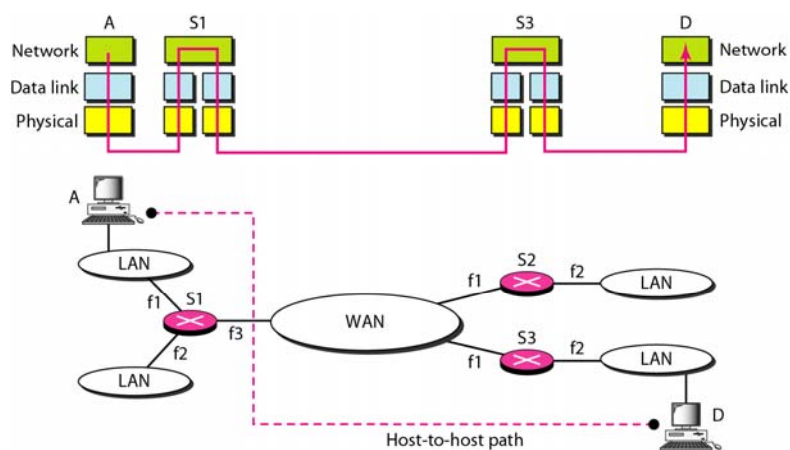# Chapter 20
Network Layer
IP and Address Mapping

Dr. Mznah Al-Rodhaan

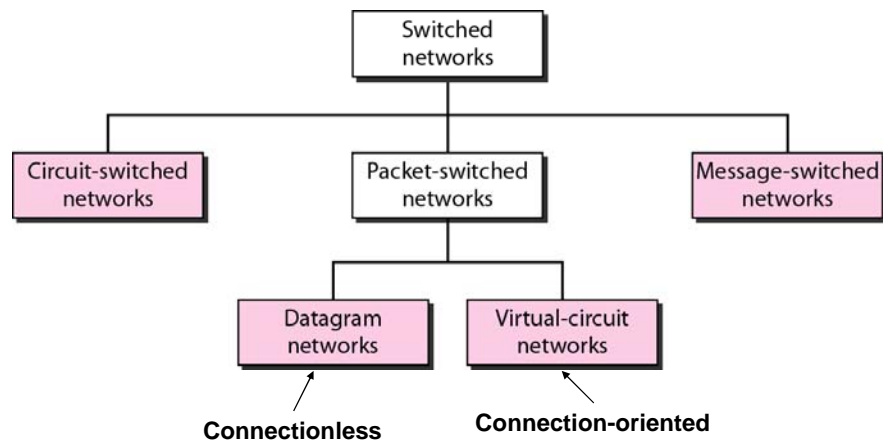
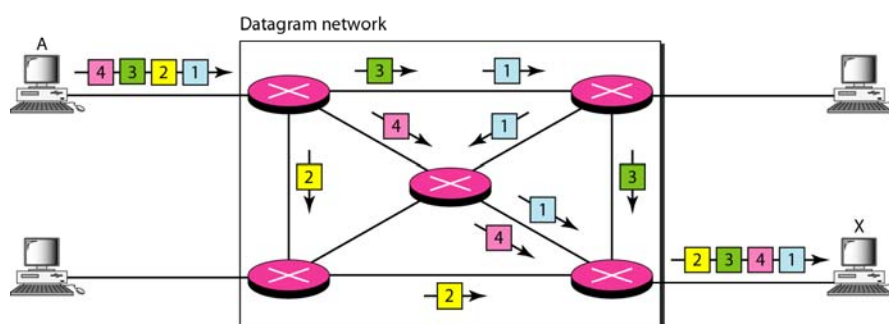## *Network layer in an internetwork*

Based on
Data Communications and Networking, 4th Edition. by Behrouz A. Forouzan, McGraw-Hill Companies, Inc., 2007   Dr. Mznah Al-Rodhaan

20.2

Taxonomy of switched networks

A datagram network with four switches (routers)

Switching in the Internet

Switching at the network layer in the Internet uses the datagram approach to packet switching.

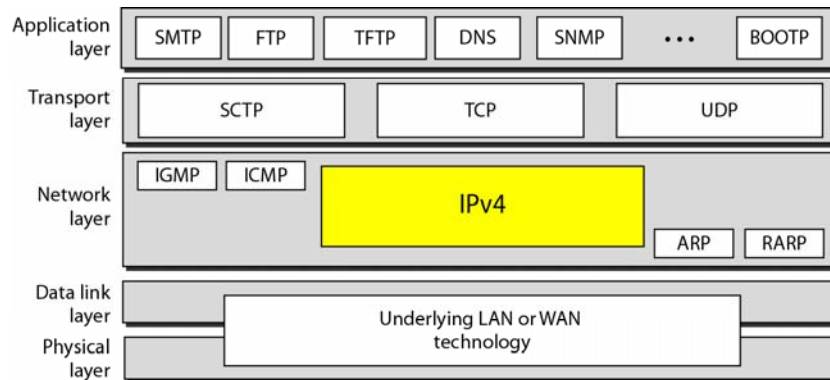## Communication at the network layer in the Internet is connectionless.

IPv4

The Internet Protocol version 4 (IPv4) is the delivery mechanism used by the TCP/IP protocols.

Topics discussed in this section:
   Datagram
   Fragmentation
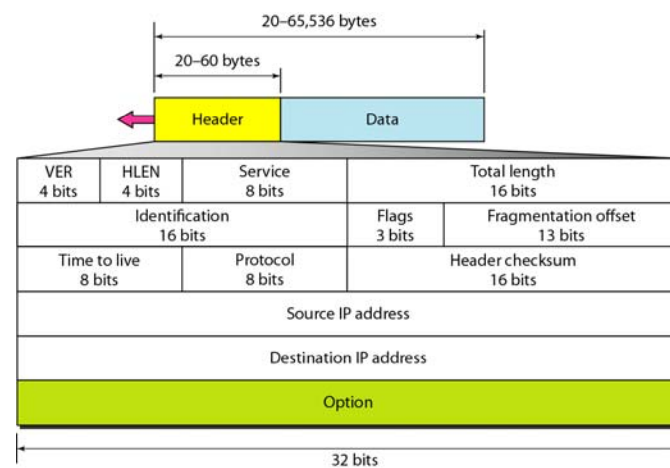   **Checksum**
   Options

20.6

Position of IPv4 in TCP/IP protocol suite

20.7

IPv4 datagram format

20.8

IP Packet Format

0	4	8	16	19	31

Version	HLEN	Service	Length		
Identification			Flags	Fragment Offset	
TTL		Protocol	IP Header Checksum		
Source IP Address					
Destination IP Address					
Options (variable)				Pad (variable)	
Data					

Current IP Protocol Version is 4, called IPv4

0	4	8	16	19	31

Version	HLEN	Services	Length		
Identification			Flags	Fragment Offset	
TTL		Protocol	IP Header Checksum		
Source IP Address					
Destination IP Address					
Options (variable)					

Length of IP Header in number of 4 bytes words including options. Maximum header size is 60 bytes. Header length = HLEN*4

0	4	8	16	19	31
Version	HLEN	Services		Length	
Identification			Flags	Fragment Offset	
TTL		Protocol	IP Header Checksum		
Source IP Address					
Destination IP Address					
Options (variable)					

Based on
Data Communications and Networking, 4th Edition. by Behrouz A. Forouzan, McGraw-Hill Companies, Inc., 2007   Dr. Mznah Al-Rodhaan
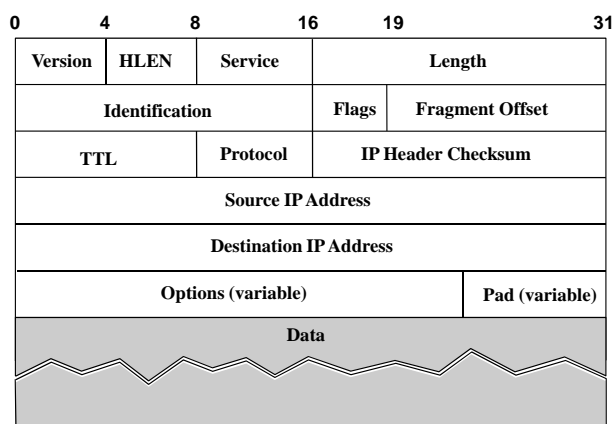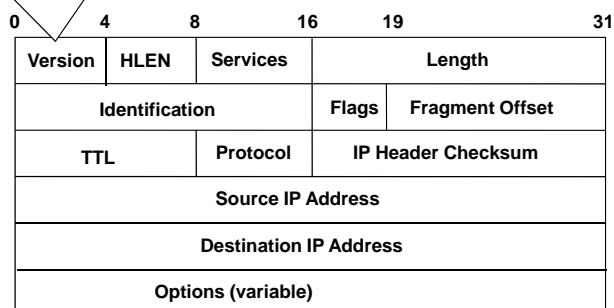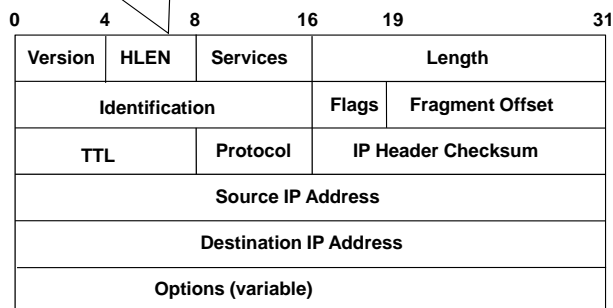
The service field is composed of a 3-bit precedence field. (Which are largely ignored in current routers). 4 services bits and an unused bit that must be zero.

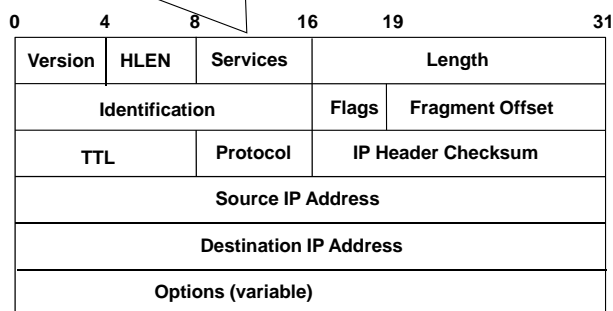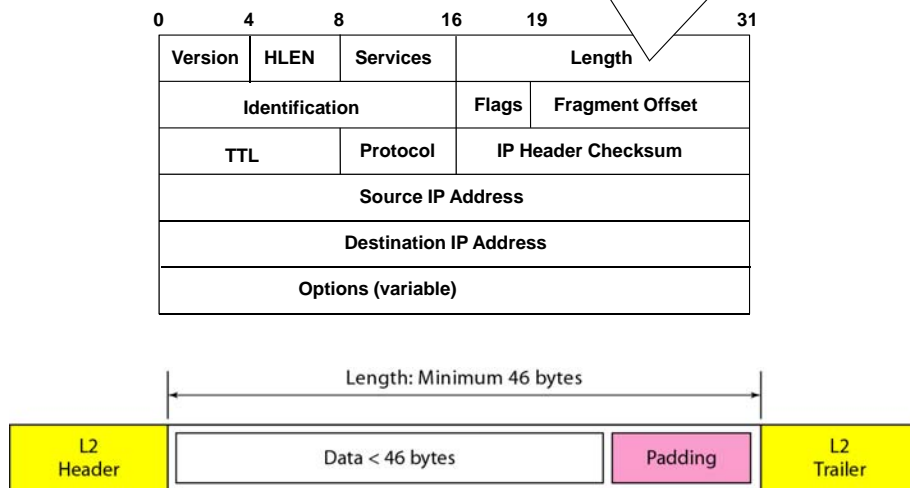| 0	4	8	16	19	31
Version	HLEN	Services		Length	
Identification			Flags	Fragment Offset	
TTL		Protocol	IP Header Checksum		
Source IP Address					
Destination IP Address					
Options (variable)					

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Total length of IP datagram in bytes. It is a 16 bit field. Largest size of an IP datagram is 65635 bytes. Maximum header size is 60 bytes. Link layer MTU may restrict this size further.

0	4	8	16	19	31
Version	HLEN	Services		Length	
Identification			Flags	Fragment Offset	
TTL		Protocol	IP Header Checksum		
Source IP Address					
Destination IP Address					
Options (variable)					

Length: Minimum 46 bytes

L2 Header	Data < 46 bytes	Padding	L2 Trailer

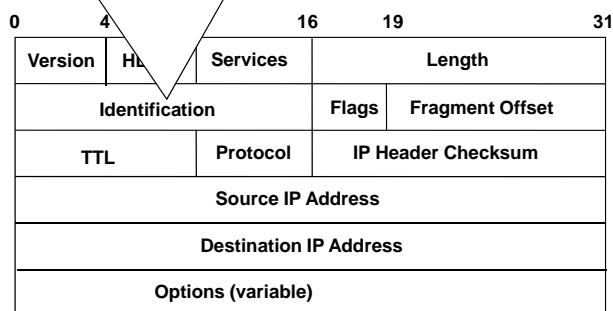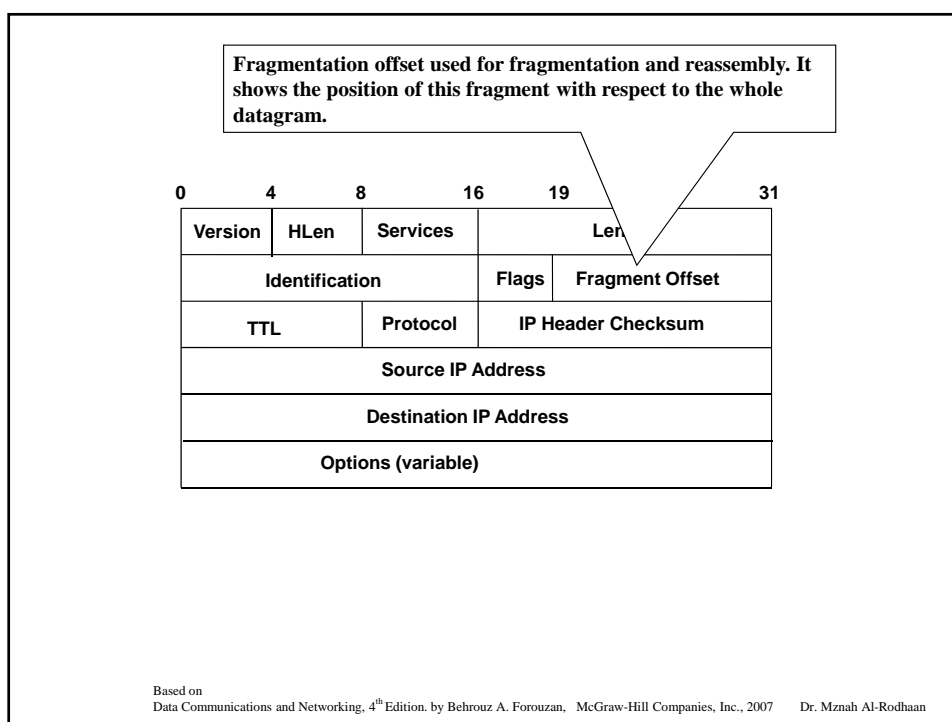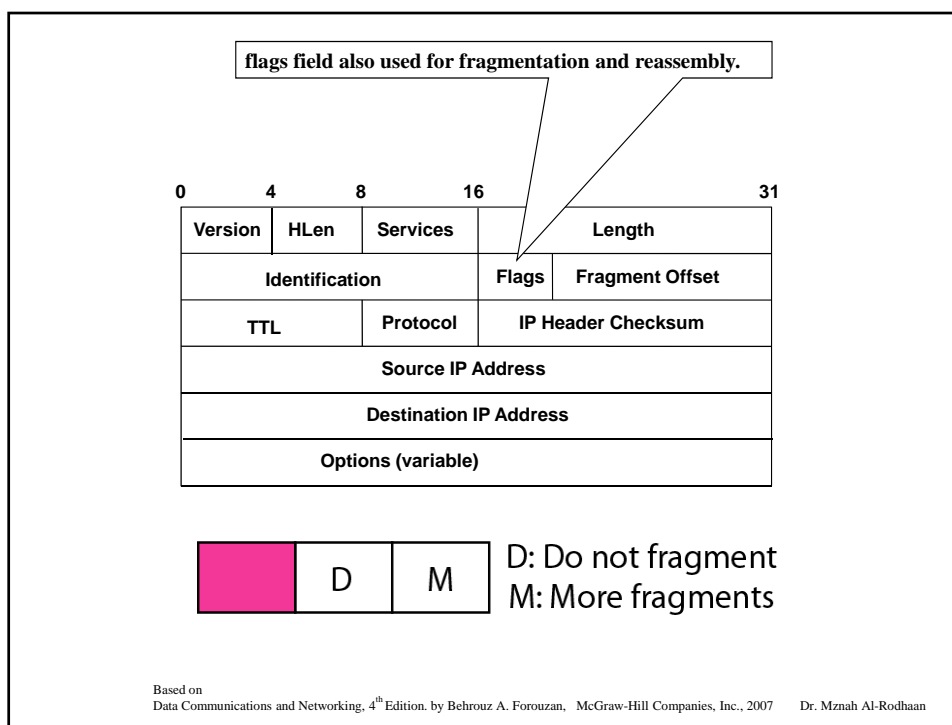Based on
Data Communications and Networking, 4th Edition. by Behrouz A. Forouzan, McGraw-Hill Companies, Inc., 2007   Dr. Mznah Al-Rodhaan

Identification field uniquely identifies each datagram sent by a host. It is normally incremented by one each time a host sends a datagram. Very useful for fragmentation and reassembly.
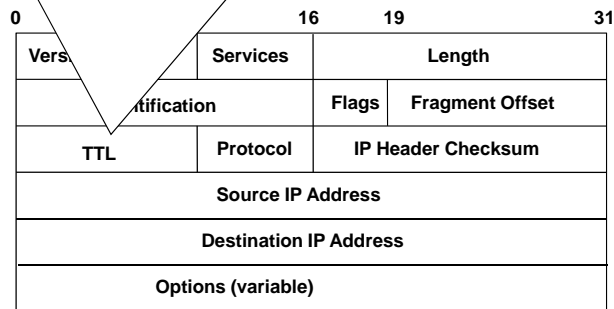
0	4	16	19	31
Version	HL	Services	Length	
Identification		Flags	Fragment Offset	
TTL	Protocol	IP Header Checksum		
Source IP Address				
Destination IP Address				
Options (variable)				

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flags field also used for fragmentation and reassembly.

0	4	8	16		31
Version	HLen	Services		Length	
Identification			Flags	Fragment Offset	
TTL		Protocol	IP Header Checksum		
Source IP Address					
Destination IP Address					
Options (variable)					

	D	M

D: Do not fragment
M: More fragments

Fragmentation offset used for fragmentation and reassembly. It shows the position of this fragment with respect to the whole datagram.

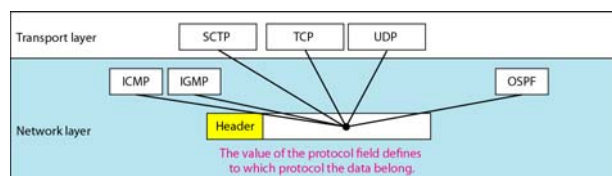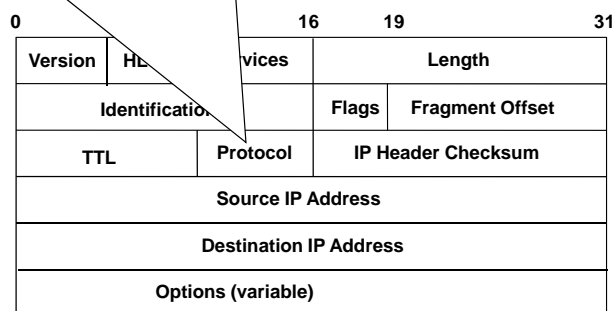| 0	4	8	16	19	31
Version	HLen	Services		Len	
Identification			Flags	Fragment Offset	
TTL		Protocol	IP Header Checksum		
Source IP Address					
Destination IP Address					
Options (variable)					

Time-to-live (TTL) field sets an upper limit on how man routers a datagram can go through. Every router decrements TTL by 1 before sending it forward. If TTL reaches 0 the datagram is dropped and an ICMP message is sent to the host application.

0		16	19	31
Vers	Services		Length	
tification		Flags	Fragment Offset	
TTL	Protocol	IP Header Checksum		
Source IP Address				
Destination IP Address				
Options (variable)				

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Data Communications and Networking, 4th Edition. by Behrouz A. Forouzan, McGraw-Hill Companies, Inc., 2007   Dr. Mznah Al-Rodhaan

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Identifies the protocol that sent the datagram. The protocol (today) can be ICMP, IGMP, TCP, UDP

0		16	19	31
Version	HD vices		Length	
Identification		Flags	Fragment Offset	
TTL	Protocol	IP Header Checksum		
Source IP Address				
Destination IP Address				
Options (variable)				

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The header checksum is calculated over the IP header only. TCP, UDP etc protect their own data and header by a checksum.

0	4	8	16	19	31
Version	HLEN	Services			
Identification			Flags	Fragment Offset	
TTL		Protocol	IP Header Checksum		
Source IP Address					
Destination IP Address					
Options (variable)					

Example 20.1

An IPv4 packet has arrived with the first 8 bits as shown:

01000010

The receiver discards the packet. Why?

Solution

(0100) show the version ✓.

The next 4 bits (0010) show header length (2 × 4 = 8bytes).

The minimum number of bytes in the header must be 20.

The packet has been corrupted in transmission.

Example 20.2

In an IPv4 packet, the value of HLEN is 1000 in binary. How many bytes of options are being carried by this packet?

Solution

The HLEN value is 8, which means the total number of bytes in the header is 8 × 4, or 32 bytes. The first 20 bytes are the base header, the next 12 bytes are the options.

Example 20.3

In an IPv4 packet, the value of HLEN is 5, and the value of the total length field is 0x0028. How many bytes of data are being carried by this packet?

Solution

The HLEN value is 5, which means the total number of bytes in the header is 5 × 4, or 20 bytes (no options). The total length is 40 bytes, which means the packet is carrying 20 bytes of data (40 − 20).

Example 20.4

An IPv4 packet has arrived with the first few hexadecimal digits as shown.

0x45000028000100000102 . . .

How many hops can this packet travel before being dropped? The data belong to what upper-layer protocol?

Solution

To find the time-to-live field, we skip 8 bytes. The time-to-live field is the ninth byte, which is 01. This means the packet can travel only one hop. The protocol field is the next byte (02).

Fragmentation

Maximum transfer unit (MTU)
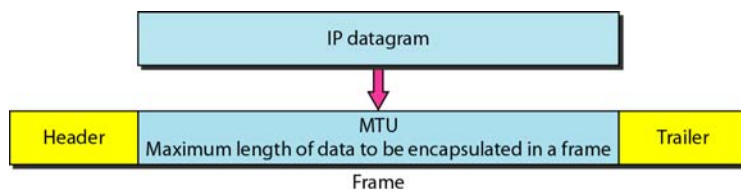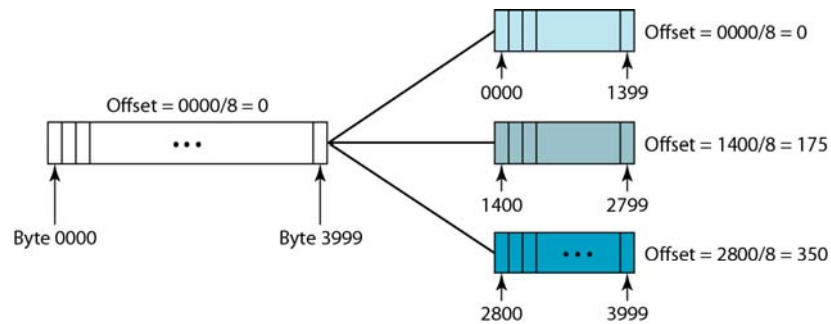
Fragmentation example

Detailed fragmentation example
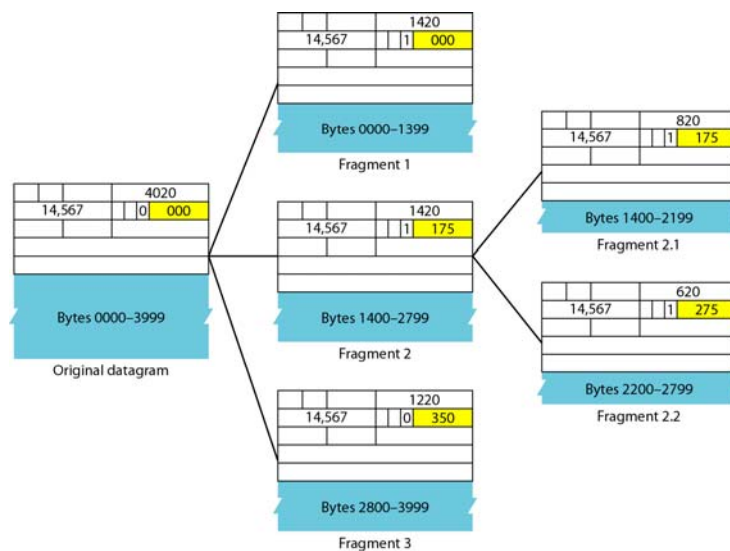
Reading from the text book

❑ Chapter 20 from 4th edition (section 20.1 until the end of page 594 except service Type and differentiated services)
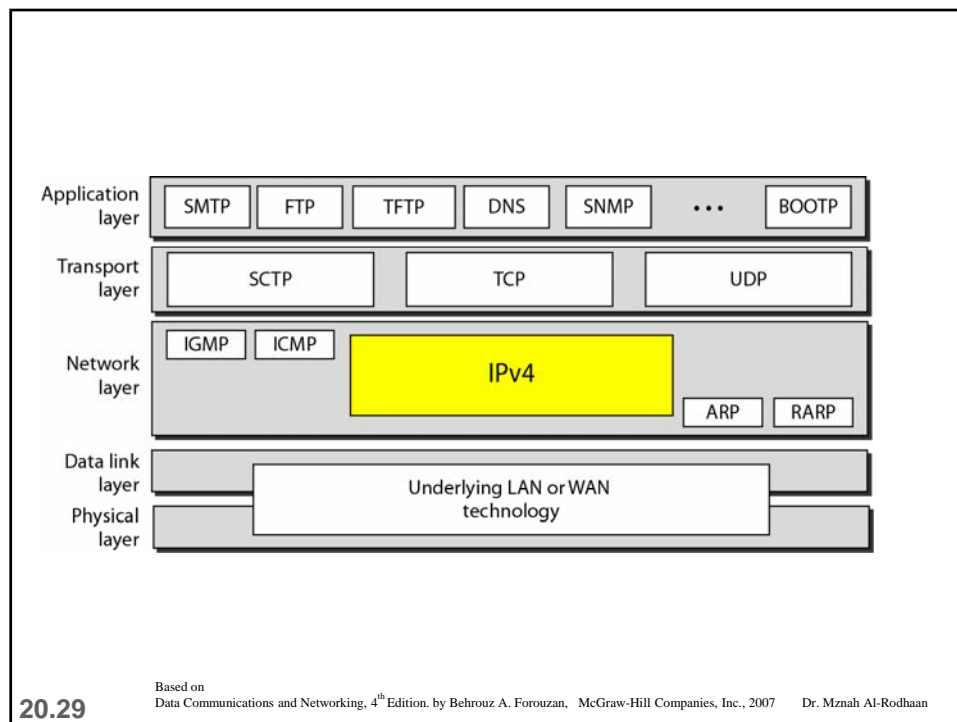
Chapter 21

Network Layer

Address Mapping

Application layer	SMTP	FTP	TFTP	DNS	SNMP	...	BOOTP
Transport layer	SCTP		TCP			UDP	
Network layer	IGMP	ICMP	IPv4			ARP	RARP
Data link layer			Underlying LAN or WAN technology				
Physical layer							

20.29
Based on
Data Communications and Networking, 4th Edition. by Behrouz A. Forouzan, McGraw-Hill Companies, Inc., 2007   Dr. Mznah Al-Rodhaan

Address Mapping

- The delivery of a packet to a host or a router requires two levels of addressing: *logical* and *physical*. We need to be able to map a logical address to its corresponding physical address and vice versa. This can be done by using either static or dynamic mapping.
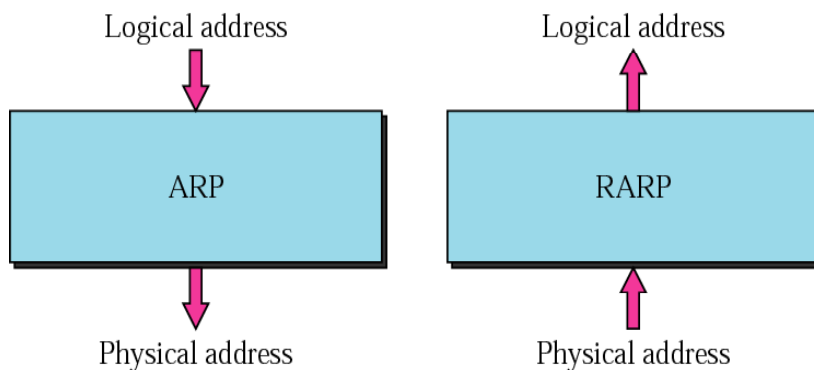
Based on
Data Communications and Networking, 4th Edition. by Behrouz A. Forouzan, McGraw-Hill Companies, Inc., 2007   Dr. Mznah Al-Rodhaan

ARP and RARP

Logical address → ARP → Physical address
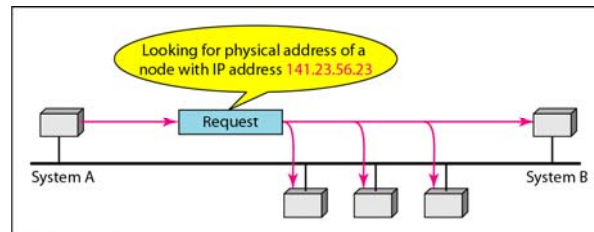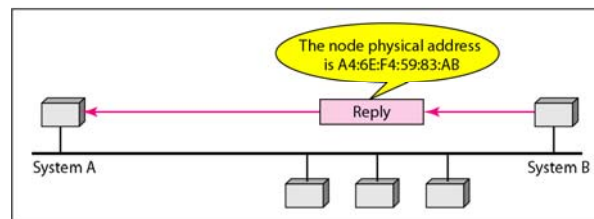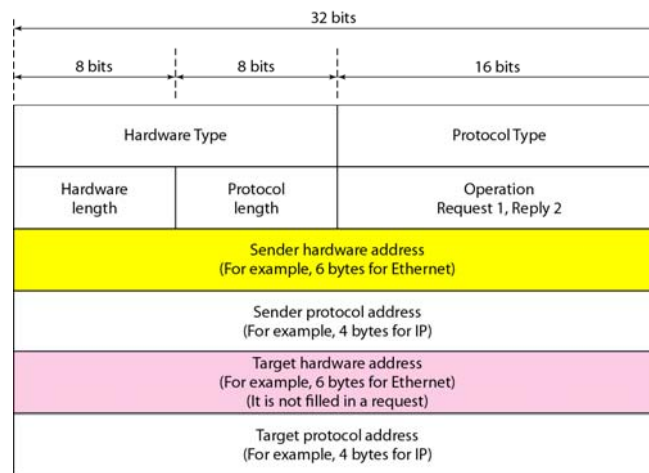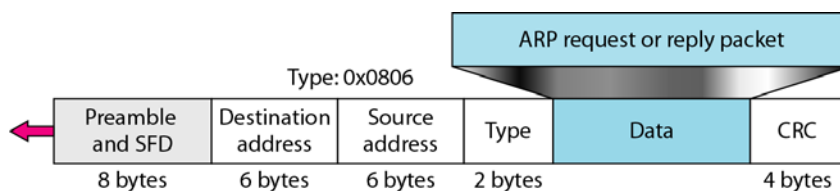
Physical address → RARP → Logical address

ARP - The Address Resolution Protocol

- An IP datagram must be encapsulated in a frame to pass through the physical network. This requires the physical address of the receiver.
- ARP associates an IP address with its physical address.
- When the physical address of another host is required an ARP query packet is sent which includes
  - IP address of sender
  - IP address of the receiver
- The intended recipient recognises its IP address and send back an ARP response which contains the physical address.

ARP operation

Looking for physical address of a node with IP address 141.23.56.23

Request

System A   System B

a. ARP request is broadcast

The node physical address is A4:6E:F4:59:83:AB

Reply

System A   System B

b. ARP reply is unicast

ARP packet

|	32 bits		
8 bits	8 bits		16 bits
Hardware Type		Protocol Type	
Hardware length	Protocol length	Operation Request 1, Reply 2	
Sender hardware address (For example, 6 bytes for Ethernet)			
Sender protocol address (For example, 4 bytes for IP)			
Target hardware address (For example, 6 bytes for Ethernet) (It is not filled in a request)			
Target protocol address (For example, 4 bytes for IP)			

21.34

Encapsulation of ARP packet

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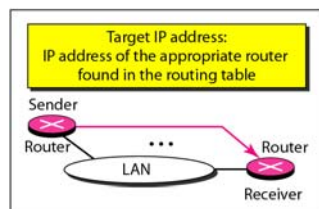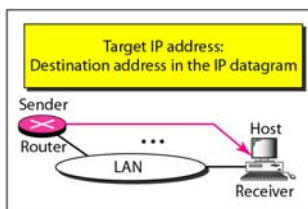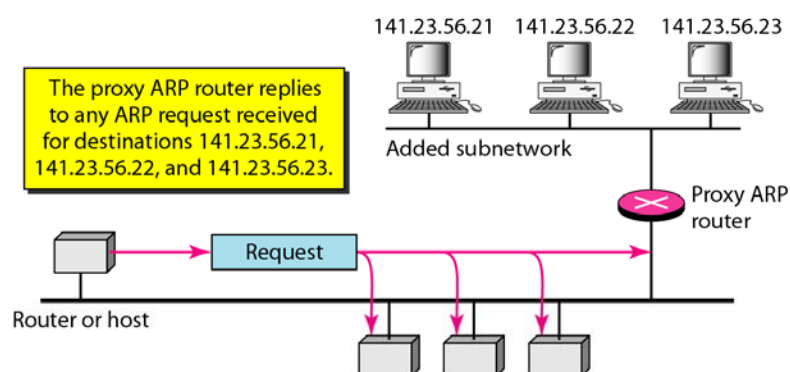
Four cases using ARP
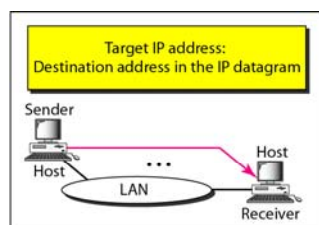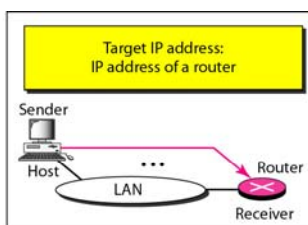
Based on
Data Communications and Networking, 4th Edition. by Behrouz A. Forouzan, McGraw-Hill Companies, Inc., 2007   Dr. Mznah Al-Rodhaan

ARP Request & Reply
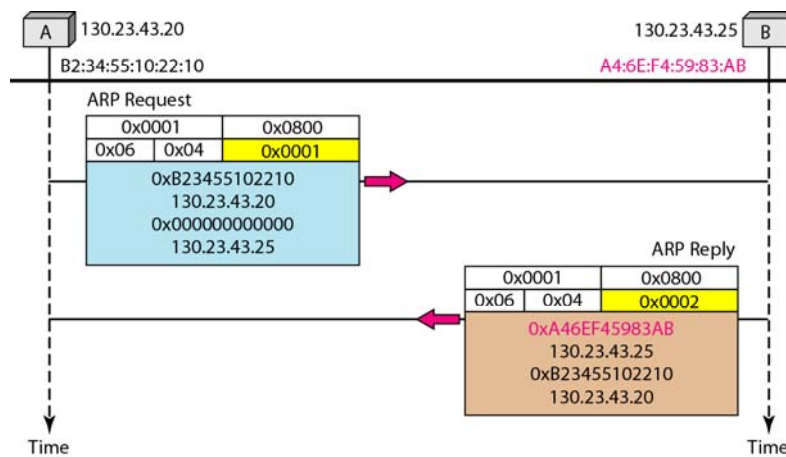
Based on
Data Communications and Networking, 4th Edition. by Behrouz A. Forouzan,   McGraw-Hill Companies, Inc., 2007   Dr. Mznah Al-Rodhaan

Proxy ARP

Based on
Data Communications and Networking, 4th Edition. by Behrouz A. Forouzan,   McGraw-Hill Companies, Inc., 2007   Dr. Mznah Al-Rodhaan

ARP functions

- Sender knows IP address
- IP asks ARP to create an ARP request message
  - sender physical address
  - sender IP address
  - target IP address
  - target physical address filled with 0's
- Message passed to data link layer; destination address = broadcast address
- All hosts receive frame; only target host accepts the packet
- Target host replies (unicast) with an ARP reply message containing the physical address
- Sender receives reply; it now knows the physical address of the target host
- IP datagram's are now unicast to the destination host

Cache Table

- A sender usually has more than one IP datagram to send to the same destination
- It is inefficient to use ARP for each datagram
- A cache table is used
  - limited size
 - mappings retained only for a limited time

RARP

- Finds the logical address for a host that only knows its physical address

- RARP request packets are broadcast; RARP reply packets are unicast

- Used by diskless machines to obtain their IP addresses

- DHCP is used now.

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Data Communications and Networking, 4th Edition. by Behrouz A. Forouzan, McGraw-Hill Companies, Inc., 2007   Dr. Mznah Al-Rodhaan

Operation
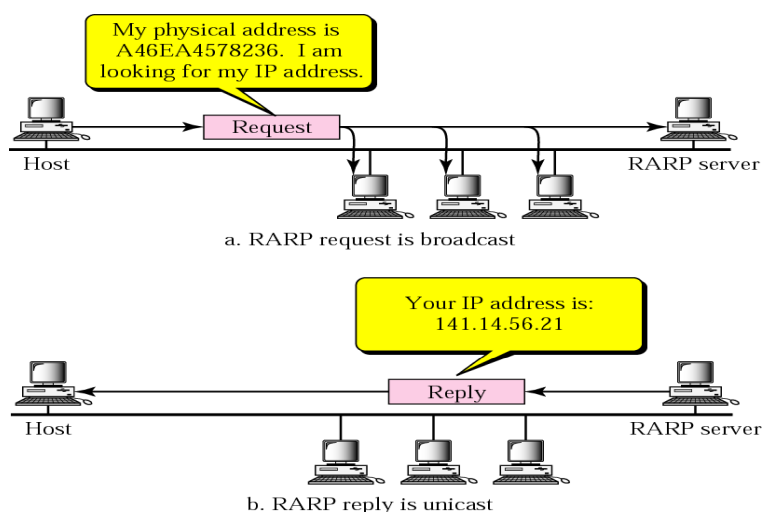
a. RARP request is broadcast

b. RARP reply is unicast

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Data Communications and Networking, 4th Edition. by Behrouz A. Forouzan, McGraw-Hill Companies, Inc., 2007   Dr. Mznah Al-Rodhaan

DHCP provides static and dynamic address allocation that can be manual or automatic.

A request is broadcast; a reply is unicast.

21-2 ICMP

The IP protocol has no error-reporting or error-correcting mechanism. The IP protocol also lacks a mechanism for host and management queries. The **Internet Control Message Protocol (ICMP)** *has been designed to compensate for the above two deficiencies. It is a companion to the IP protocol.*

Topics discussed in this section:

Types of Messages
Message Format
Error Reporting

21.44

ICMP protocol

- IP protocol is a best-effort delivery service, however it has two deficiencies
  - Lack of error control
  - Lack of assistance mechanisms
- IP protocol has no error-reporting or error-correction mechanism
  - What happens when something goes wrong?
  - What happens if a router must discard a datagram because it cannot find a route to the final destination?
  - What if the time-to-live field has a zero value?
  - What if it has to discard all fragments because not all were received in a predetermined time limit?
- IP protocol also lacks a mechanism for host and management queries.
- ICMP was designed to compensate for these deficiencies.

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Internet Control Message Protocol (ICMP)

- Encapsulated in IP packet
- Handles error and control messages
- If router cannot deliver or forward a packet, it sends an ICMP "host unreachable" message to the source
- If router receives packet that should have been sent to another router, it sends an ICMP "redirect" message to the sender; Sender modifies its routing table
- ICMP "router discovery" messages allow host to learn about routers in its network and to initialize and update its routing tables

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Data Communications and Networking, 4th Edition. by Behrouz A. Forouzan, McGraw-Hill Companies, Inc., 2007   Dr. Mznah Al-Rodhaan
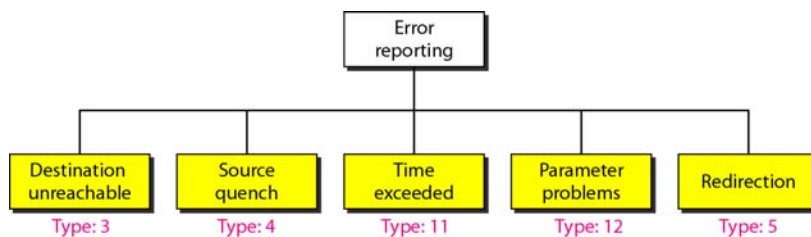
ICMP always reports error messages to the original source.

Error-reporting messages

Internet Control Message Protocol (ICMP)

ICMP is used by routers for exchanging error information and for testing. The principal ICMP message types are shown below.

Message type	Description
Destination unreachable	Packet could not be delivered
Time exceeded	Time to live field hit 0
Parameter problem	Invalid header field
Source quench	Choke packet
Redirect	Teach a router about geography

Important points about ICMP error messages:
- **No ICMP error message will be generated in response to a datagram carrying an ICMP error message.**
- **No ICMP error message will be generated for a fragmented datagram that is not the first fragment.**
- **No ICMP error message will be generated for a datagram having a multicast address.**
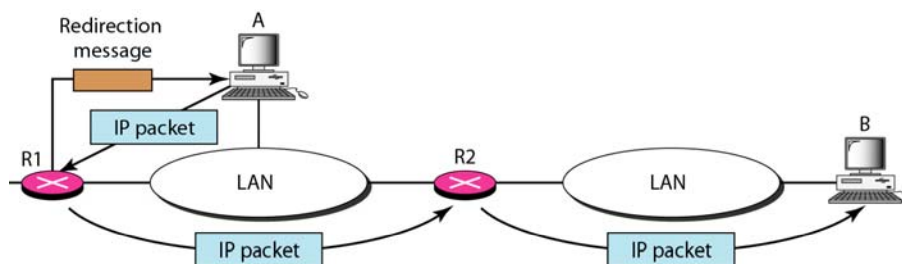- **No ICMP error message will be generated for a datagram having a special address such as 127.0.0.0 or 0.0.0.0.**

21.50

Contents of data field for the error messages
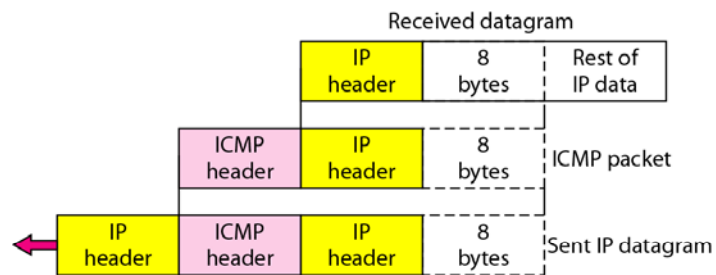
Based on
Data Communications and Networking, 4th Edition. by Behrouz A. Forouzan,   McGraw-Hill Companies, Inc., 2007   Dr. Mznah Al-Rodhaan

Redirection concept

Based on
Data Communications and Networking, 4th Edition. by Behrouz A. Forouzan,   McGraw-Hill Companies, Inc., 2007   Dr. Mznah Al-Rodhaan

Reading from the text book

❑ Chapter 21 from 4th edition (section 21.1 until the first paragraph of page 625 except BOOTP page 619)

Based on
Data Communications and Networking, 4th Edition. by Behrouz A. Forouzan, McGraw-Hill Companies, Inc., 2007   Dr. Mznah Al-Rodhaan