HO CHI MINH CITY UNIVERSITY OF SCIENCE
FACULTY OF ELECTRONICS AND TELECOMMUNICATIONS
DEPARTMENT OF TELECOMMUNICATIONS AND NETWORKS

COURSE

COMPUTER NETWORKS

Chapter 04

IP VERSION 4

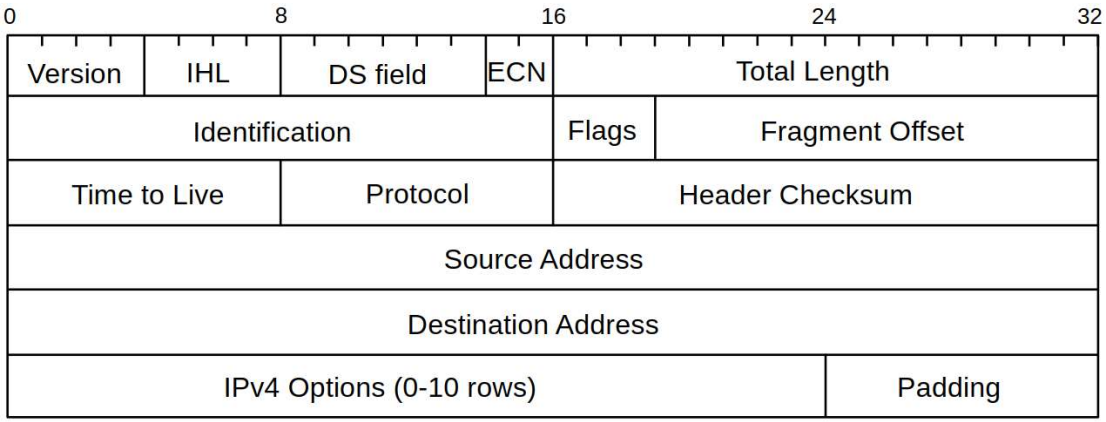
Reference: Peter L Dordal, "An Introduction to Computer Networks," Jul 26, 2019

Lecturer: Nguyen Viet Ha, Ph.D. Email: nvha@fetel.hcmus.edu.vn

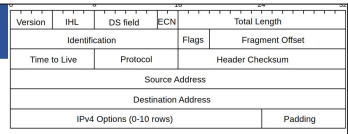
1

The IPv4 Header

1. The IPv4 Header



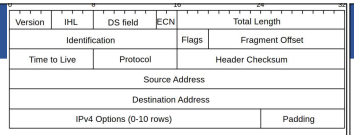
1. The IPv4 Header



- **Version:** Contains a 4-bit binary value identifying the IP packet version. For IPv4 packets, this field is always set to 0100.

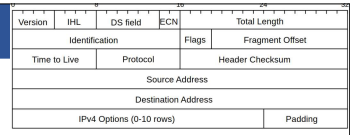
- **Differentiated Services (DS)** (Type of Service - ToS) field: 8-bit field used to determine the priority of each packet.
  - The first 6 bits identify the Differentiated Services Code Point (DSCP) value that is used by a quality of service (QoS) mechanism.
  - The last 2 bits identify the Explicit Congestion Notification (ECN) value that can be used to prevent dropped packets during times of network congestion.

1. The IPv4 Header



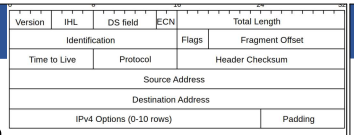
- **Time-to-Live (TTL):** Contains an 8-bit binary value that is used to limit the lifetime of a packet (referred to as hop count).
  - Decreased by one each time the packet is processed by a router, or hop. If the TTL field decrements to 0, the router discards the packet and sends an Internet Control Message Protocol (ICMP) Time Exceeded message to the source IP address.
- **Protocol:** This 8-bit binary value indicates the data payload type (upper-layer).
  - ICMP (0x01), TCP (0x06), and UDP (0x11)….
- **Source IP Address -** Contains a 32-bit binary value that represents the source IP address of the packet.
- **Destination IP Address -** Contains a 32-bit binary value that represents the destination IP address of the packet.

1. The IPv4 Header



- **Internet Header Length (IHL) -** Contains a 4-bit binary value identifying the number of 32-bit words in the header. The IHL value varies due to the Options and Padding fields.
  - Minimum: 5 → Maximum: 15
- **Total Length –** (Packet Length), this 16-bit field defines the entire packet (fragment) size, including header and data, in bytes.
  - Minimum: 20 -> Maximum: 65,535 bytes.
- **Header Checksum -** The 16-bit field is used for error checking of the IP header.
  - If the values do not match, the packet is discarded.

1. The IPv4 Header



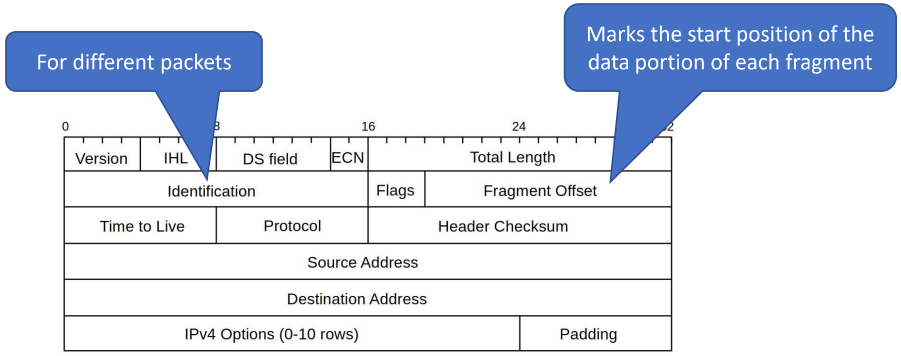
- A router may have to **fragment a packet** when forwarding it from one medium to another medium that has a smaller MTU.
- **Identification -** This 16-bit field uniquely identifies the fragment of an original IP packet.
- **Flags -** This 3-bit field identifies how the packet is fragmented. It is used with the Fragment Offset and Identification fields to help reconstruct the fragment into the original packet.
  - DF**: D**on't **F**ragments flag, MF: **M**ore **F**ragments flag
- **Fragment Offset -** This 13-bit field identifies the order in which to place the packet fragment in the reconstruction of the original unfragmented packet.

2 Fragmentation

2. Fragmentation

❖MTU is smaller than the packet that needs forwarding.

→Fragmentation (vs. reassembly)



** **size of the data portions** be divisible by 8*

*** **Fragment Offset** is the value divided to 8*

2. Fragmentation

❖Suppose **A** addresses a packet of 1500 bytes to **B**, and sends it via the LAN to the first router **R1**. The packet contains 20 bytes of IPv4 header and 1480 of data.

A — MTU 1500 — R1 — MTU 1000 — R2 — MTU 400 — R3 — MTU 1500 — B

A→R1	FragOffset
1st Fragment	
2nd Fragment	
3rd Fragment	
4th Fragment	

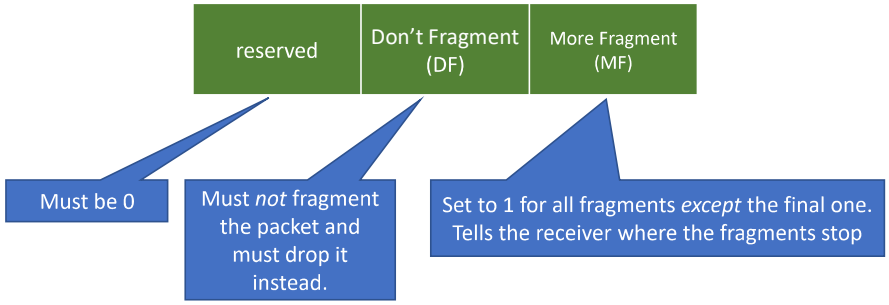
R1→R2	FragOffset
1st Fragment	
2nd Fragment	
3rd Fragment	
4th Fragment	

R2→R3	FragOffset
1st Fragment	
2nd Fragment	
3rd Fragment	
4th Fragment	

R3→B	FragOffset
1st Fragment	
2nd Fragment	
3rd Fragment	
4th Fragment	

2. Fragmentation

❖**Flag (3 bits)**



❖The fragments may not arrive in order.

➢The reassembler must identify when different arriving packets are fragments of the same original, and must figure out how to reassemble the fragments in the correct order.

2. Fragmentation

❖**Reassembly timer**

➢If a fragment arrives, a buffer is allocated.

- Because of the ***FragOffset*** field, the fragment can then be **stored** in the buffer **in the appropriate position**.

➢Reassembly timer is started.

➢When all fragments have arrived, the packet is sent on up as a completed IPv4 packet.

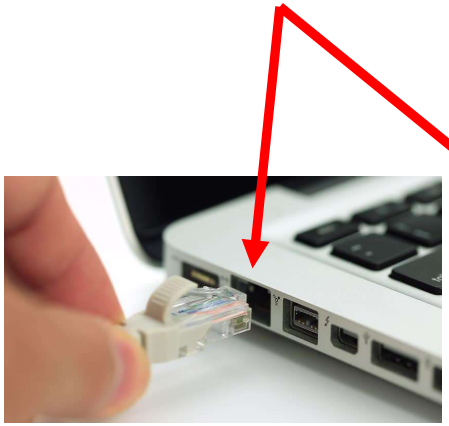
➢On the other hand, if the **reassembly timer expires**, all the pieces received so far are **discarded**.

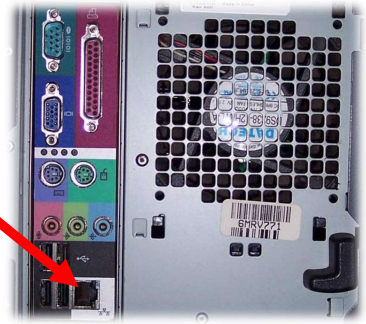
3 Interfaces

3. Interfaces

❖IP addresses are assigned not to hosts or nodes, but to **interfaces**.

➢E.g., LAN interface in PC.





3. Interfaces

❖**Loopback** interface

➢Providing a way to deliver IP packets to other processes on the same machine.

- IPv4 loopback address: "127.0.0.1"
- IPv6 loopback address: "::1"

➢Client/server testing.

➢Check the processes in current host.

❖**Virtual** interface

➢VPN connections.

➢Virtual machine

3. Interfaces

❖**Multihomed hosts**

➢A non-router host with multiple non-loopback network interfaces is often said to be **multihomed**.

- Interfaces are been used simultaneously, with different IP addresses assigned to each.
- E.g., Laptops have both an Ethernet interface and a Wi-Fi interface.

4 Special Addresses

4. Special Addresses

❖**Private addresses**

- ➢IPv4 addresses intended only for site internal use.
- ➢If a packet shows up at any non-private router (e.g., at an ISP router), with a private IPv4 address as either source or destination address, the packet should be dropped.
  - ○10.0.0.0 to 10.255.255.255 (10.0.0.0/8)
  - ○172.16.0.0 to 172.31.255.255 (172.16.0.0/12)
  - ○192.168.0.0 to 192.168.255.255 (192.168.0.0/16)

4. Special Addresses

❖**Broadcast addresses**

- ➢Used in conjunction with LAN-layer broadcast.
  - ○Sending a packet from one host to all hosts in the network.

❖**Multicast addresses**

- ➢Delivering to a specified **set of addresses**.
  - ○Examples:
    - ▪Video and audio broadcasts
    - ▪Routing information exchange by routing protocols
    - ▪Distribution of software
    - ▪Remote gaming

4. Special Addresses

❖**Broadcast addresses**

- ➢Used in conjunction with LAN-layer broadcast.
  - ○Sending a packet from one host to all hosts in the network.

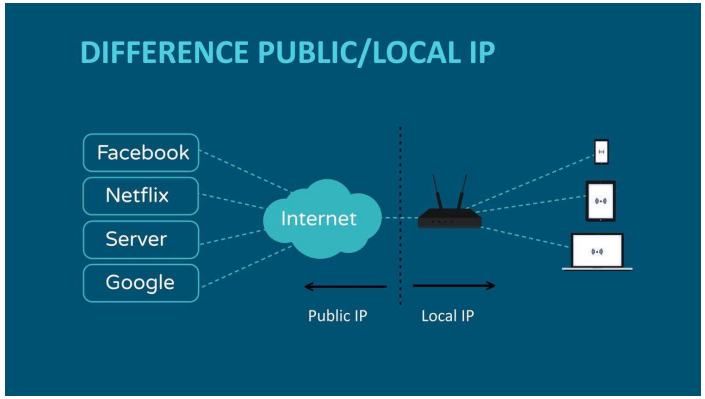
❖**Multicast addresses**

- ➢The address with first byte beginning **1110**.
  - ○224.0.0.0 to 239.255.255.255.
    - ▪**Link local** - 224.0.0.0 to 224.0.0.255 (E.g., routing information exchanged by routing protocols)
    - ▪**Globally scoped addresses** - 224.0.1.0 to 238.255.255.255 (E.g., 224.0.1.1 has been reserved for Network Time Protocol)

4. Special Addresses

❖**Public Addresses:**

➢These addresses are designed to be used in the hosts that are publicly accessible from the Internet.



5 The Classless IP Delivery Algorithm

5. The Classless IP Delivery Algorithm

❖**Classful** (discontinuation)

➢**Fixed** the network portion and host portion

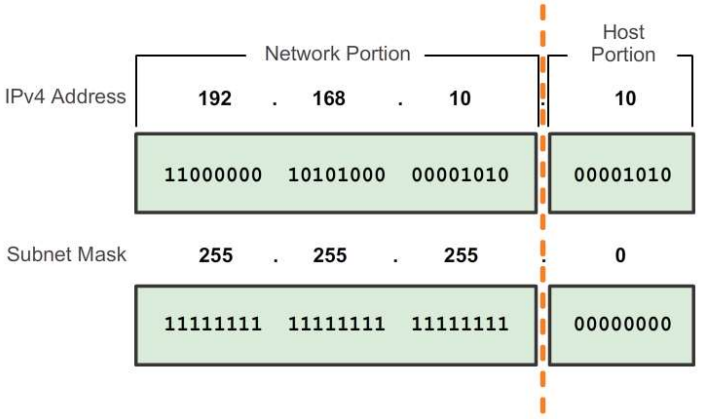
Class	High Order Bits	First Octet Range	Number of Network Bits	Number of Host Bits	Number of Networks	Number of Hosts per Network
A	0	0-127	8	24	128	16,777,216
B	10	128-191	16	16	16,384	65,536
C	110	192-223	24	8	2,097,152	256
D	1110	224-239	Used for Multicasting to multiple hosts.			
E	1111	240-255	Reserved for research and development.			

5. The Classless IP Delivery Algorithm

❖**Classless**

➢**Dynamic** network portion and host portion

- Have to use **Subnet Mask**



5. The Classless IP Delivery Algorithm

❖**Classless**

➢**Dynamic** network portion and host portion

IPv4 Address

11000000 10101000 00001010	00001010

Subnet Mask

11111111 11111111 11111111	00000000

Network Address

11000000 10101000 00001010	00000000

prefix length = 24 → 192.168.10.0/24

5. The Classless IP Delivery Algorithm

❖**IP Destination**

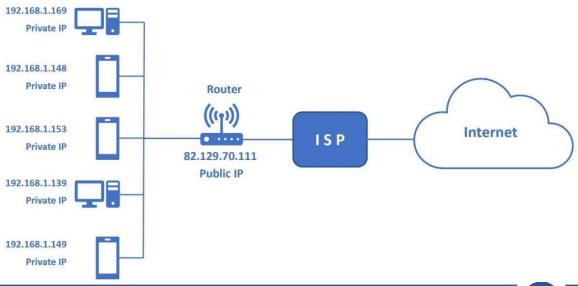
➢**Local**

- The host delivers the packet to its final destination via the LAN connected to the corresponding interface.

➢**Non-Local**

- The host **lookup** the forwarding table and sends the packet to the associated next_hop.

❖The forwarding table may also contain a ***default entry for the next_hop***, which it may return in cases when the destination does not match any known network. (**0.0.0.0/0**)



6

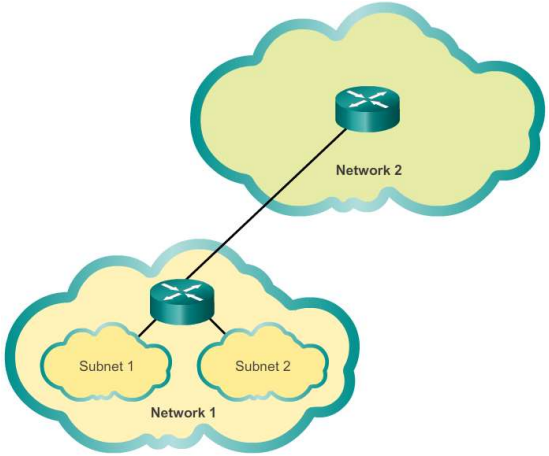
IPv4 Subnets

6. IPv4 Subnets

❖**Subnet**

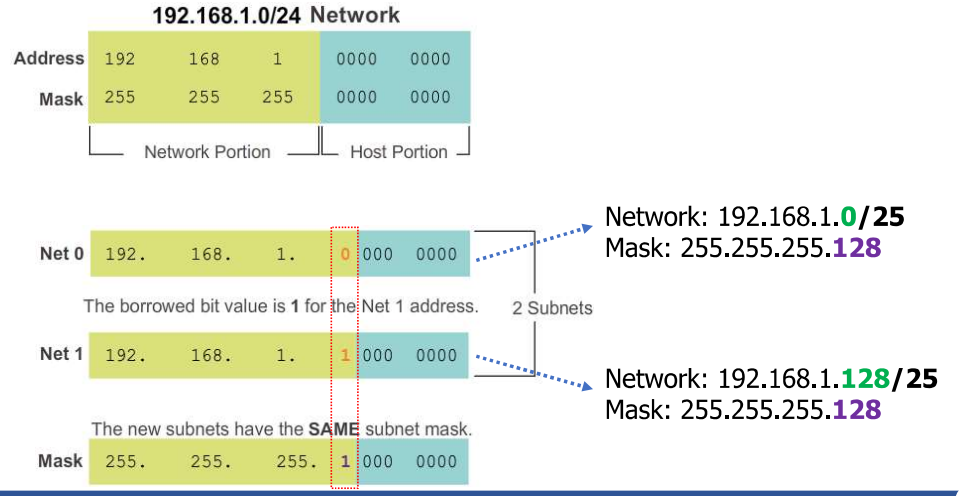
➢Idea: A site to appear to the outside world as a single IP network, but for further IP-layer routing to be supported inside the site.

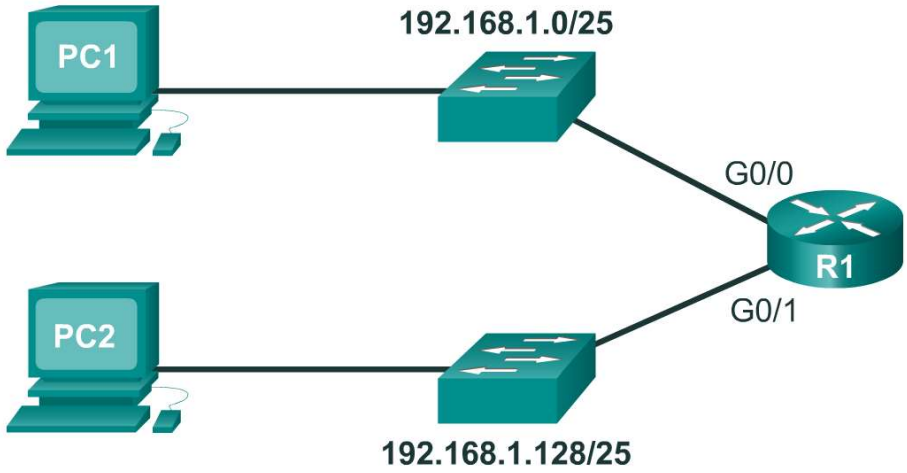
➢**Hierarchical routing**: first we route to the primary network, then inside that site we route to the subnet, and finally the last hop delivers to the host.



❖ Borrowing Bits (of Host portion) to create Subnets

➢ *EX: Borrowing 1 bit* 2^1 *= 2 subnets*





Address Range of **192.168.1.0/25** subnet

Network Address

192. 168. 1. 0 000 0000 = 192.168.1.0

First Host Address

192. 168. 1. 0 000 0001 = 192.168.1.1

Last Host Address

192. 168. 1. 0 111 1110 = 192.168.1.126

Broadcast Address

192. 168. 1. 0 111 1111 = 192.168.1.127

Address Range of **192.168.1.128/25** subnet

Network Address

192. 168. 1. 1 000 0000 = 192.168.1.128

First Host Address

192. 168. 1. 1 000 0001 = 192.168.1.129

Last Host Address

192. 168. 1. 1 111 1110 = 192.168.1.254

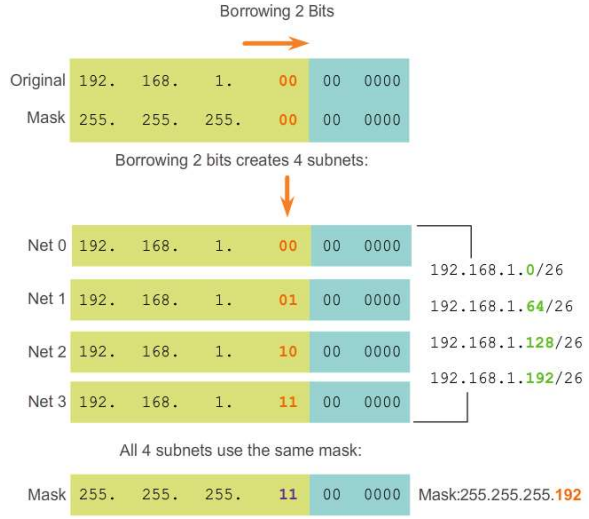
Broadcast Address

192. 168. 1. 1 111 1111 = 192.168.1.255

6. IPv4 Subnets

❖**Need 4 Subnets?**

➢Borrowing 2 bits to create 4 subnets. **2^2 = 4 subnets**

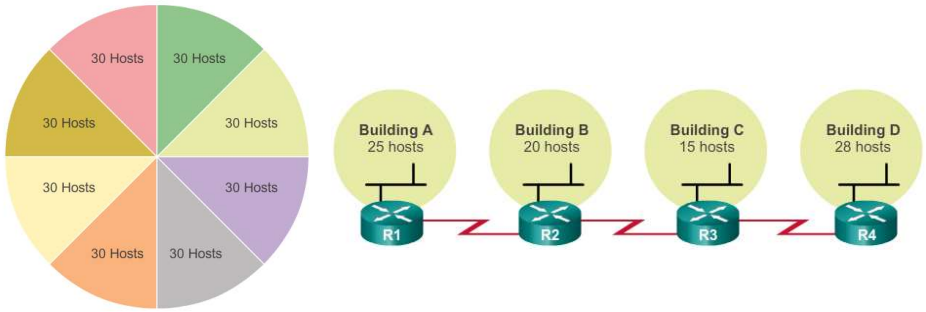


7

VLSM (Variable Length Subnet Masking)

7. VLSM

❖Traditional subnetting - same number of addresses is allocated for each subnet.



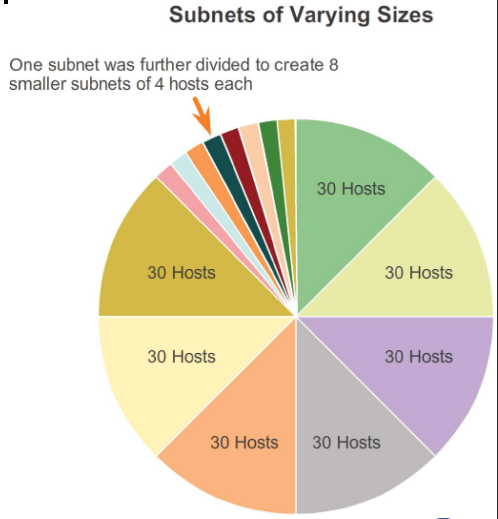
❖Subnets that require fewer addresses have unused (**wasted**) addresses.

➢For example, WAN links only need 2 addresses.

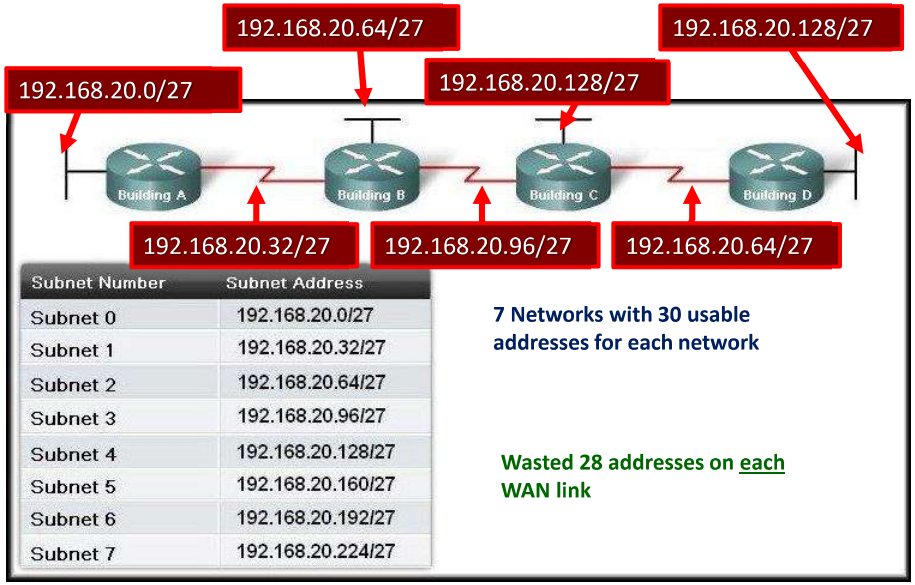
7. VLSM

❖**Variable Length Subnet Mask (VLSM)** or subnetting a subnet provides more efficient use of addresses.

- ❖ VLSM enables a network number to be configured with different subnet masks on different interfaces.
- ❖ Network is first subnetted, and then the subnets are subnetted again.
- ❖ Process repeated as necessary to create subnets of various sizes.



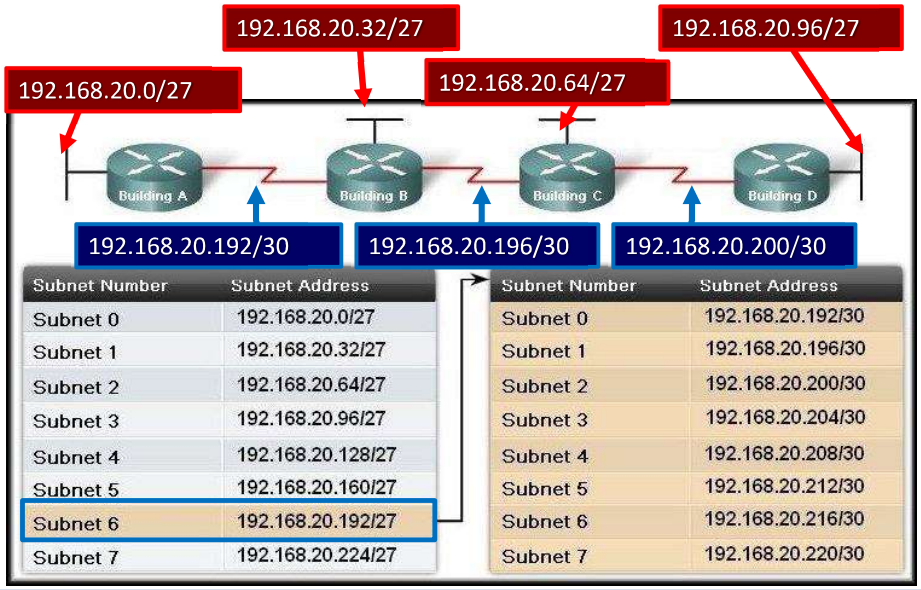
10.0.0.0/8	Subnet	using /16	
Subnet	1st Host	Last Host	Broadcast
10.0.0.0/16	10.0.0.1	10.0.255.254	10.0.255.255
10.1.0.0/16	10.1.0.1	10.1.255.254	10.1.255.255
10.2.0.0/16	Subnet	1st Host	Last Host	Broadcast
Sub-subnet Using /24	10.2.0.0/24	10.2.0.1	10.2.0.254	10.2.0.255
	10.2.1.0/24	10.2.1.1	10.2.1.254	10.2.1.255
	10.2.2.0/24	10.2.2.1	10.2.2.254	10.2.2.255
	Etc.			
	10.2.255.0/24	10.2.255.1	10.2.255.254	10.2.255.255
10.3.0.0/16	10.3.0.1	10.3.255.254	10.3.255.255	
Etc.				
10.255.0.0/16	10.255.0.1	10.255.255.254	10.255.255.255	



Subnet Number	Subnet Address
Subnet 0	192.168.20.0/27
Subnet 1	192.168.20.32/27
Subnet 2	192.168.20.64/27
Subnet 3	192.168.20.96/27
Subnet 4	192.168.20.128/27
Subnet 5	192.168.20.160/27
Subnet 6	192.168.20.192/27
Subnet 7	192.168.20.224/27

7 Networks with 30 usable addresses for each network

Wasted 28 addresses on each WAN link



Subnet Number	Subnet Address
Subnet 0	192.168.20.0/27
Subnet 1	192.168.20.32/27
Subnet 2	192.168.20.64/27
Subnet 3	192.168.20.96/27
Subnet 4	192.168.20.128/27
Subnet 5	192.168.20.160/27
Subnet 6	192.168.20.192/27
Subnet 7	192.168.20.224/27

Subnet Number	Subnet Address
Subnet 0	192.168.20.192/30
Subnet 1	192.168.20.196/30
Subnet 2	192.168.20.200/30
Subnet 3	192.168.20.204/30
Subnet 4	192.168.20.208/30
Subnet 5	192.168.20.212/30
Subnet 6	192.168.20.216/30
Subnet 7	192.168.20.220/30

❖Steps for VLSM:

1. List the number of hosts required per network beginning with the largest to the smallest.
2. Convert the subnet mask to binary.
3. Draw a line where the network portion ends.
4. Ask yourself the question… *How many bits do I need to support the required number of hosts?*
5. Move the line to show your new network portion.
6. Determine your new magic number.
7. Finish subnetting using the new magic number.

❖The starting address is always the first network.

❖You cannot go past the *next* network of the *previous level*.

8 Address Resolution Protocol: ARP

8. Address Resolution Protocol: ARP

❖If a host finds that the destination IP address matches the network address of one of its interfaces, it is to deliver the packet via the LAN.

➢Looking up the LAN address (MAC address).

→**ARP**

❖**ARP cache:** Storing of <IPv4,LAN> address pairs for other hosts on the network.

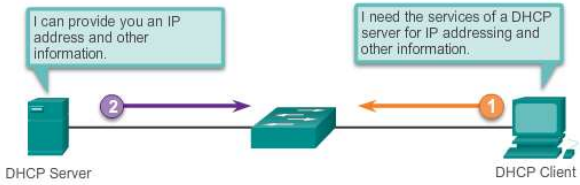
➢ARP-cache entries eventually expire. The timeout interval used to be on the order of 10 minutes, but Linux systems now use a much smaller timeout (~30 seconds observed in 2012).

8. Address Resolution Protocol: ARP

9 Dynamic Host Configuration Protocol (DHCP)

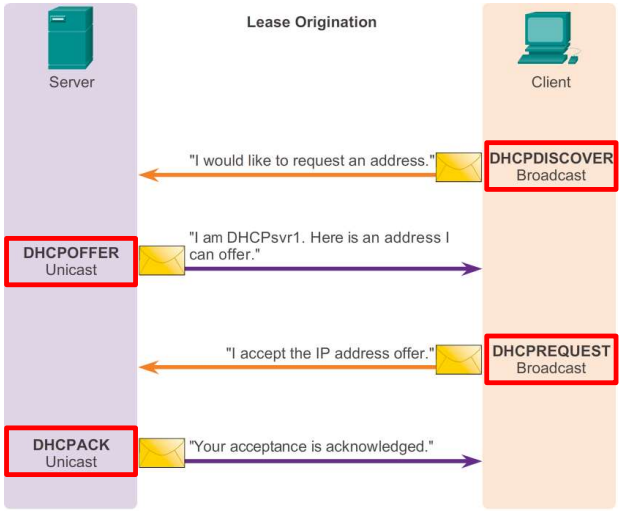
9. Dynamic Host Configuration Protocol (DHCP)

- DHCP works in a client/server mode.
  - ➢When the client connects, the server assigns or leases an IP address to the device.
  - ➢The device connects to the network with that leased IP address until the lease period expires.
  - ➢The host must contact the DHCP server periodically to extend the lease.
  - ➢The leasing of addresses assures that addresses that are no longer used are returned to the address pool for use by other devices.



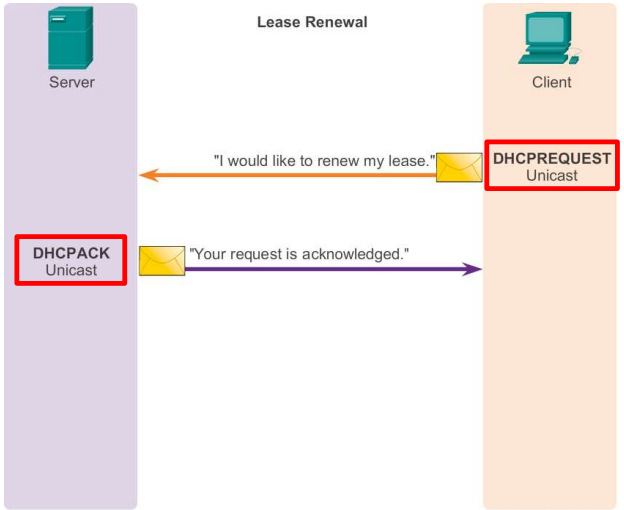
9. Dynamic Host Configuration Protocol (DHCP)

❖**Lease Origination:** 4 Step Process.



9. Dynamic Host Configuration Protocol (DHCP)

❖**Lease Renewal:** 2 Step Process



10 Internet Control Message Protocol (ICMP)

10. Internet Control Message Protocol

❖ICMP is a protocol for sending IP-layer error and status messages.

❖ICMP messages are identified by an 8-bit type field.

Type	Description
Echo Request	`ping` queries
Echo Reply	`ping` responses
Destination Unreachable	Destination **network** unreachable
	Destination **host** unreachable
	Destination **port** unreachable
	Fragmentation required but DF flag set
	Network administratively prohibited
Source Quench	Congestion control
Redirect Message	Redirect datagram for the **network**
	Redirect datagram for the **host**
	Redirect for TOS and network
	Redirect for TOS and host
Router Solicitation	Router discovery/selection/solicitation
Time Exceeded	TTL expired in transit
	Fragment reassembly time exceeded
Bad IP Header or Parameter	Pointer indicates the error
	Missing a required option
	Bad length
Timestamp,Timestamp Reply	Like `ping`, but requesting a timestamp from the destination

Queries sent by one host to another

Error sent by a router to the sender

10. Internet Control Message Protocol

❖The **Destination Unreachable** type has a large number of subtypes:

➢**Network unreachable:** some router had no entry for forwarding the packet, and no default route

➢**Host unreachable:** the packet reached a router that was on the same LAN as the host, but the host failed to respond to ARP queries

10. Internet Control Message Protocol

❖The **Destination Unreachable** type has a large number of subtypes:

➢**Port unreachable:**

- The packet was sent to a UDP port on a given host, but that port was not open.
  - TCP, on the other hand, deals with this situation by replying to the connecting endpoint with a reset packet.

- FYI: the UDP Port Unreachable message is sent to the host, not to the application on that host that sent the undeliverable packet, and so is close to useless as a practical way for applications to be informed when packets cannot be delivered.

10. Internet Control Message Protocol

❖The **Destination Unreachable** type has a large number of subtypes:

➢**Fragmentation required but DF flag set:** a packet arrived at a router and was too big to be forwarded without fragmentation. However, the Don't Fragment bit in the IPv4 header was set, forbidding fragmentation.

➢**Administratively Prohibited:** this is sent by a router that knows it can reach the network in question, but has configure intro to drop the packet and send back Administratively Prohibited messages. A router can also be configured to blackhole messages: to drop the packet and send back nothing.

10. Internet Control Message Protocol

❖**Traceroute and Time Exceeded**

➢The traceroute program uses ICMP Time Exceeded messages.

➢A packet is sent to the destination with the **TTL** set from **1** until the ICMP query reaches to the destination.

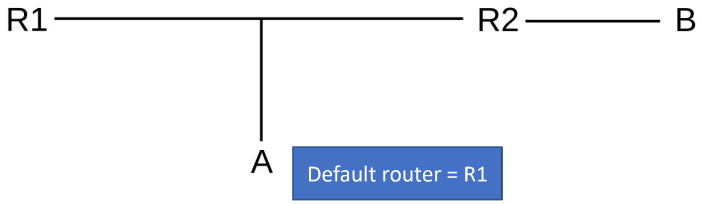
- Router drops packet having TTL=0 and returns ICMP Time Exceeded.

10. Internet Control Message Protocol

❖**Redirects**

➢Most non-router hosts start up with an IPv4 forwarding table consisting of a single (default) router.

➢ICMP Redirect messages help hosts learn of other useful routers.



❖**Router Solicitation**

➢These ICMP messages are used by some router protocols to identify immediate neighbors.

QA

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