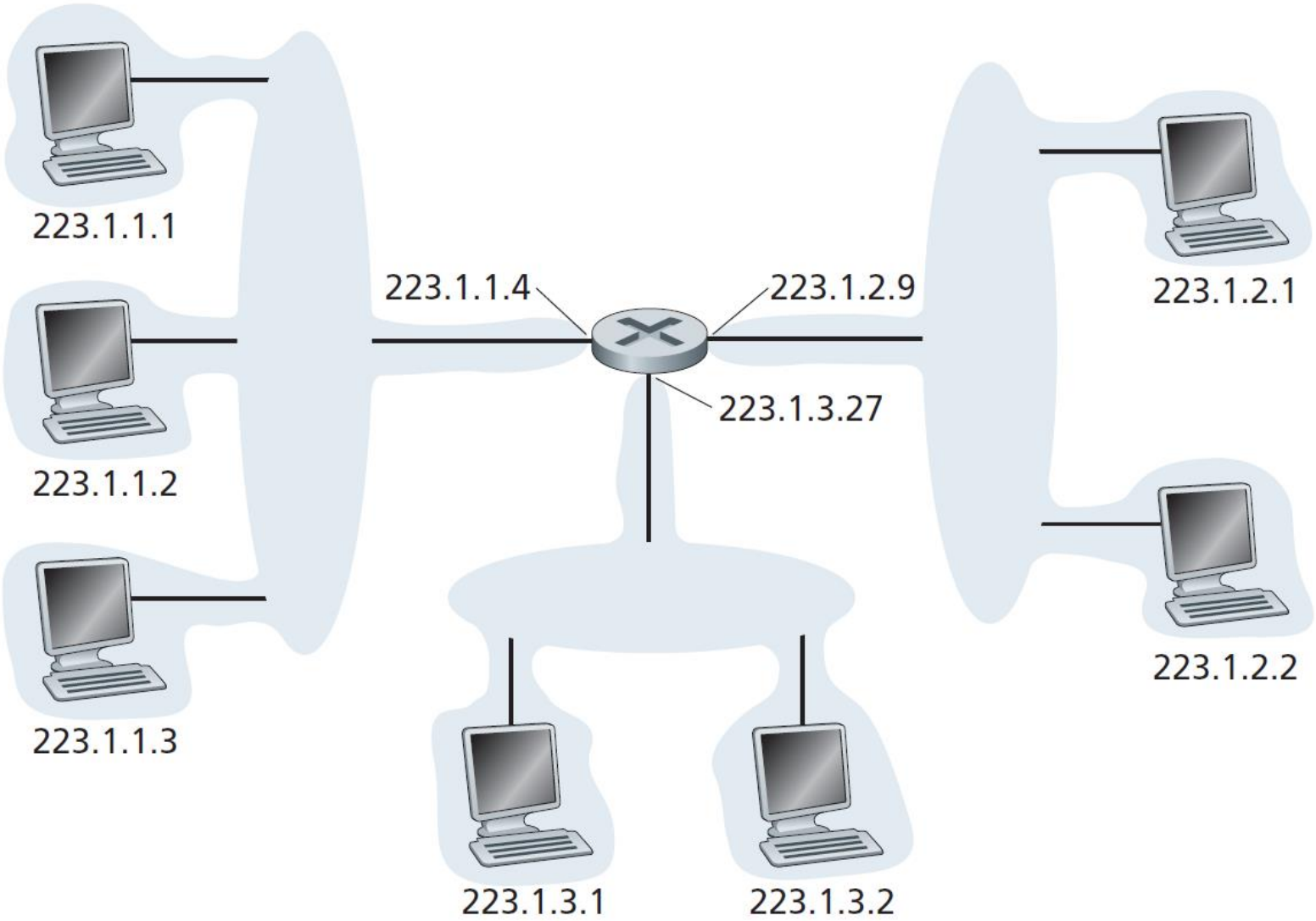
- **Dual-stack** approach, where IPv6 nodes also have a complete IPv4 implementation. Such a node, referred to as an IPv6/IPv4 node in RFC 4213, has the ability to send and receive both IPv4 and IPv6 datagrams. IPv6/IPv4 nodes must have both IPv6 and IPv4 addresses

Tunneling



- Suppose two IPv6 nodes (for example, B and E in Figure want to interoperate using IPv6 datagrams but are connected to each other by intervening IPv4 routers.
- We refer to the intervening set of IPv4 routers between two IPv6 routers as a **tunnel**, as illustrated in Figure
- With tunneling, the IPv6 node on the sending side of the tunnel (for example, B) takes the *entire* IPv6 datagram and puts it in the data (payload) field of an IPv4 datagram.

Intervening IPv4 routers in the tunnel route this IPv4 datagram among themselves, just as they would any other datagram, blissfully unaware that the IPv4 datagram itself contains a complete IPv6 datagram


223.1.1.1
223.1.1.2
223.1.1.3
223.1.1.4
223.1.2.9
223.1.3.27
223.1.2.1
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