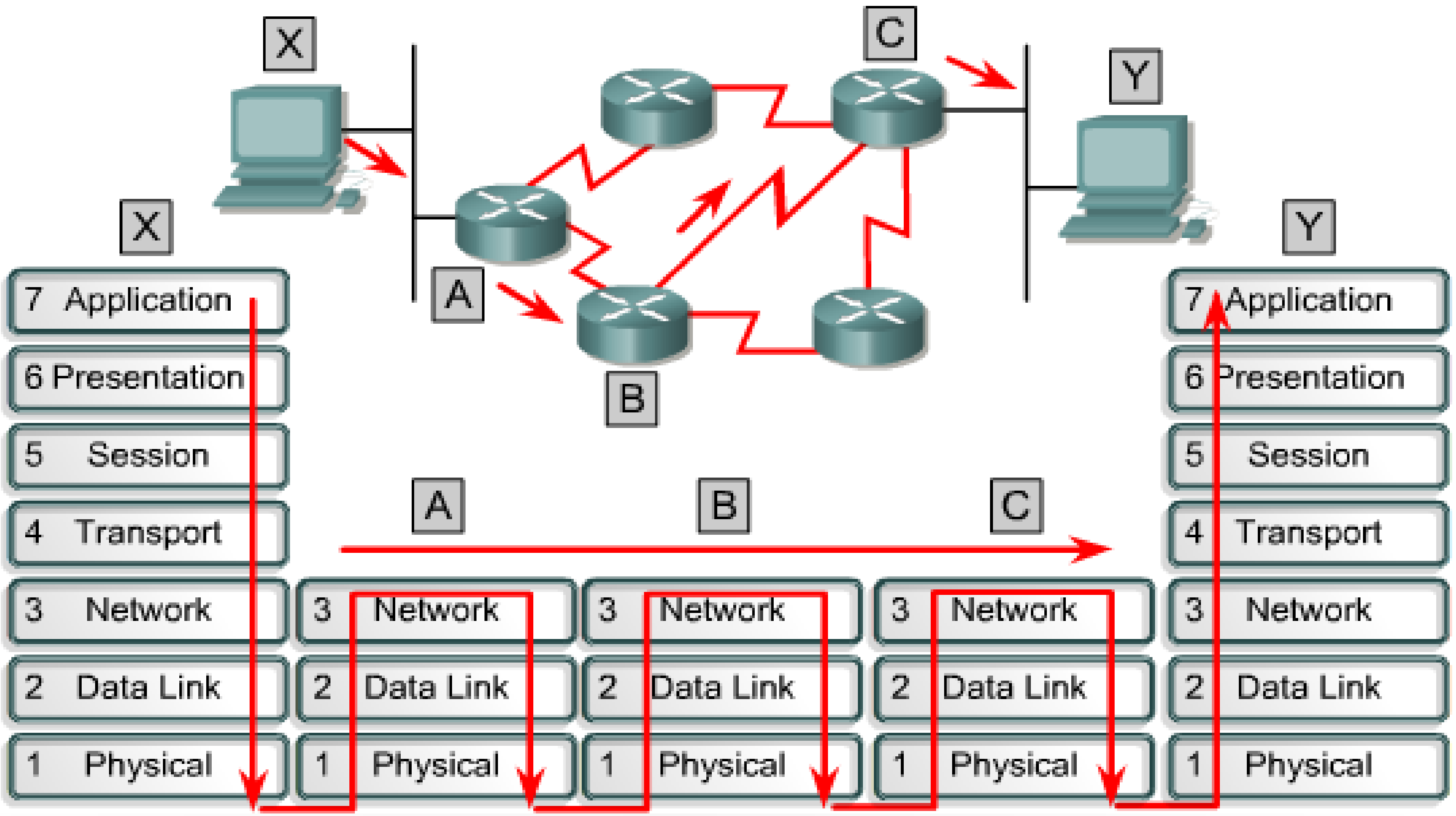
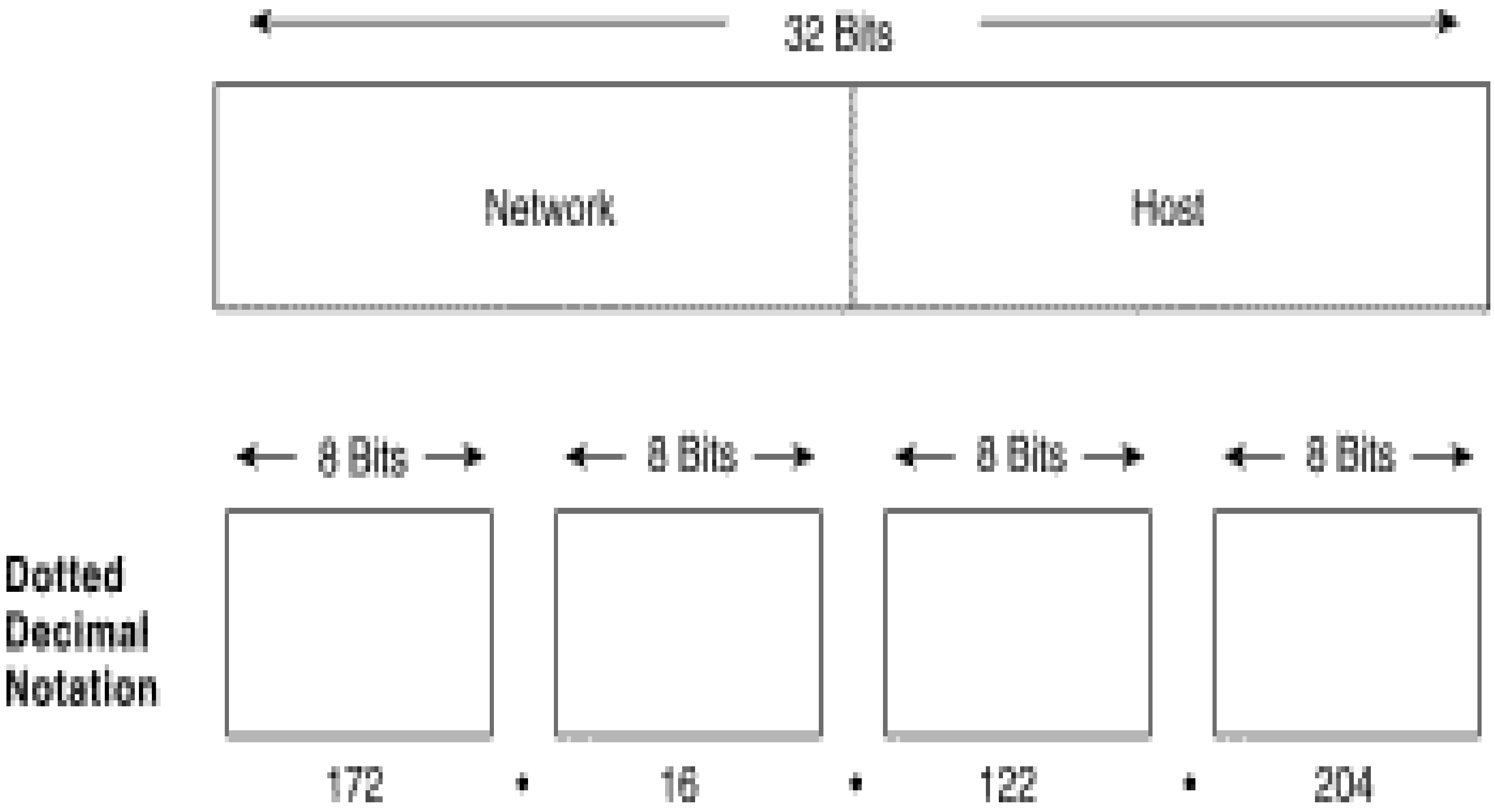
IP Addressing

- IP is a connectionless, unreliable, best-effort delivery protocol.
- All nodes are identified using an IP address.
- IP accepts whatever data is passed down to it from the upper layers and forwards the data in the form of IP packets.
- Packets are delivered from the source to the destination using IP address.
- IP address is for the **interface** of a host.
- Multiple interfaces mean multiple IP addresses.



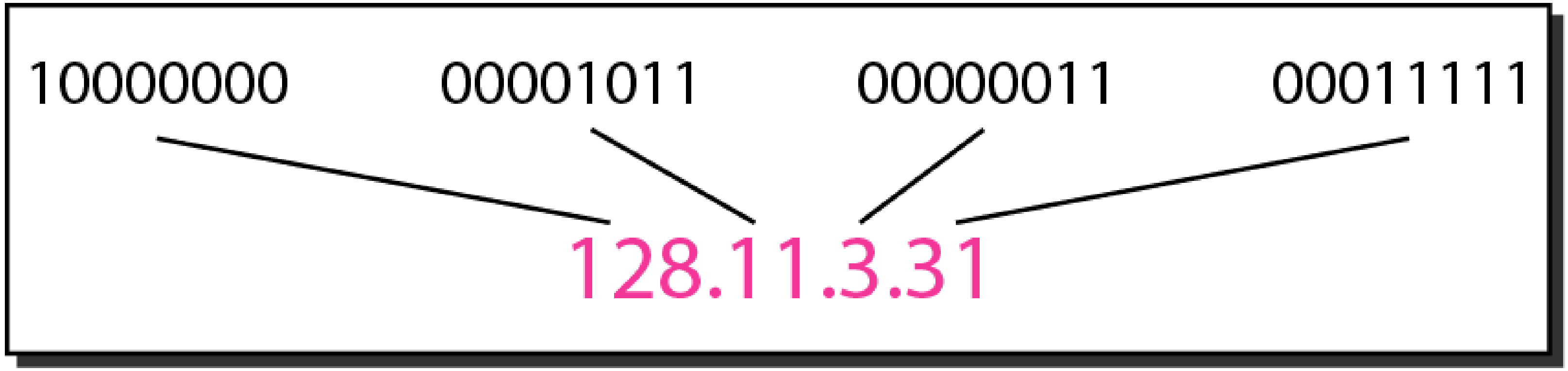
Each router provides its services to support upper-layer functions.

IP Address


32 Bits
Network
Host
8 Bits
8 Bits
8 Bits
8 Bits
Dotted
Decimal
Notation
172
•
16
•
122
•
204

IPv4 Addresses

- IPv4 address is a **32 bit** address.
- IPv4 addresses are unique and universal (all nodes connecting Internet must have IP addresses).
- Address space of IPv4 is 2^{32}



Classful Addressing

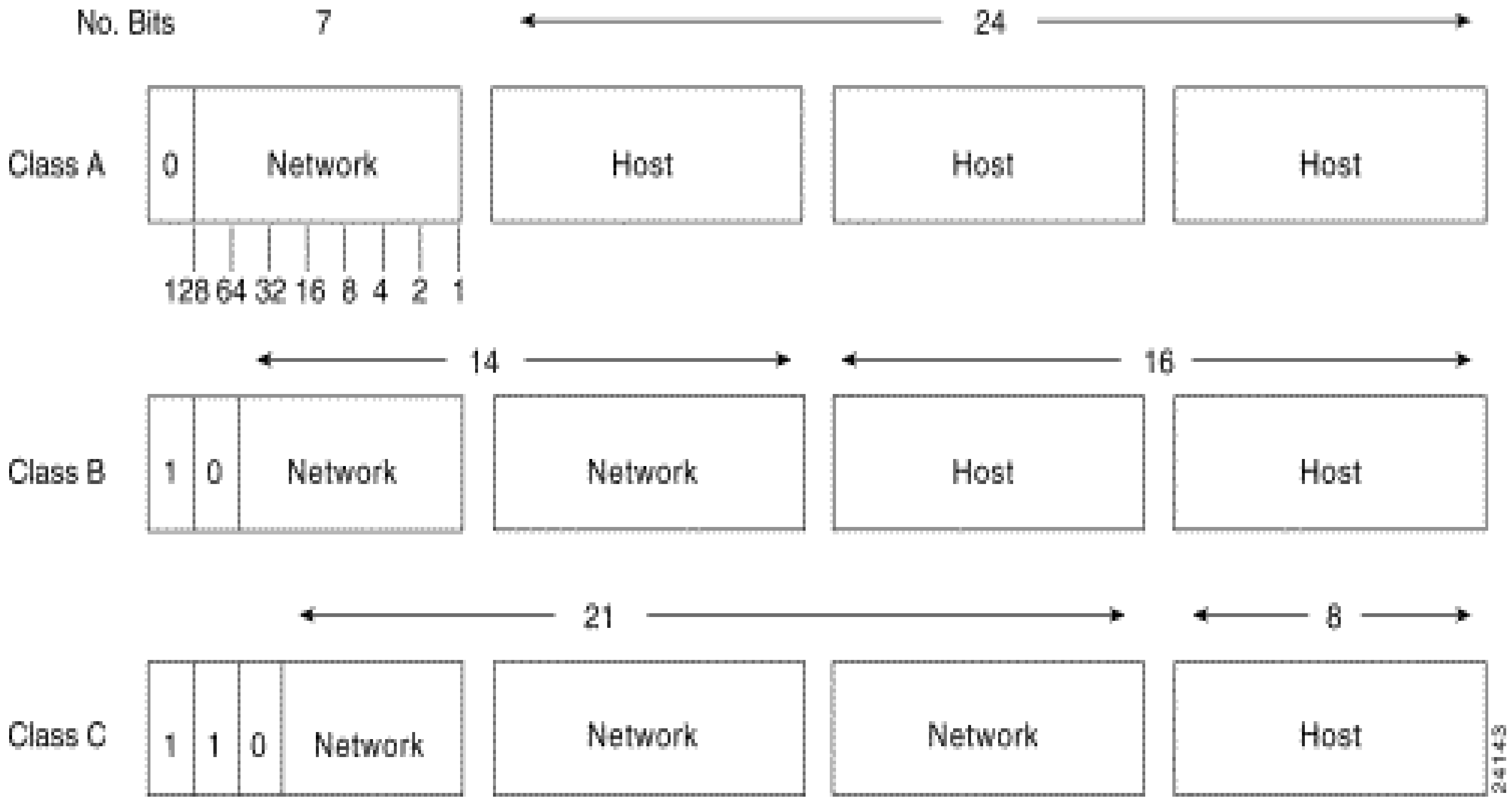
- The address space is divided into five classes: A, B, C, D, and E.
- A large part of the available addresses are wasted.
- Almost obsolete.

	First byte	Second byte	Third byte	Fourth byte
Class A	0			
Class B	10			
Class C	110			
Class D	1110			
Class E	1111			

a. Binary notation

	First byte	Second byte	Third byte	Fourth byte
Class A	0–127			
Class B	128–191			
Class C	192–223			
Class D	224–239			
Class E	240–255			

b. Dotted-decimal notation


No. Bits
7
24
Class A
0
Network
Host
Host
Host
128 64 32 16 8 4 2 1
14
16
Class B
1
0
Network
Network
Host
Host
21
8
Class C
1
1
0
Network
Network
Network
Host
24143

Number of blocks and block size in classful IPv4 addressing

Class	*Number of Blocks*	*Block Size*	*Application*
A	128	16,777,216	Unicast
B	16,384	65,536	Unicast
C	2,097,152	256	Unicast
D	1	268,435,456	Multicast
E	1	268,435,456	Reserved

- **Class A**: Address begins with bit 0. It has 8 bit network number (range 0.0.0.0-to-127.255.255.255), 24 bit host number.
- **Class B**: Address begins with bits 10. It has 16 bit network number (range: 128.0.0.0-to-191.255.255.255), 16 bit host number.
- **Class C**: Address begins with bits 110. It has 24 bit network number (range: 192.0.0.0-to-223.255.255.255), 8 bit host number.
- **Class D**: Begins with 1110, multicast addresses (224.0.0.0-to-239.255.255.255)
- **Class E**: Begins with 11110, unused

IPv4 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

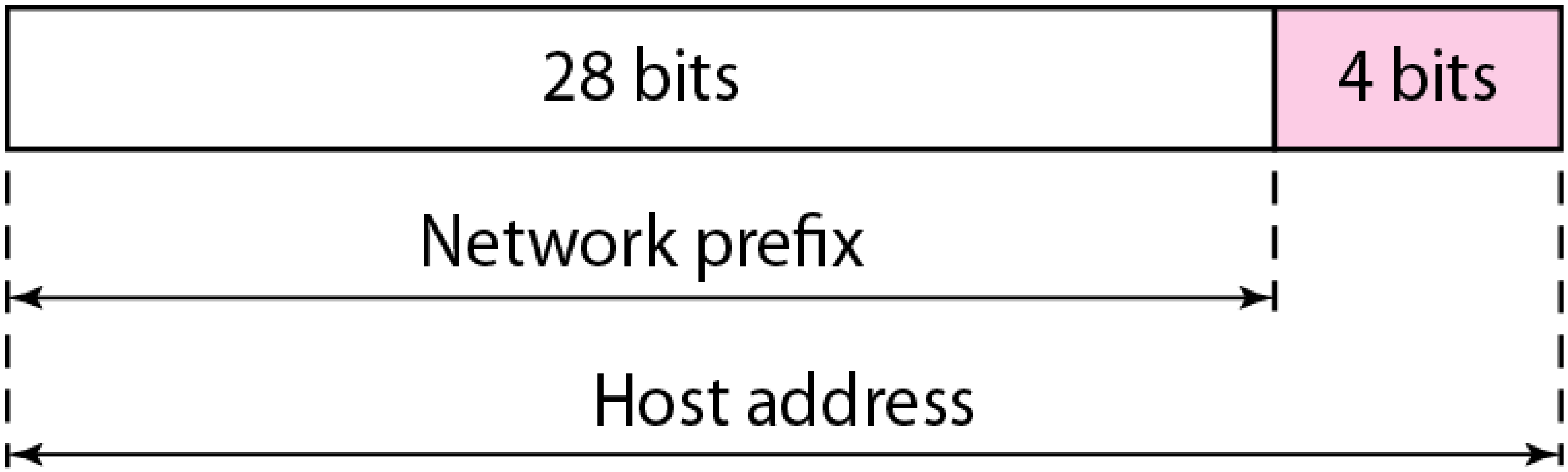
subnet part

host part

11001000 00010111 00010000 00000000

200.23.16.0/23

- IPv4 addressing- a block of addresses can be defined as a.b.c.d/x
- a.b.c.d defines one of the addresses and the /x defines the mask.
- Usually a.b.c.d is the first address in the address block.
- The first address in the block can be found by setting the rightmost 32-x bits to 0s.
- The last address in the block can be found by setting the rightmost 32-x bits 1s.
- Number of addresses in the block can be found by using the formula 2^{32-n}
- The first address in a block is normally not assigned to any device.
- It is used as the network address that represents the organization to the rest of the world.



- Each address in the block can be considered as a two-level hierarchical structure:

The leftmost n bits (prefix) define the network. The rightmost 32-n bits define the host.

- Number of subnet bits is called subnet mask

Subnetting

- ***223.1.17.0/24, ip addresses are 2^(32-24) = 256***
- ***Subnet 1 needs 2^6=64, 223.1.17.0/26***
- ***last address: 223.1.17.63***
- ***Subnet 2 needs 2^6=64, 223.1.17.64/26***
- ***last address: 223.1.17.127***
- ***Subnet 3 needs 2^7 = 128, 223.1.17.128/25***

Figure 19.10 *A NAT implementation*

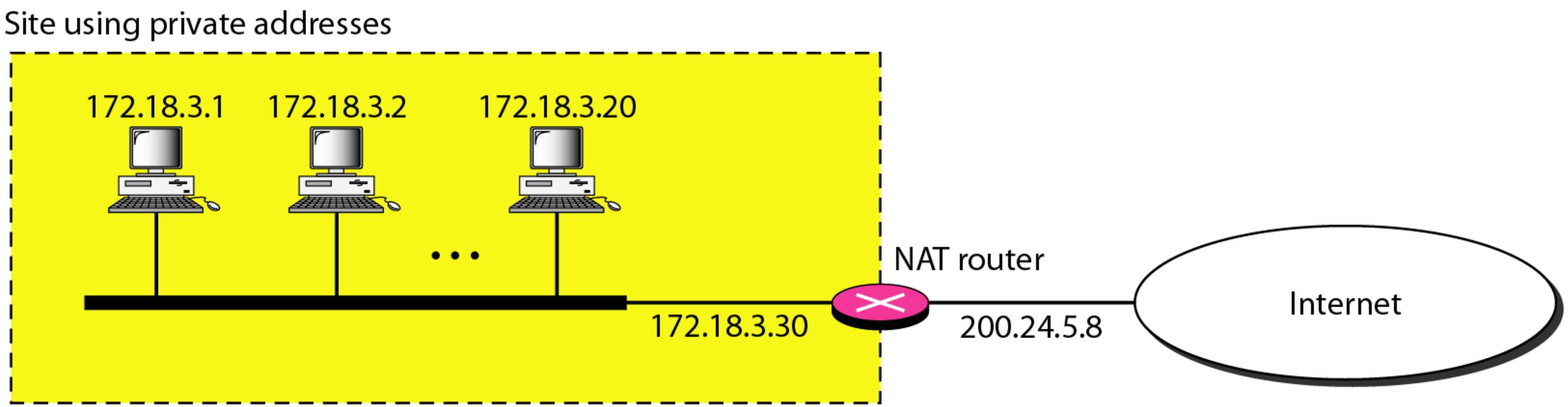
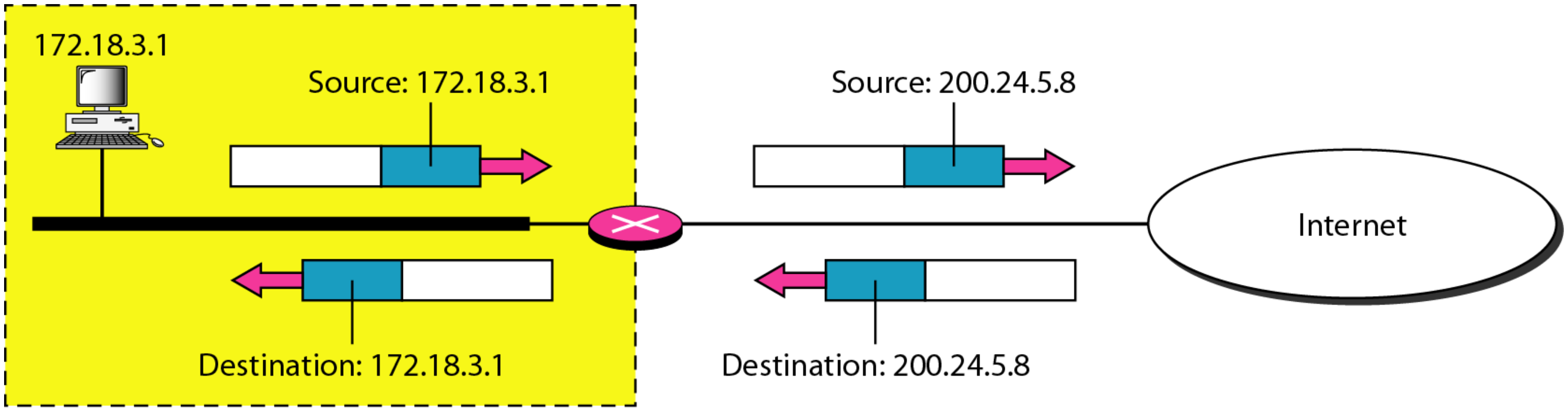
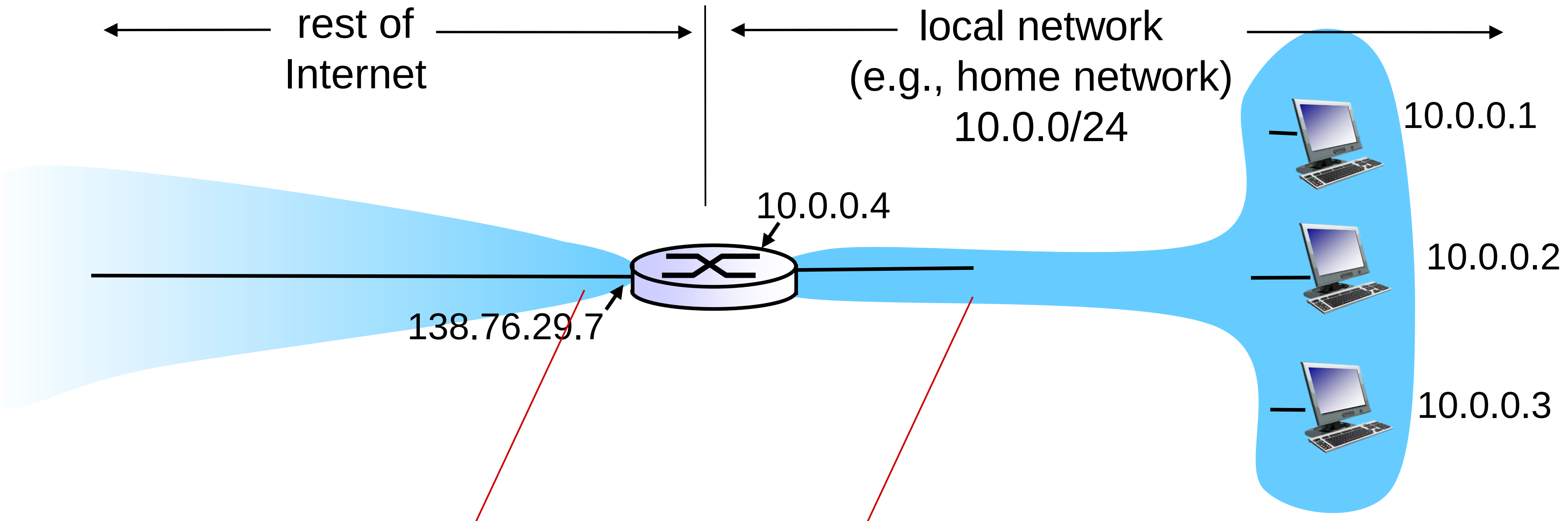


Figure 19.11 *Addresses in a NAT*



NAT: network address translation



all datagrams *leaving* local network have *same* single source NAT IP address: 138.76.29.7,different source port numbers

datagrams with source or destination in this network have 10.0.0/24 address for source, destination (as usual)

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:

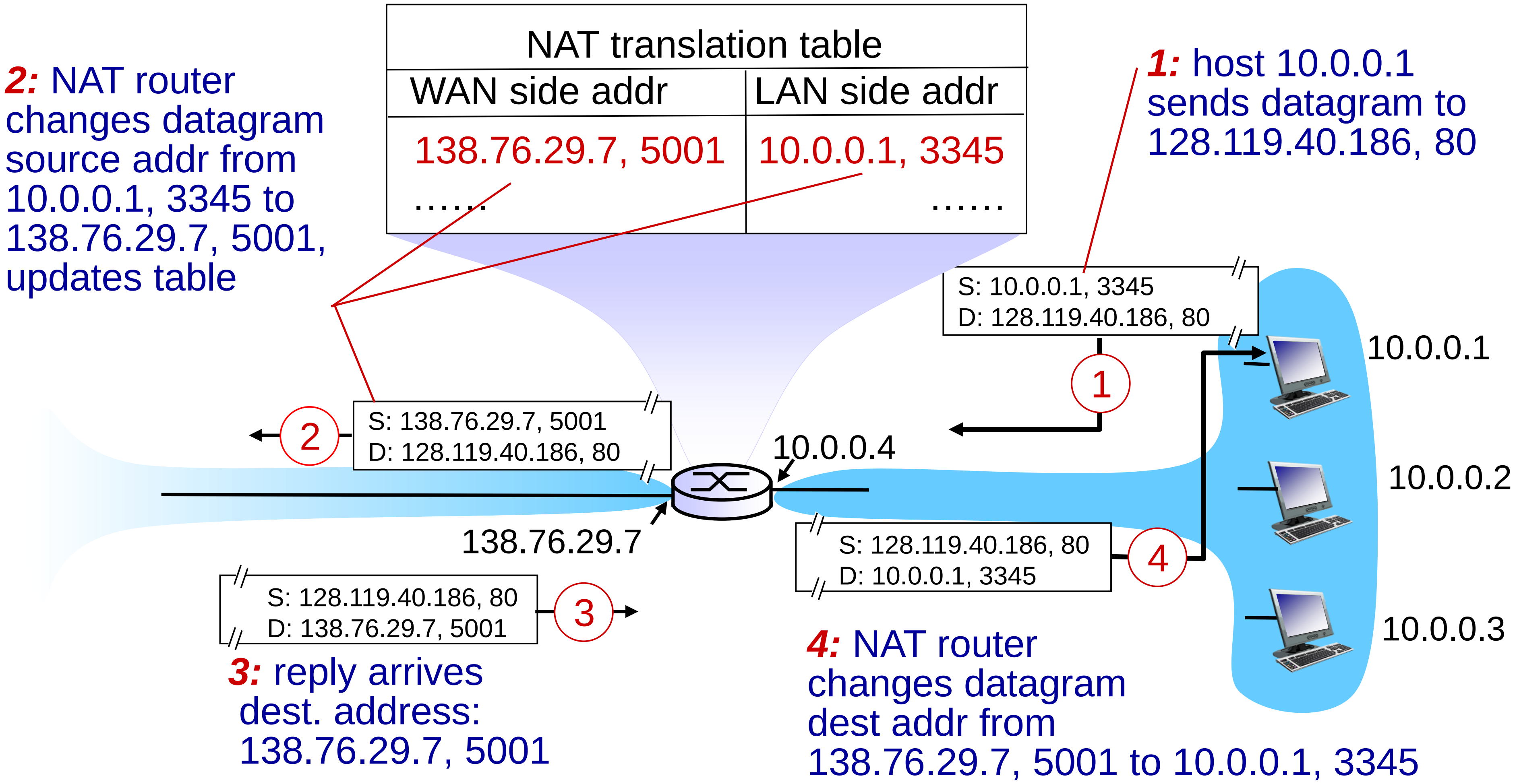
- *outgoing datagrams: replace* (source IP address, port #) of every outgoing datagram to (NAT IP address, new port #)

  . . . 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: replace* (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



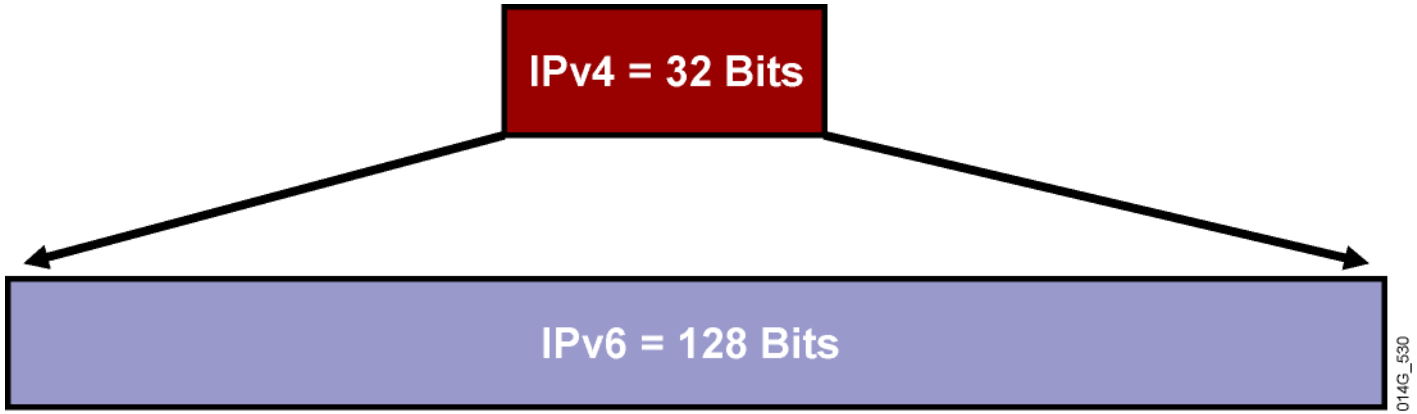
ICMP: internet control message protocol

- 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

IPv6 Addresses

- Address depletion may occur with IPv4.
- IPv6 address is 128 bits long.



IPv6: motivation

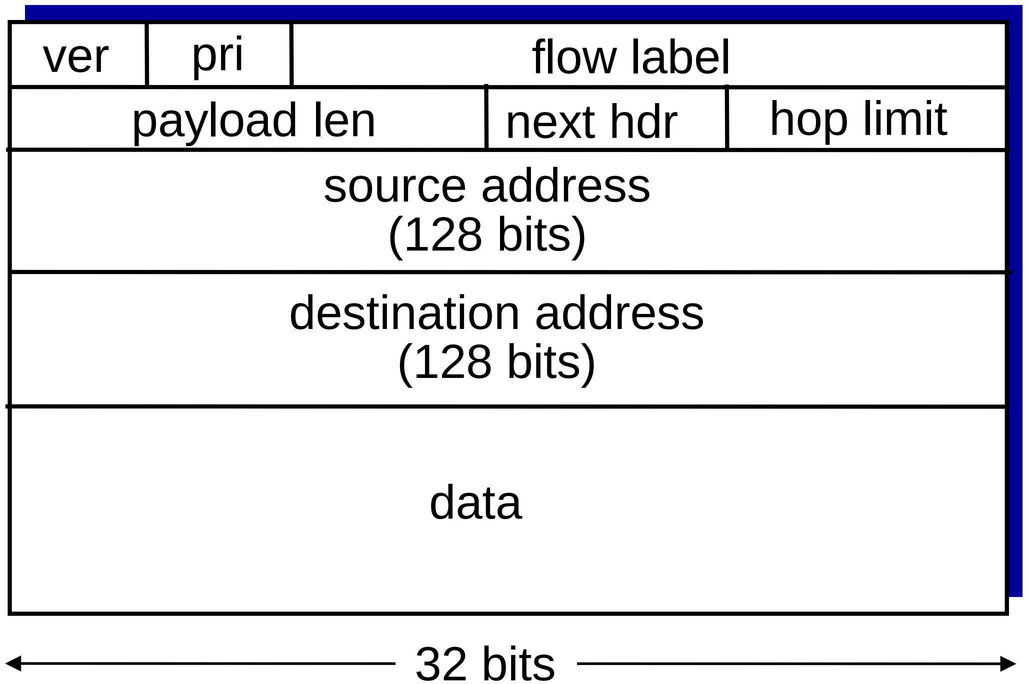
- *initial motivation:* 32-bit address space soon to be completely allocated.
- additional motivation:
  - header format helps speed processing/forwarding
  - header changes to facilitate QoS

IPv6 datagram format:

- fixed-length 40 byte header
- no fragmentation allowed

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



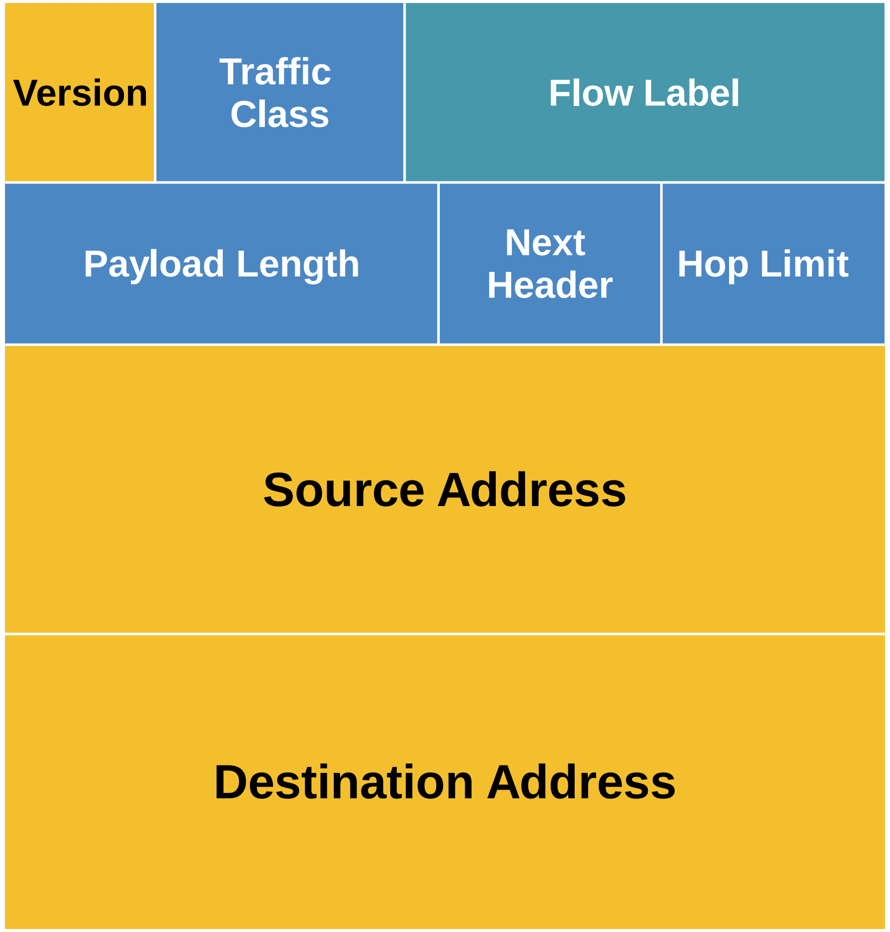
Other changes from IPv4

- *checksum:* removed entirely to reduce processing time at each hop
- *options:* allowed, but outside of header, indicated by "Next Header" field
- *ICMPv6:* new version of ICMP
  - additional message types, e.g. "Packet Too Big"
  - multicast group management functions

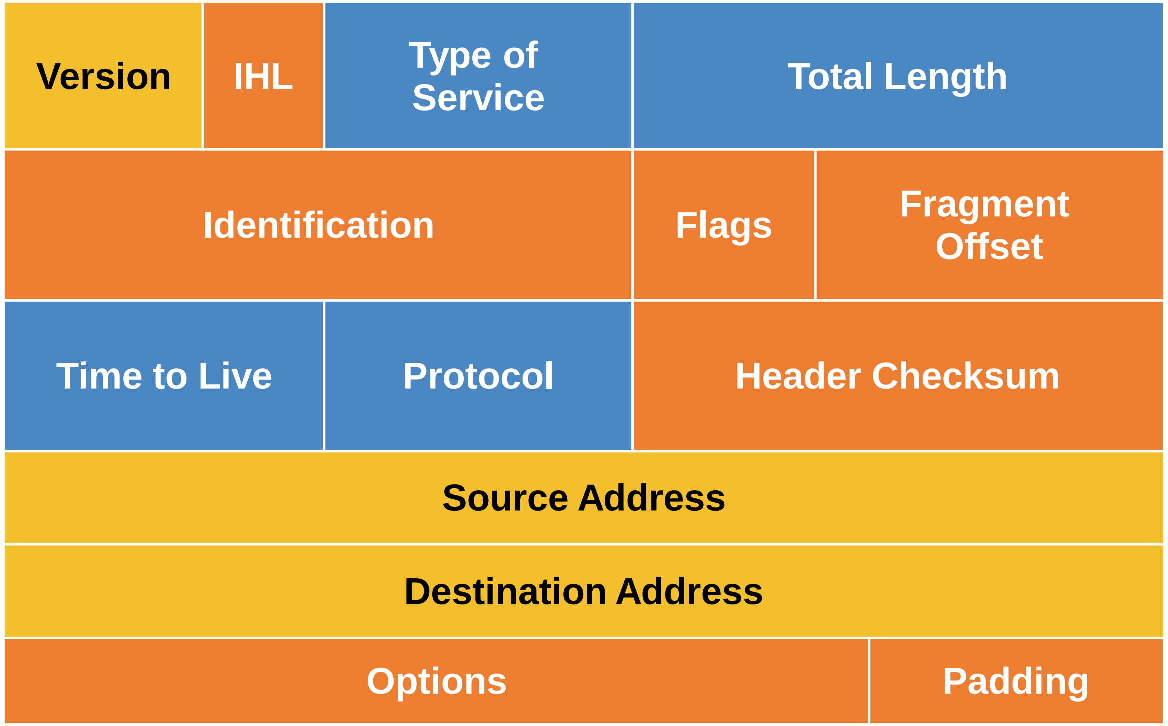
IPv6 Header Format

- **IPv4: 20 Bytes + Options IPv6: 40 Bytes + Extension Header**

IPv6 Header



IPv4 Header



IPv6 Address Types

- Unicast
- Address is for a single interface.
- Multicast
- One-to-many
- Enables more efficient use of the network
- Uses a larger address range
- Anycast
    - **One-to-nearest (allocated from unicast address space).**
    - **Multiple devices share the same address.**
    - **All anycast nodes should provide uniform service.**
    - **Source devices send packets to anycast address.**
    - **Routers decide on closest device to reach that destination.**
    - **Suitable for load balancing and content delivery services.**

IPv6 Address Scope

- **Link-local**: The scope is the local link (nodes on the same subnet)
- **Unique-local**: The scope is the organization (private site addressing)
- **Global**: The scope is global (IPv6 Internet addresses)

- ***x*:*x*:*x*:*x*:*x*:*x*:*x*:*x*, where *x* is a 16-bit hexadecimal field**

IPv6 Address Representation: Link Local

- Hosts on the same link (the same subnet) use these automatically configured addresses to communicate with each other.
- Neighbour discovery provides address resolution.
- Following illustration shows the structure of a link-local address.

1111 1110 10 (10 bits)	**000 . . . 000** (54 bits)	**Interface ID** (64 bits)

IPv6 Address Representation: Unique Local

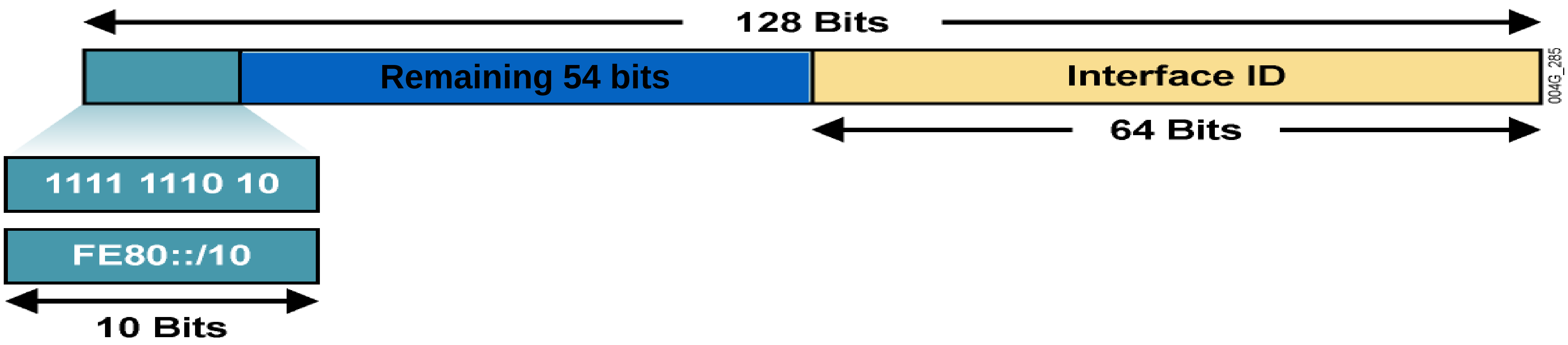
- IPv6 unicast unique-local addresses are similar to IPv4 private addresses.

- The scope of a unique-local address is the internetwork of an organization’s site. (You can use both global addresses and unique-local addresses in your network)

-

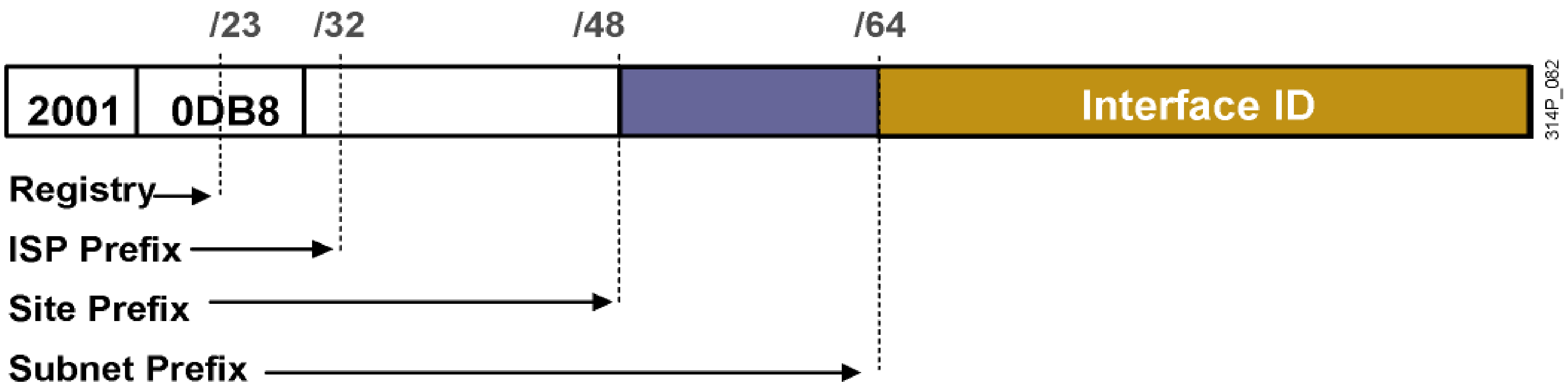
- The prefix for unique-local addresses is FC00::/8.

IPv6 Address Representation: Link Local



- Mandatory address for communication between two IPv6 devices
- Automatically assigned by router as soon as IPv6 is enabled

IPv6 Address Representation: Global Unicast



Global unicast and anycast addresses are defined by a global routing prefix, a subnet ID, and an interface ID.

DHCPv6

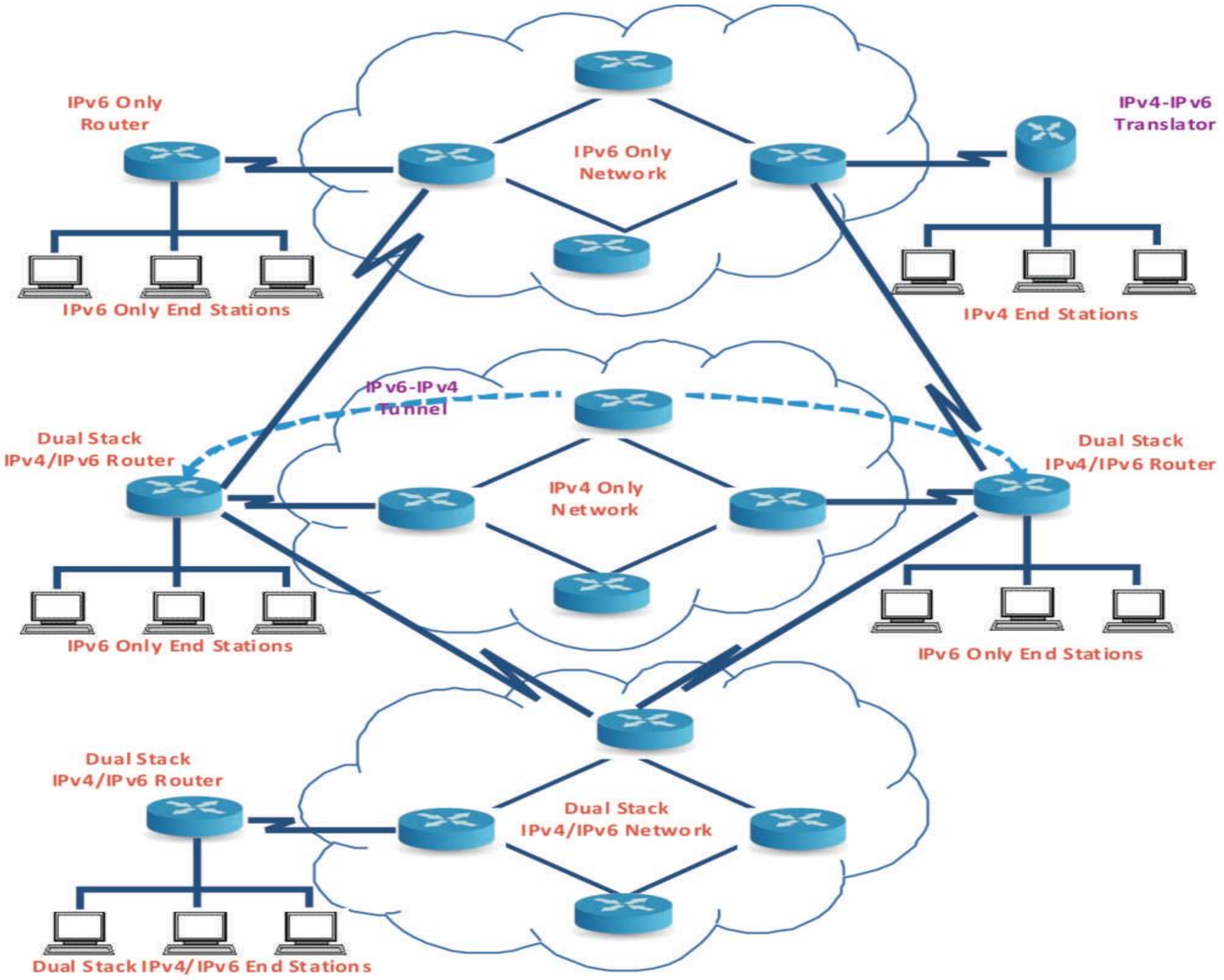
- Stateful Configuration
- Provides not only IP address, also other configuration parameters like DNS

Transition to IPv6

Transition Options:

- Dual Stack
- IPv6-IPv4 Tunnel
- IPv6-IPv4 Translation

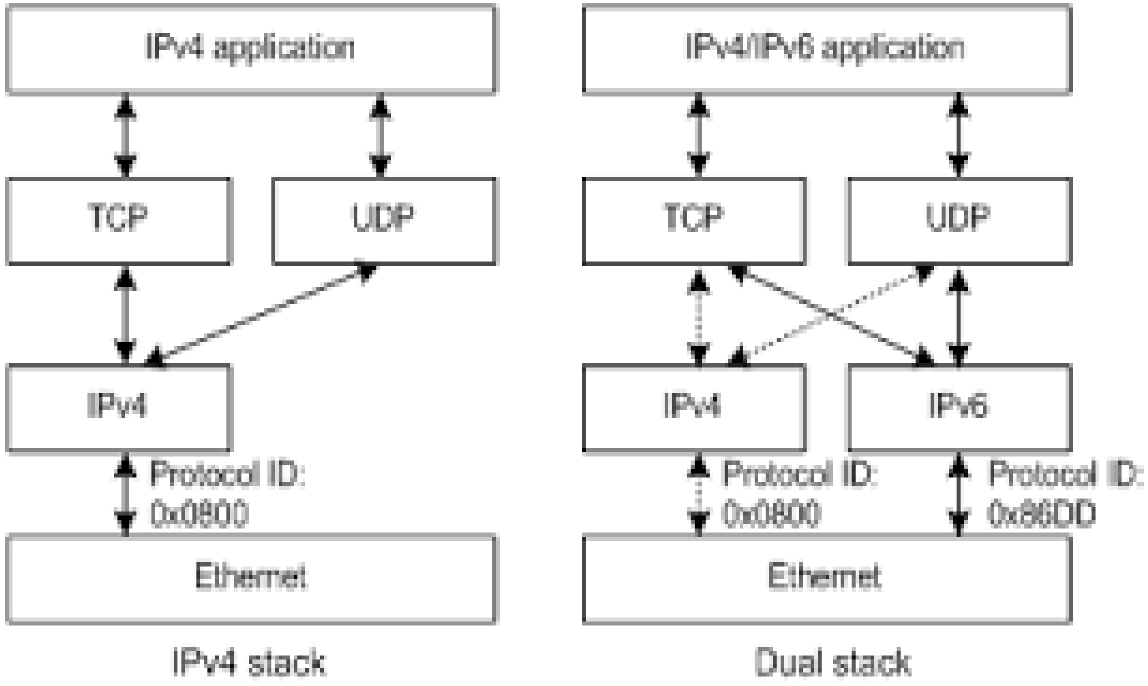
Transition Mechanism



Dual stack hosts and network

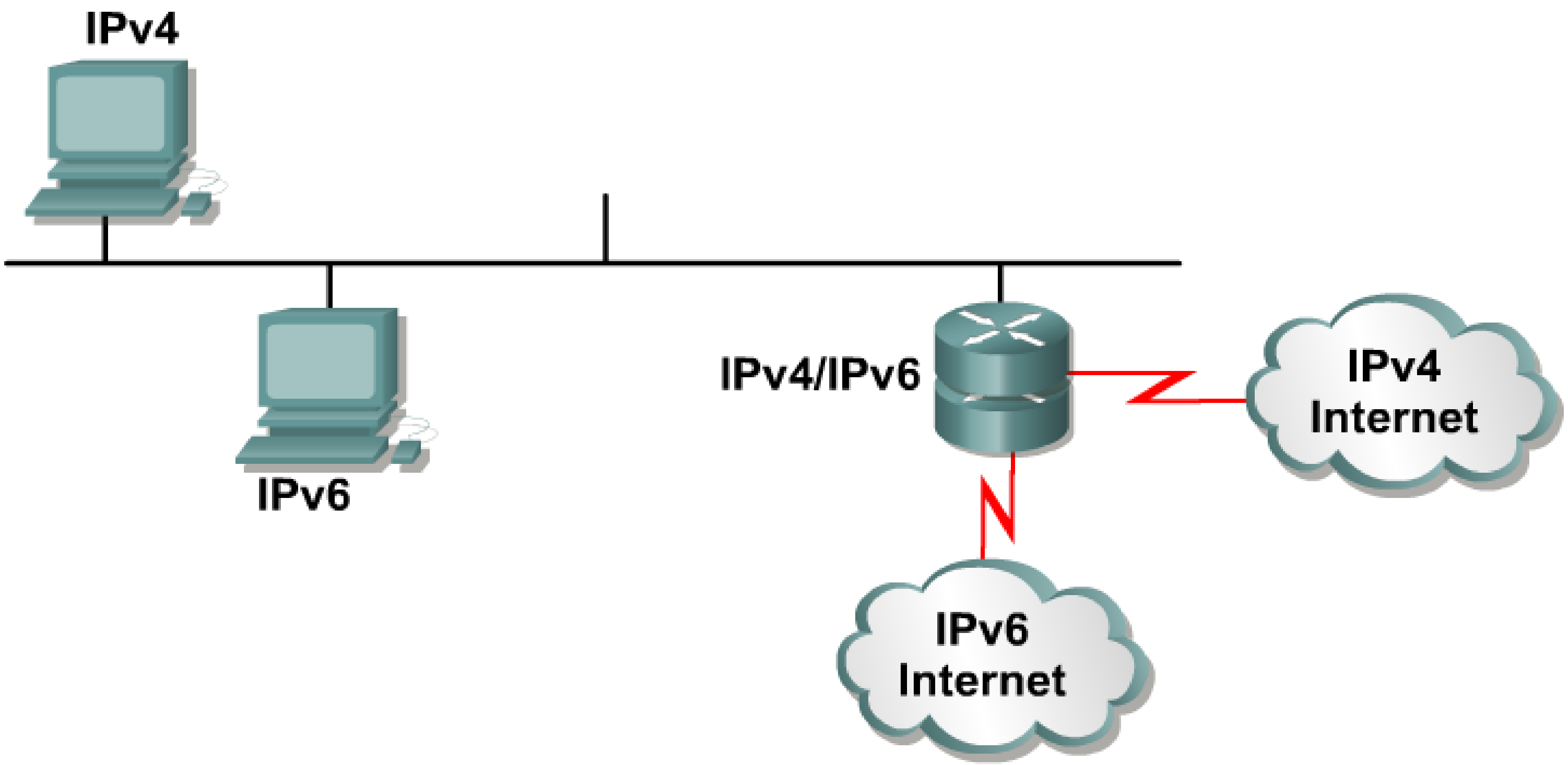
- This allows all the end hosts and intermediate network devices (like routers, switches, modems etc.) to have both IPv4 and IPv6 addresses and protocol stack.
- If both the end stations support IPv6, they can communicate using IPv6; otherwise they will communicate using IPv4.
- This will allow both IPv4 and IPv6 to coexist and slow transition from IPv4 to IPv6 can happen.

Dual Stack



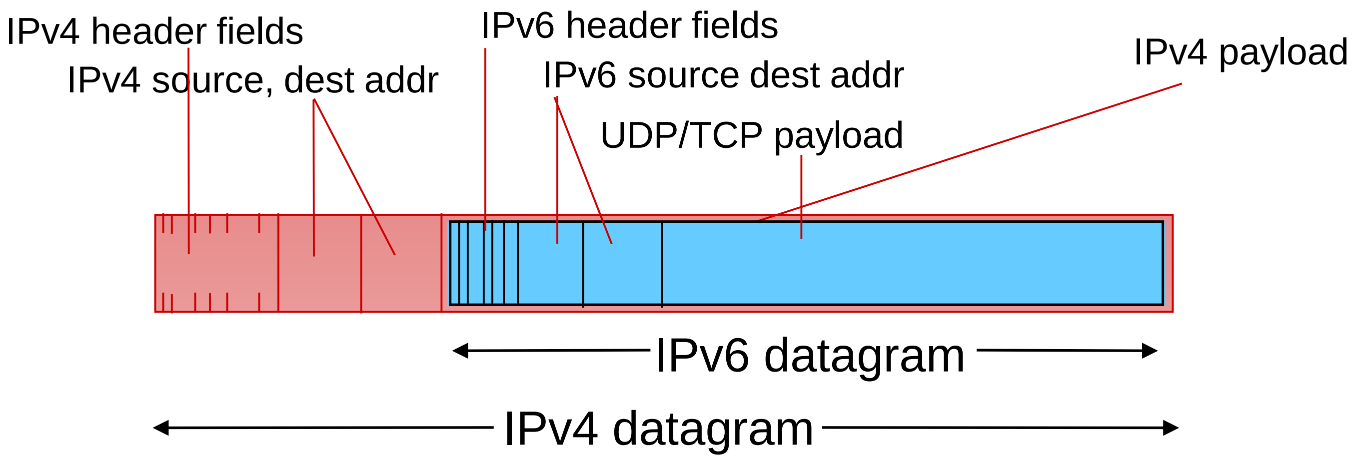
IPv4 application
TCP
UDP
IPv4
Protocol ID:
0x0800
Ethernet
IPv4 stack
IPv4/IPv6 application
TCP
UDP
IPv4
IPv6
Protocol ID:
0x0800
Protocol ID:
0x86DD
Ethernet
Dual stack

Dual Stack Hosts and Network

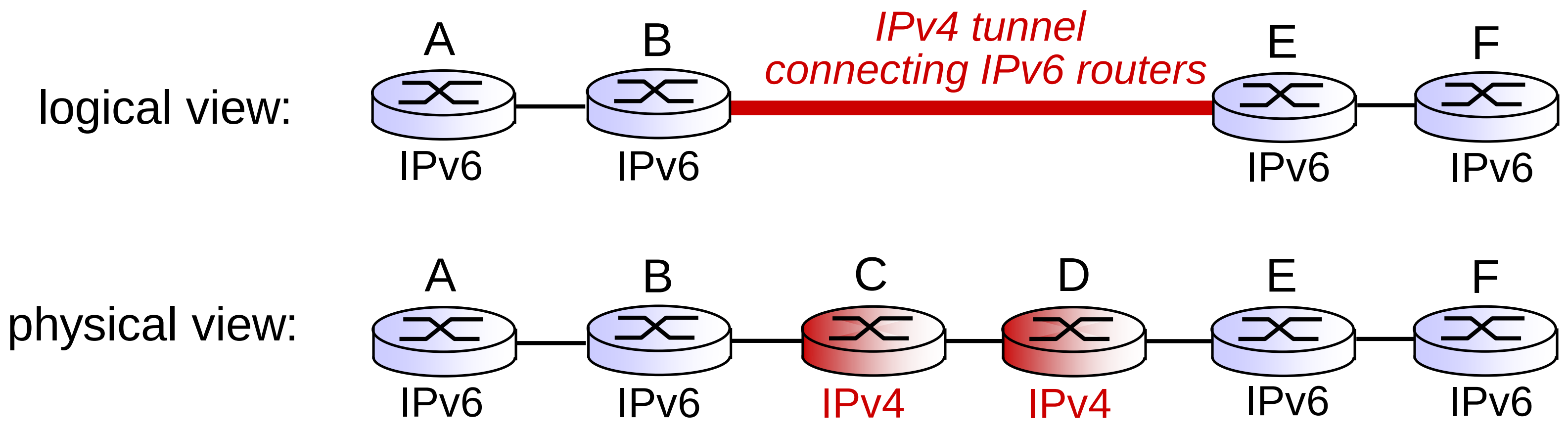


Transition from IPv4 to IPv6

- not all routers can be upgraded simultaneously
  - no "flag days"
  - how will network operate with mixed IPv4 and IPv6 routers?
- *tunneling:* IPv6 datagram carried as *payload* in IPv4 datagram among IPv4 routers

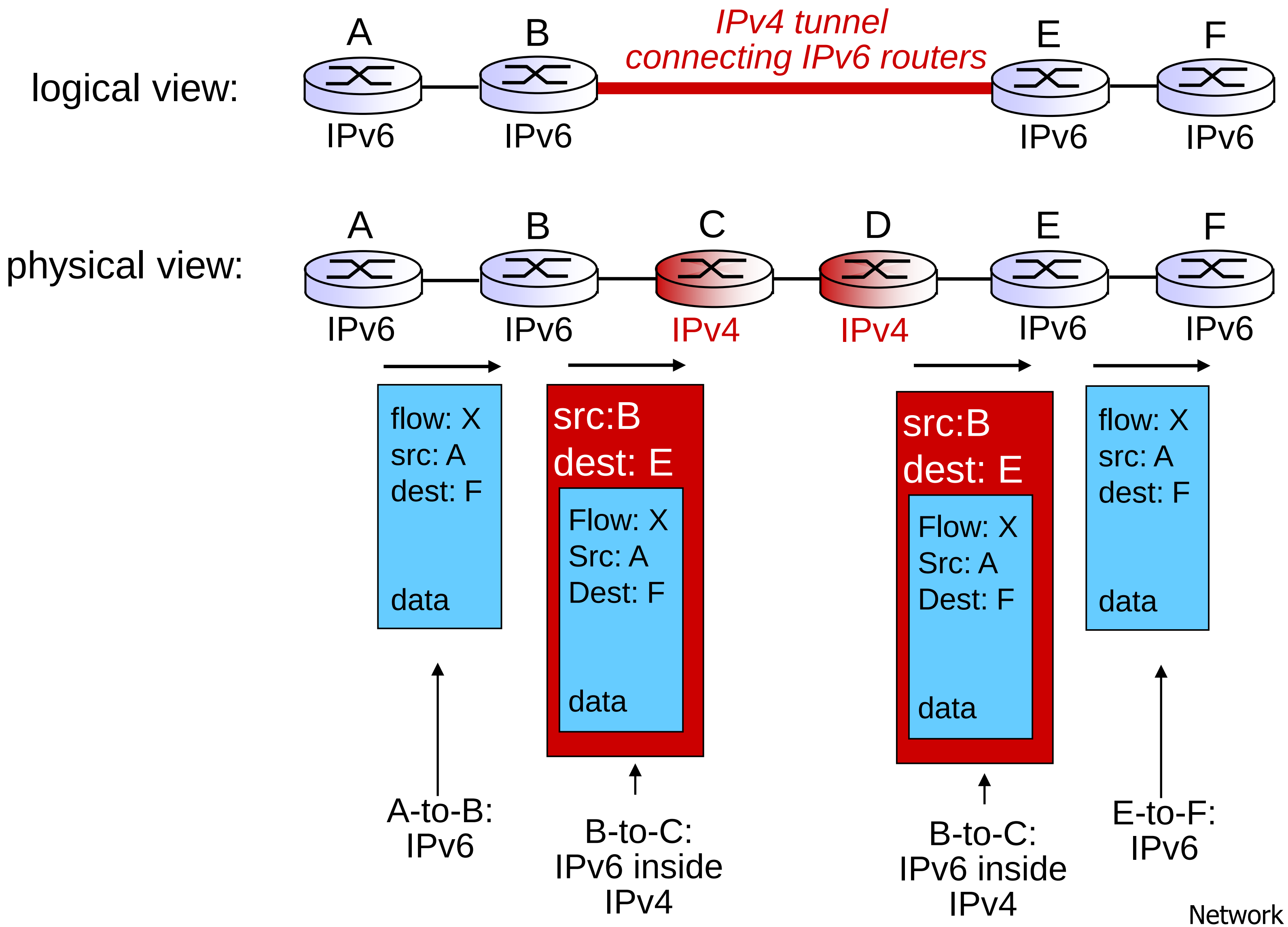


Tunneling



IPv4 tunnel
connecting IPv6 routers
logical view:
A
B
E
F
IPv6
IPv6
IPv6
IPv6
physical view:
A
B
C
D
E
F
IPv6
IPv6
IPv4
IPv4
IPv6
IPv6

Tunneling


logical view:
A
B
IPv4 tunnel
connecting IPv6 routers
E
F
IPv6
IPv6
IPv6
IPv6
physical view:
A
B
C
D
E
F
IPv6
IPv6
IPv4
IPv4
IPv6
IPv6
flow: X
src: A
dest: F
data
src:B
dest: E
Flow: X
Src: A
Dest: F
data
src:B
dest: E
Flow: X
Src: A
Dest: F
data
flow: X
src: A
dest: F
data
A-to-B:
IPv6
B-to-C:
IPv6 inside
IPv4
B-to-C:
IPv6 inside
IPv4
E-to-F:
IPv6

IPv6-IPv4 Translation

- This allows communication between IPv4 only and IPv6 only end stations
- The job of the translator is to translate IPv6 packets into IPv4 packets by doing address and port translation and vice versa.