

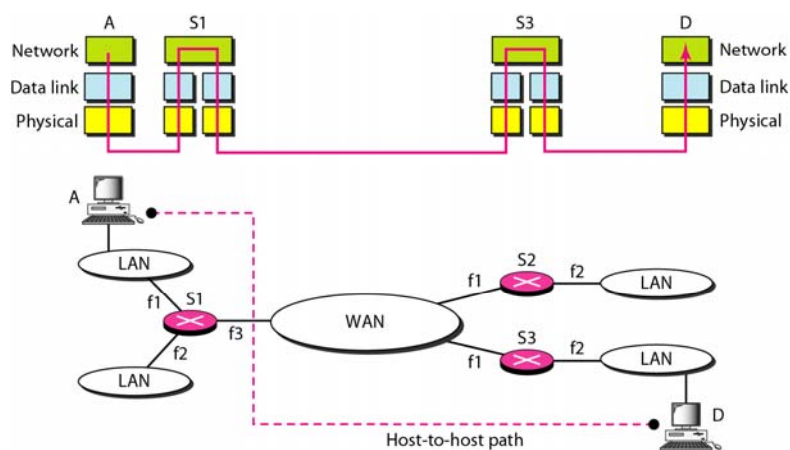
# Chapter 20

## Network Layer

### IP and Address Mapping

Dr. Mznah Al-Rodhaan

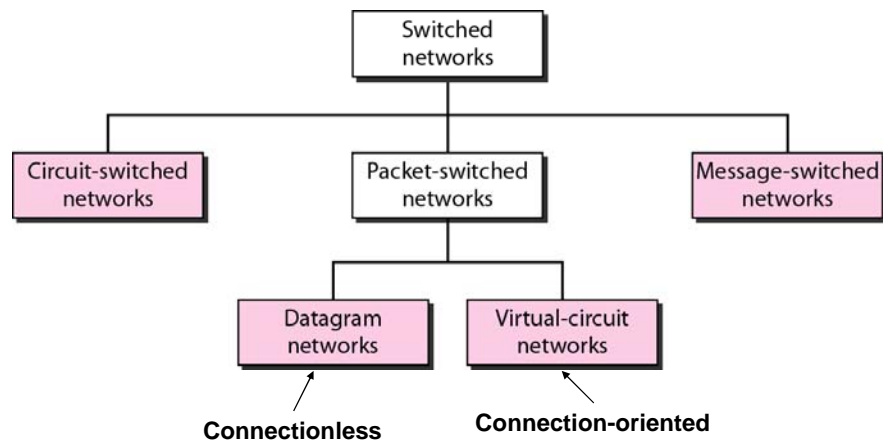
#### *Network layer in an internetwork*



20.2

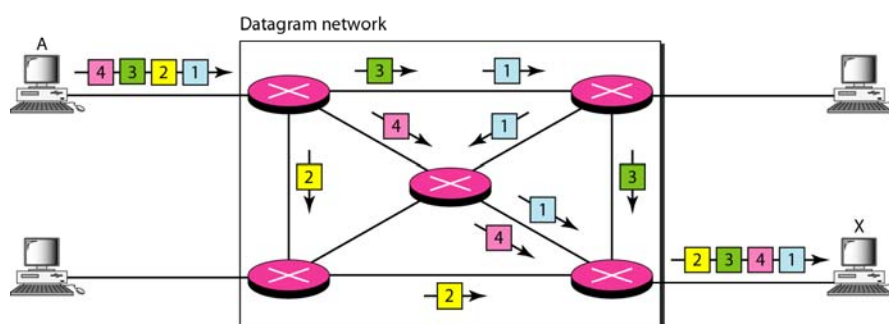
Based on  
Data Communications and Networking, 4<sup>th</sup> Edition, by Behrouz A. Forouzan, McGraw-Hill Companies, Inc., 2007 Dr. Mznah Al-Rodhaan

## ***Taxonomy of switched networks***



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

## ***A datagram network with four switches (routers)***



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

## *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.**

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

## **IPv4**

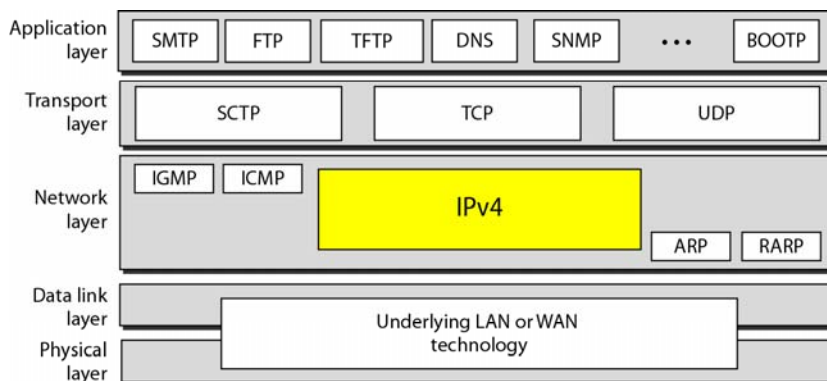
---

***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**

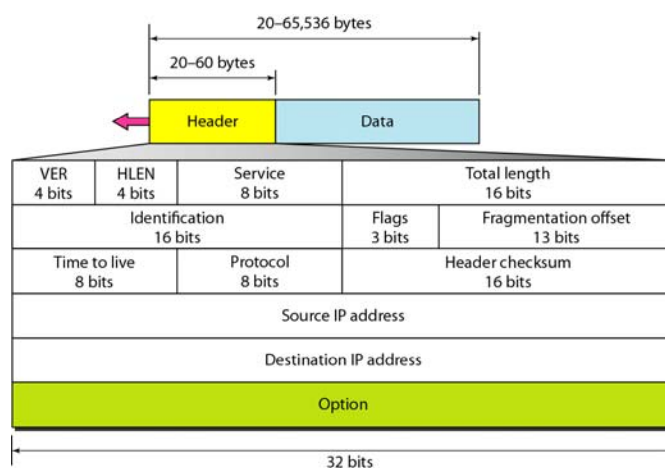
## Position of IPv4 in TCP/IP protocol suite



20.7

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

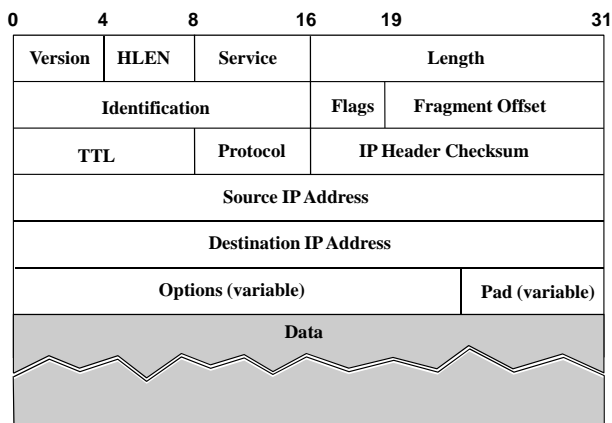
## IPv4 datagram format



20.8

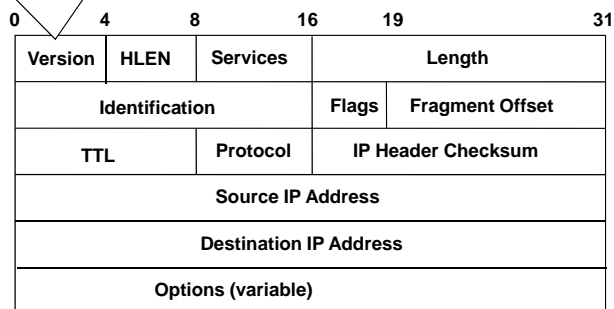
Based on  
Data Communications and Networking, 4<sup>th</sup> Edition, by Behrouz A. Forouzan, McGraw-Hill Companies, Inc., 2007 Dr. Mznah Al-Rodhaan

## IP Packet Format



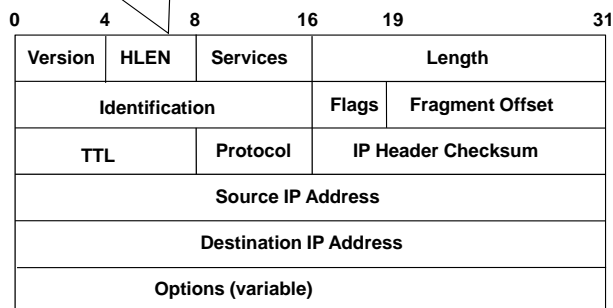
Based on  
Data Communications and Networking, 4<sup>th</sup> Edition, by Behrouz A. Forouzan, McGraw-Hill Companies, Inc., 2007 Dr. Mznah Al-Rodhaan

Current IP Protocol Version is 4, called IPv4



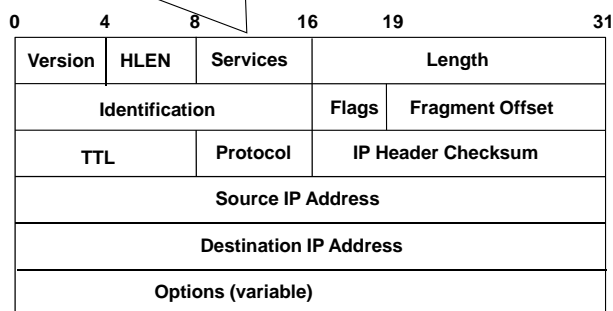
Based on  
Data Communications and Networking, 4<sup>th</sup> Edition, by Behrouz A. Forouzan, McGraw-Hill Companies, Inc., 2007 Dr. Mznah Al-Rodhaan

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



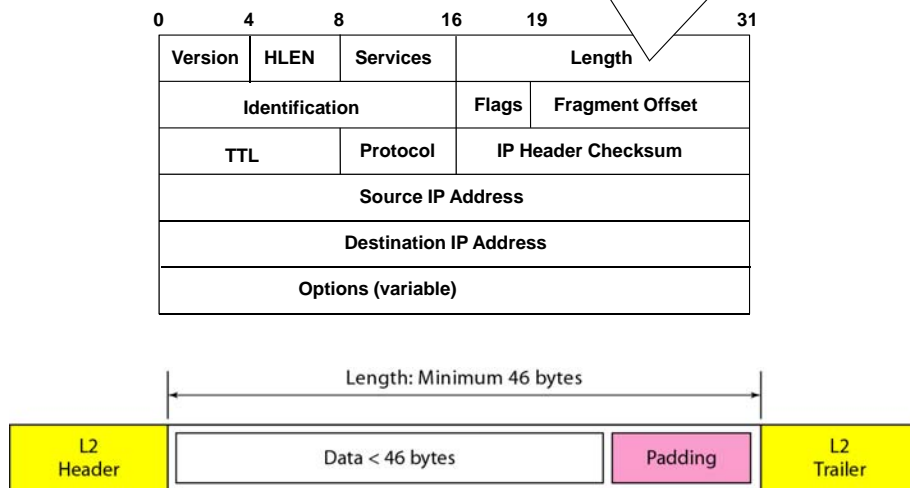
Based on  
Data Communications and Networking, 4<sup>th</sup> Edition, by Behrouz A. Forouzan, McGraw-Hill Companies, Inc., 2007 Dr. Mznah Al-Rodhaan

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.



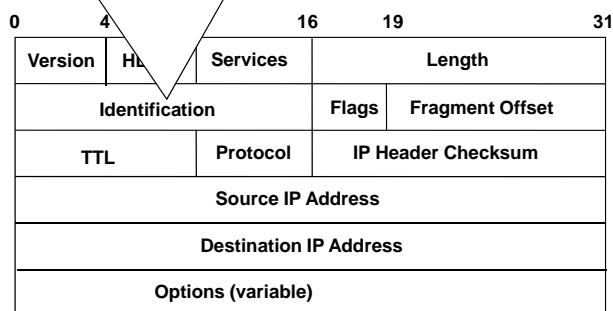
Based on  
Data Communications and Networking, 4<sup>th</sup> Edition, by Behrouz A. Forouzan, McGraw-Hill Companies, Inc., 2007 Dr. Mznah Al-Rodhaan

Total length of IP datagram in bytes. It is a 16 bit field. Largest size of an IP datagram is 65535 bytes. Maximum header size is 60 bytes. Link layer MTU may restrict this size further.

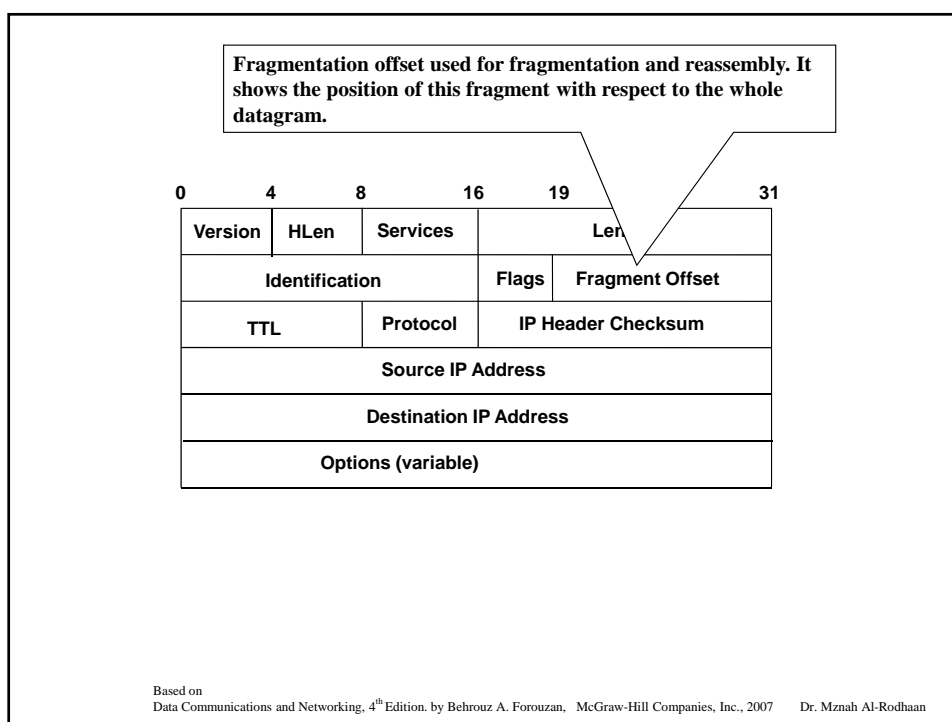
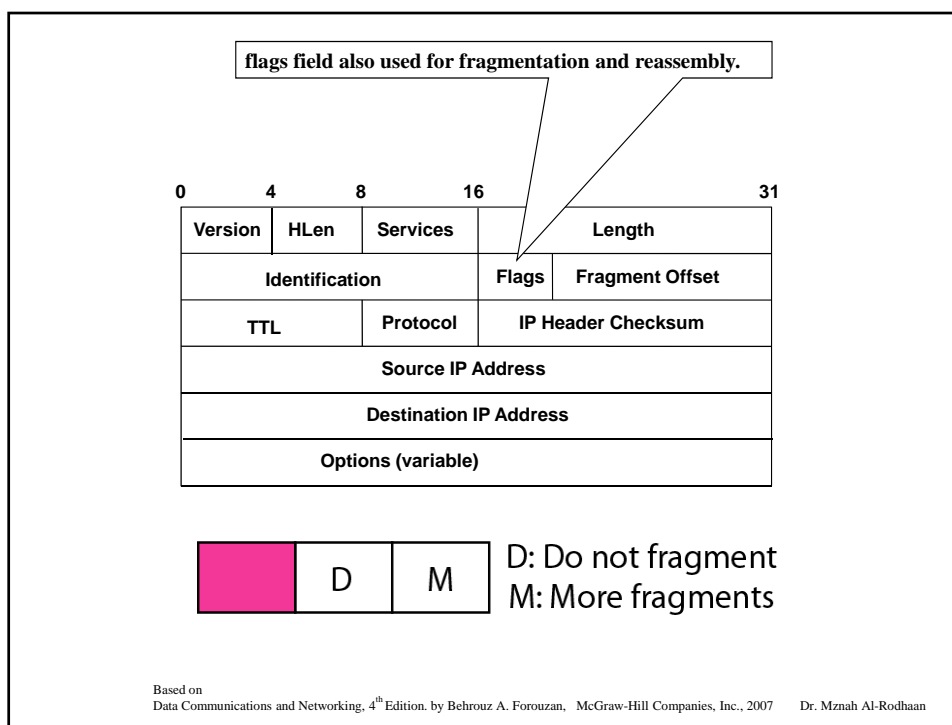


Based on  
Data Communications and Networking, 4<sup>th</sup> Edition, by Behrouz A. Forouzan, McGraw-Hill Companies, Inc., 2007 Dr. Mznah Al-Rodhaan

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.

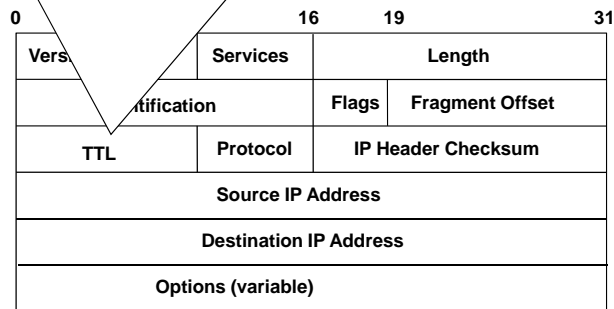


Based on  
Data Communications and Networking, 4<sup>th</sup> Edition, by Behrouz A. Forouzan, McGraw-Hill Companies, Inc., 2007 Dr. Mznah Al-Rodhaan



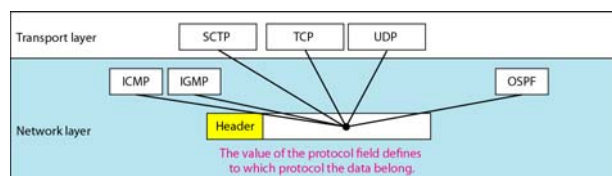
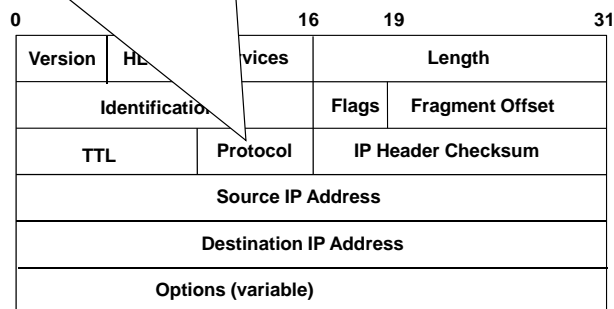


**Time-to-live (TTL ) field sets an upper limit on how man routers a datagram can go through. Every router decrements TTL by 1 before sending it forward. If TTL reaches 0 the datagram is dropped and an ICMP message is sent to the host application.**



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

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



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

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)					

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

### 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 ( $2 \times 4 = 8$ bytes).*

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

*The packet has been corrupted in transmission.*

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

### **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  $8 \times 4$ , or 32 bytes. The first 20 bytes are the base header, the next **12** bytes are the options.*

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

### **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  $5 \times 4$ , or 20 bytes (no options). The total length is 40 bytes, which means the packet is carrying **20** bytes of data ( $40 - 20$ ).*

**20.22**

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

### 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

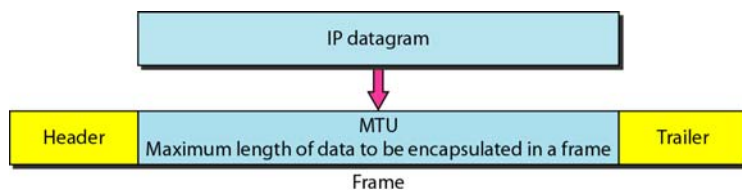
*To find the time-to-live field, we skip 8 bytes. The time-to-live field is the ninth byte, which is 01. This means the packet can travel only one hop. The protocol field is the next byte (02).*

20.23

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

## Fragmentation

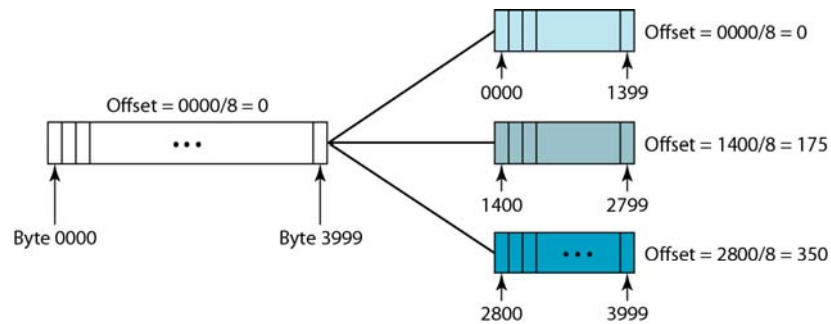
*Maximum transfer unit (MTU)*



20.24

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

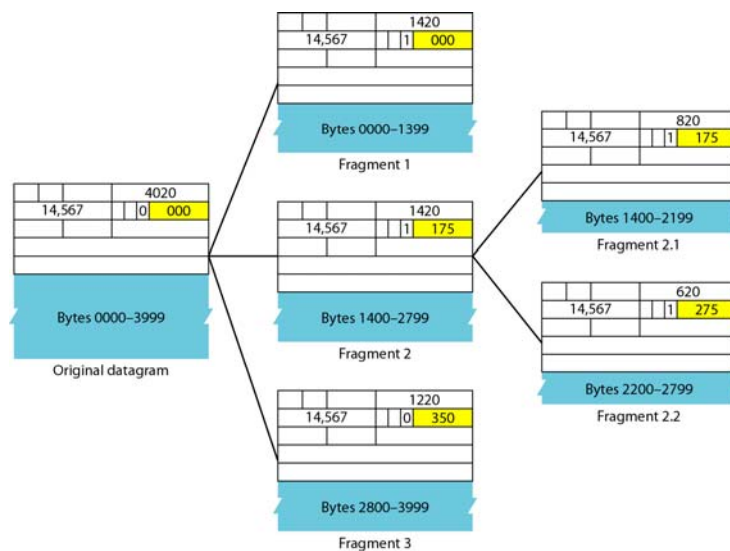
## Fragmentation example



20.25

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

## Detailed fragmentation example



20.26

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

## Reading from the text book

- ❑ Chapter 20 from 4<sup>th</sup> edition (section 20.1 until the end of page 594 except service Type and differentiated services )

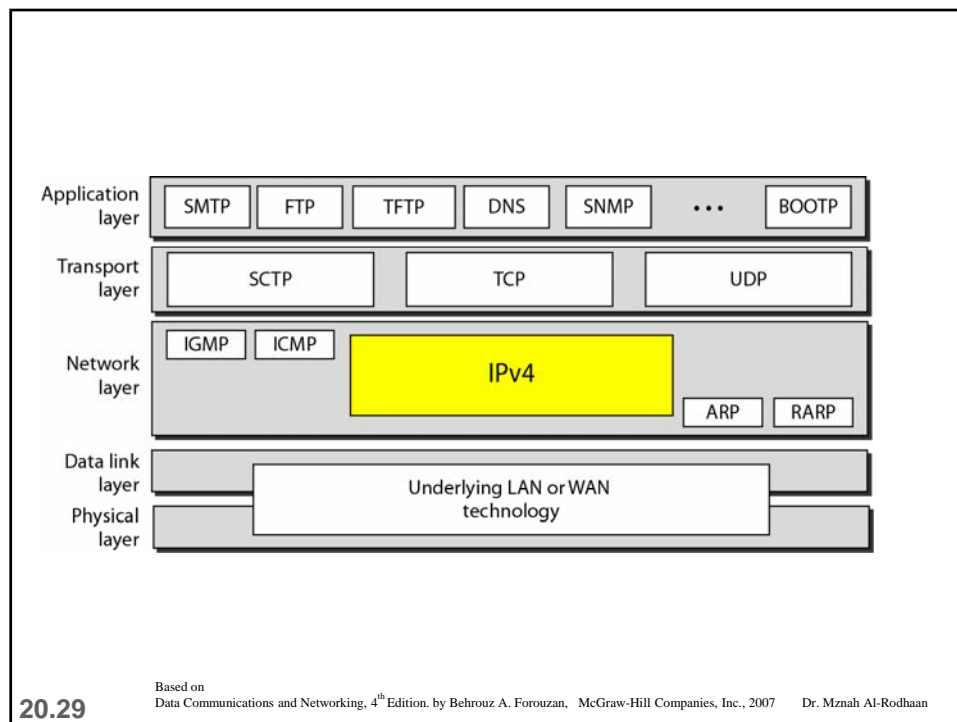
Based on  
Data Communications and Networking, 4<sup>th</sup> Edition. by Behrouz A. Forouzan, McGraw-Hill Companies, Inc., 2007 Dr. Mznah Al-Rodhaan

# Chapter 21

## Network Layer

## Address Mapping

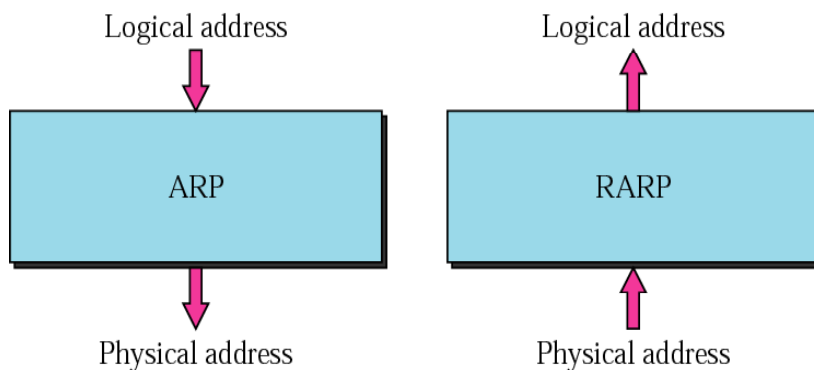
Based on  
Data Communications and Networking, 4<sup>th</sup> Edition. by Behrouz A. Forouzan, McGraw-Hill Companies, Inc., 2007 Dr. Mznah Al-Rodhaan



## 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.

## ARP and RARP



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

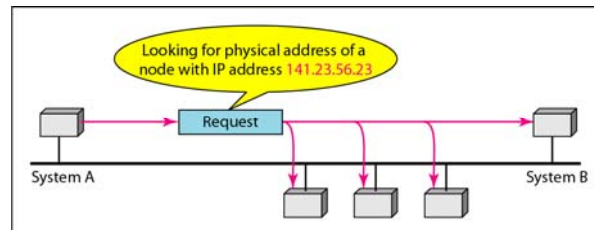
## ARP - The Address Resolution Protocol

- 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.

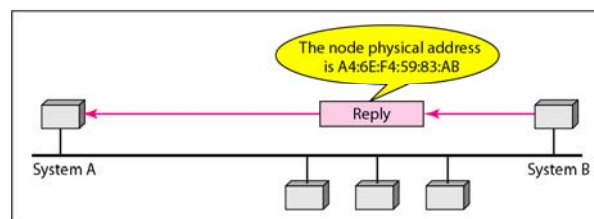
Based on  
Data Communications and Networking, 4<sup>th</sup> Edition, by Behrouz A. Forouzan, McGraw-Hill Companies, Inc., 2007 Dr. Mznah Al-Rodhaan



## ARP operation



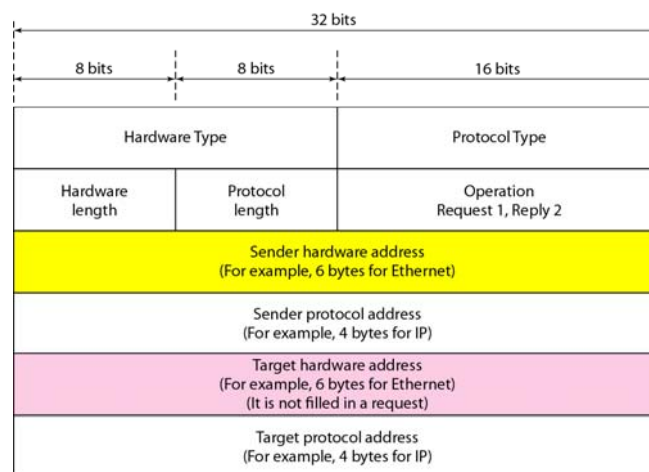
a. ARP request is broadcast



b. ARP reply is unicast

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

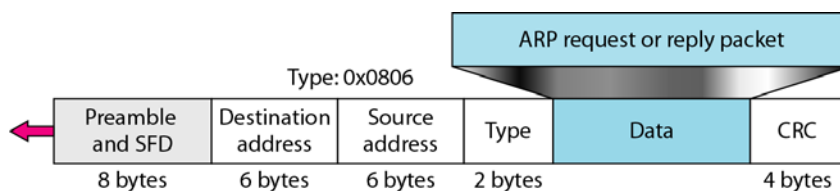
## ARP packet



21.34

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

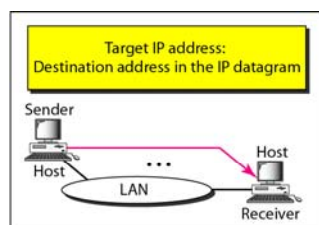
## Encapsulation of ARP packet



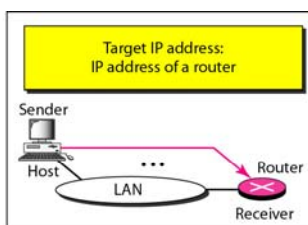
21.35

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

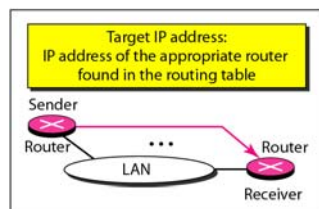
## Four cases using ARP



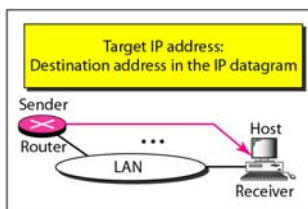
Case 1. A host has a packet to send to another host on the same network.



Case 2. A host wants to send a packet to another host on another network. It must first be delivered to a router.



Case 3. A router receives a packet to be sent to a host on another network. It must first be delivered to the appropriate router.

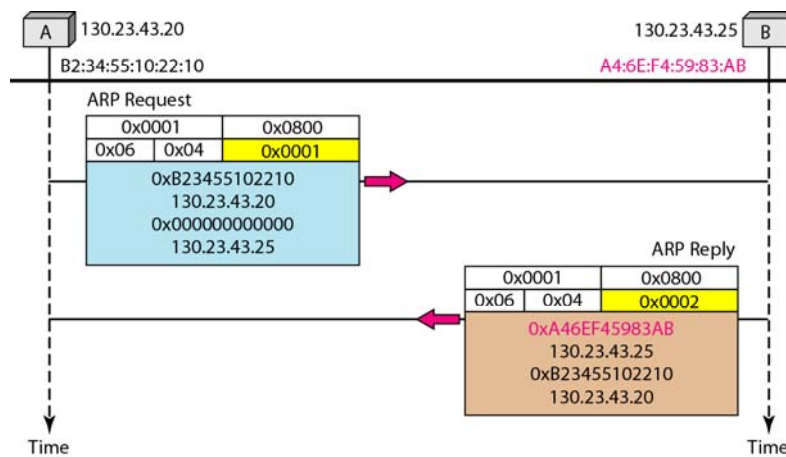


Case 4. A router receives a packet to be sent to a host on the same network.

21.36

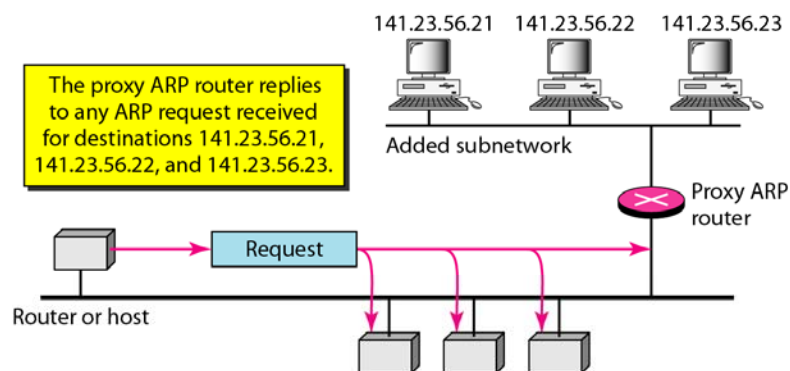
Based on  
Data Communications and Networking, 4<sup>th</sup> Edition, by Behrouz A. Forouzan, McGraw-Hill Companies, Inc., 2007 Dr. Mznah Al-Rodhaan

## ARP Request & Reply



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

## Proxy ARP



Based on  
Data Communications and Networking, 4<sup>th</sup> 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

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

## 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

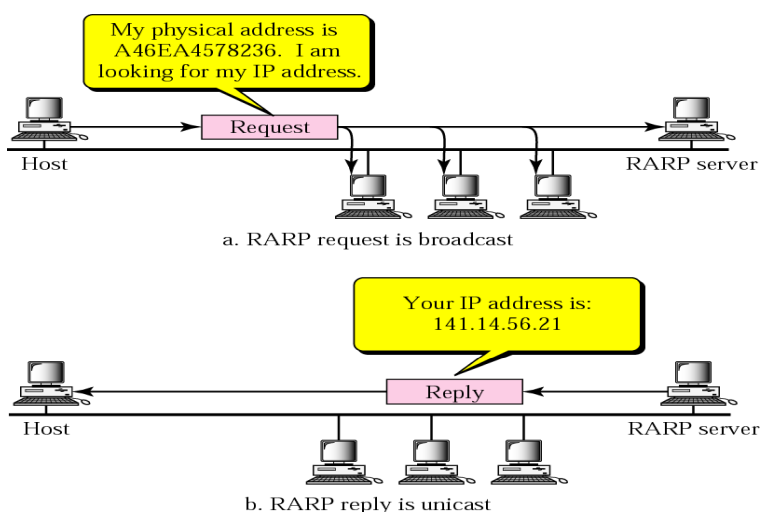
Based on  
Data Communications and Networking, 4<sup>th</sup> Edition, by Behrouz A. Forouzan, McGraw-Hill Companies, Inc., 2007 Dr. Mznah Al-Rodhaan

## 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.

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

## Operation



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

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

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**A request is broadcast;  
a reply is unicast.**

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

## **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**

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

## 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.

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

## 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

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

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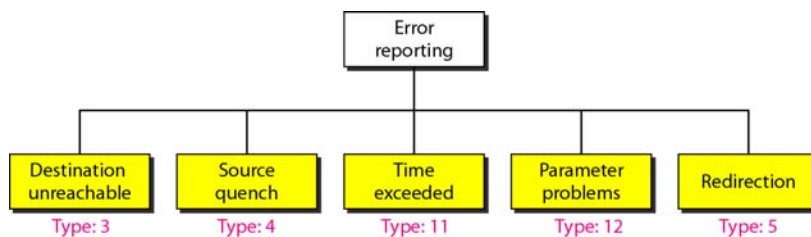
**ICMP always reports error messages to the original source.**

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

### *Error-reporting messages*

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21.48

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## 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.

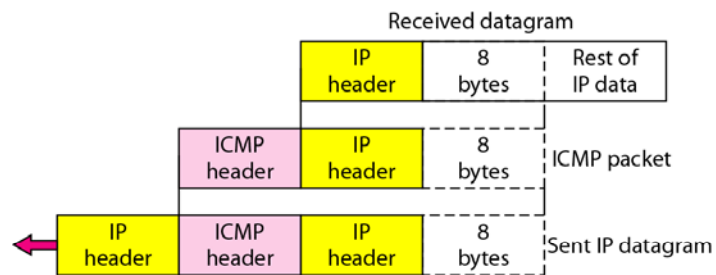
Message type	Description
Destination unreachable	Packet could not be delivered
Time exceeded	Time to live field hit 0
Parameter problem	Invalid header field
Source quench	Choke packet
Redirect	Teach a router about geography

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

### 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.

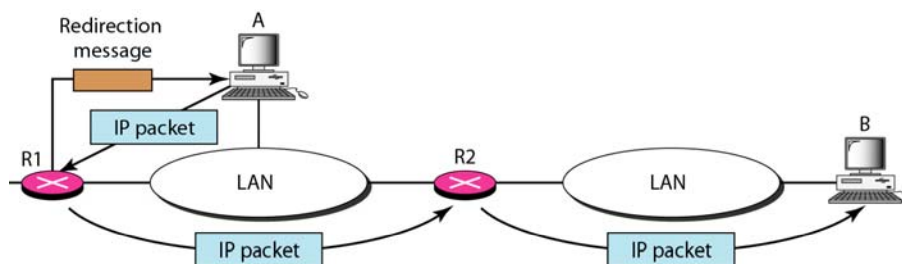
### *Contents of data field for the error messages*



21.51

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

### *Redirection concept*



21.52

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

## Reading from the text book

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

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