Module 1

IP/MAC Addresses and TCP/IP Suite

Dr. Natarajan Meghanathan
Associate Professor of Computer Science
Jackson State University
E-mail: natarajan.meghanathan@jsums.edu

Module 1 Topics

- 1.1 MAC Address
- 1.2 Class-based IP Address and Private IP Address
- 1.3 Subnetting and CIDR
- 1.4 End-to-End Packet Transmission across the Internet
- 1.5 ISO/OSI Model and TCP/IP Model

Unicast, Multicast and Broadcast

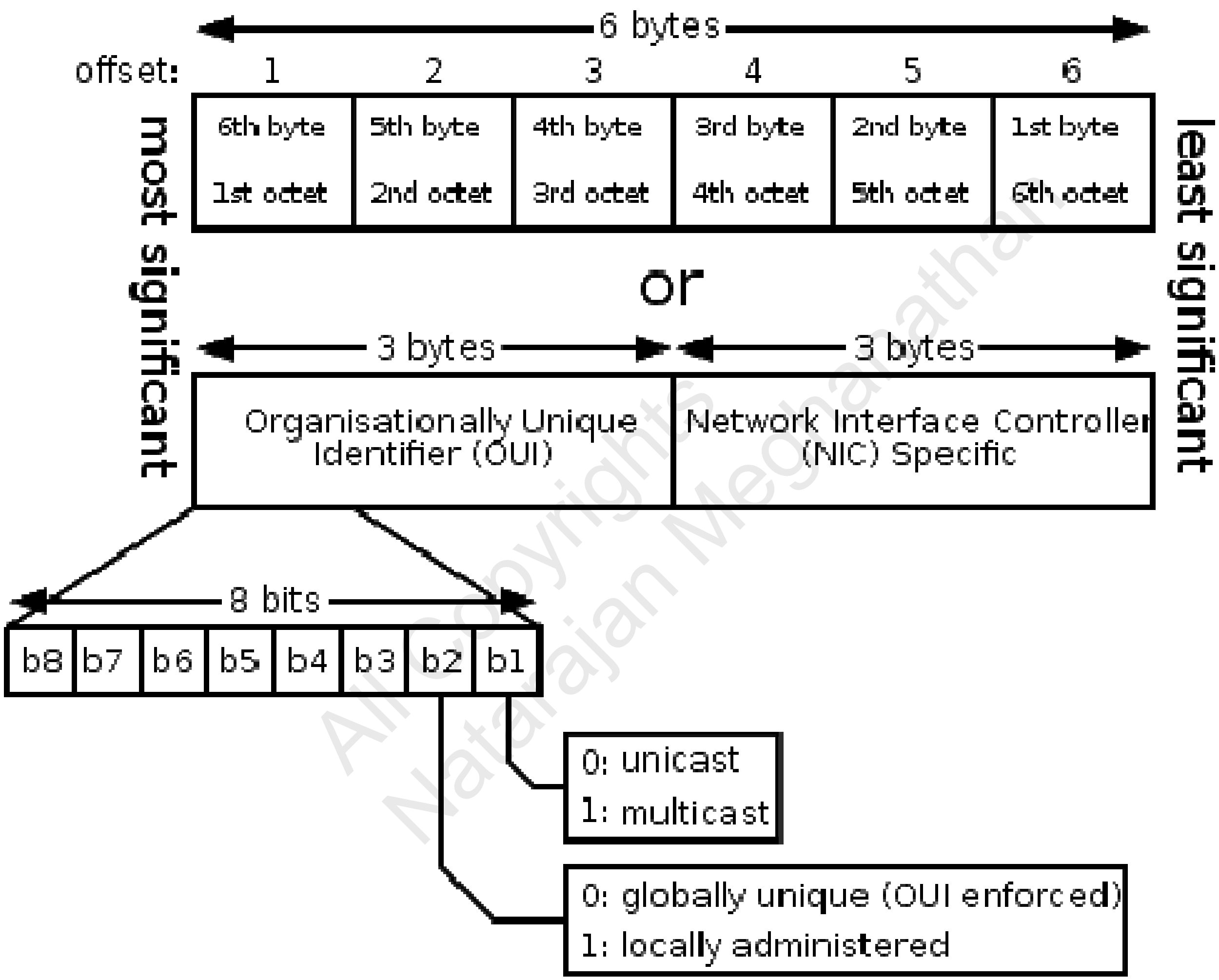
- There are three possible types of communication within a Local Area Network (LAN) as well as in the Internet.
  - Unicast – message sent from one source to one destination.
  - Multicast – message sent from one source to multiple destinations (receivers).
  - Broadcast – message sent from one source to all the other hosts in the network.

- Unless every pair of hosts in the LAN/Internet are connected directly to each other, we need to have some addressing scheme to uniquely identify the receiving machine as well as the sending machine.

Media Access Control (MAC) Addressing Scheme

- The MAC (Media Access Control) Address is a physical address, assigned to the Network Interface Card (NIC).
- The NIC of a host is typically configured with the unicast MAC address for each of its interfaces as well as the multicast addresses to which the host has subscribed to.
- IEEE assigns a block of addresses to each vendor
  - and allows the vendor to assign a unique value to each device
  - there is a 3-byte Organizationally Unique ID (OUI)
    - OUI identifies the equipment vendor
    - a 3-byte block that identifies a particular NIC

Structure of a MAC Address



Source: http://en.wikipedia.org/wiki/File:MAC-48_Address.svg

Examples for MAC Address

- Identify whether the following MAC addresses are global or locally unique and also identify whether they are multicast or unicast addresses?
  - 0A:5F:BC:AD:23:10
    - Writing the Most Significant Byte (0A) in binary: 00001010; the LSB bits b2 is 1 and b1 is 0. So, the MAC address is a locally administered unicast address
  - 49:12:AB:12:CE:FF
    - Writing the MSB (49) in binary: 01001001; the LSB bits b2 is 0 and b1 is 1. So, the MAC address is a globally unique multicast address
- Note: all the 48 bits are 1 for a broadcast address that can be used within a LAN.

1.2 Class-based IP Address and Private IP Address

Motivation for IP Address and Port Numbers

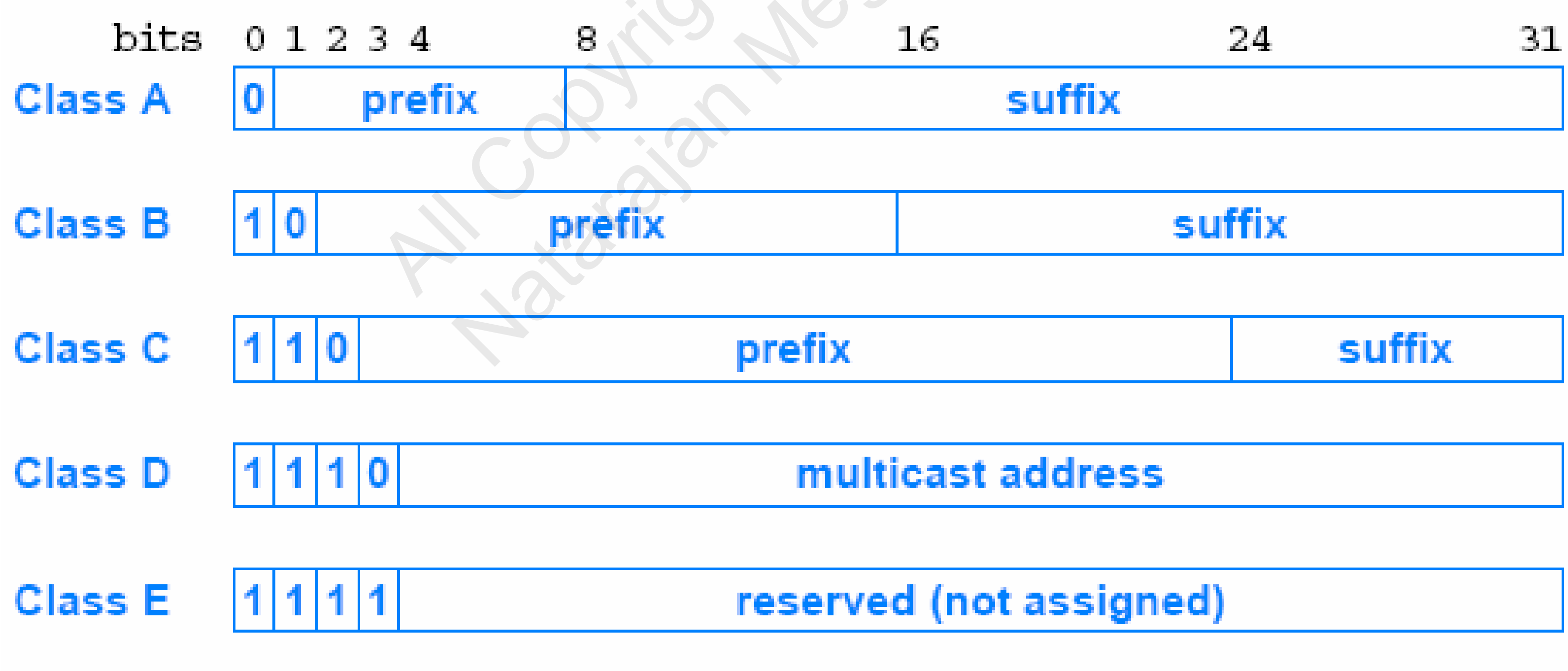
- The MAC address does not change even if we move around our host to another network/LAN in the Internet.
- We need a logical addressing scheme that can be used to uniquely identify a machine/NIC in the Internet, depending on the network to which the machine/NIC is attached to.
- To distinguish the different applications running on a particular host, we assign a unique port number for each process running on a host so that the destination process can be delivered the message.
  - Process Ids cannot be used for port numbers as they change with each instantiation of the process; and different OS may have different ways of assigning port numbers to user-defined programs/ processes.

IP Address – v4

- Each host connected to the Internet is assigned a 32-bit unique IP address.
- The IP address is hierarchical: comprises of a network part (prefix) and a host part (suffix).
  - Network number (prefix) assignments must be coordinated globally
  - Suffixes are assigned locally (within a network) without global coordination
- How many bits to place in each part of an IP address?
  - The prefix needs sufficient bits to allow a unique network number to be assigned to each physical network in the Internet
  - The suffix needs sufficient bits to permit each computer attached to a network to be assigned a unique suffix
- No simple choice was possible to allocate bits!
  - Choosing a large prefix accommodates many networks; but, limits the size of each network
  - Choosing a large suffix means each physical network can contain many computers; but, limits the total number of networks

Classes of IP Address

- Internet contains a few large physical networks and many small networks
- The original classful IP addressing divided the IP address space into three (3) primary classes
  - each class has a different size prefix and suffix
- The first four bits of an IP address determined the class to which the address belonged



Dotted Decimal Notation

- Dotted decimal notation is a syntactic form that IP software uses to express the 32-bit number binary values.
- Each 8-bit section of the 32-bit number is represented as a decimal value and periods are used to separate the sections.
- The first byte of the address in dotted decimal notation can be used to identify the class of an address

32-bit Binary Number	Equivalent Dotted Decimal
10000001 00110100 00000110 00000000	129 . 52 . 6 . 0
11000000 00000101 00110000 00000011	192 . 5 . 48 . 3
00001010 00000010 00000000 00100101	10 . 2 . 0 . 37
10000000 00001010 00000010 00000011	128 . 10 . 2 . 3
10000000 10000000 11111111 00000000	128 . 128 . 255 . 0

Range of IP Addresses and Network Prefixes for Different Classes

Class	Range of Integer Values for the 1st 8 bits
A	1 through 126
B	128 through 191
C	192 through 223
D	224 through 239
E	240 through 255

Address Class	Bits in Network Part	Max. # Networks	Bits in Host Part	Max. # Hosts per Network
A	7	126	24	$2^{24} - 2$
B	14	2^{14}	16	$2^{16} - 2$
C	21	2^{21}	8	$2^{8} - 2$

Special IP addresses

- IP defines a set of addresses that are reserved and cannot be assigned to hosts.

Network address

- Denotes the prefix assigned to a network.
- IP reserves the host suffix containing all 0s for the network address.
- Thus, a network address cannot be used as the destination address of a packet as it does not refer to any host attached to the network.

- Example: The address 128.11.0.0/16 denotes a network with prefix assigned as 128.11.

Directed Broadcast Address

- **Broadcast** – Sending a copy of a packet to all the hosts on a network.
- If the network hardware has the broadcast capability (configured to a broadcast address) then, a single transmission of the packet with the broadcast address will result in the packet reaching all the hosts on the network.
- If the network hardware does not have the broadcast capability, then separate copies of the packet must be sent to each host on the network.

- **Directed broadcasting** - A single copy of the packet travels across the internet until it reaches the targeted physical network and is then delivered to all hosts on the network.
- Directed broadcast addressing is used to broadcast a packet on a targeted physical network.
- To support, broadcasting to all hosts in a network, the host suffix that contains all 1s is reserved and cannot be used as part of a host IP address.

Limited Broadcast/ This Computer Address

- Limited broadcast – the broadcast done on the local physical network.
- IP reserves the address consisting of all 1 bits to be used as the limited broadcast address.
- Limited broadcast is used during system startup when a computer does not know its network number.

- **This computer address** – used during boot up.
- The computer does not know its IP address but needs to communicate with a server machine that assigns the IP address. The communication protocol uses IP that needs each packet to have the address of the source and the destination.
- To overcome the above requirement of address specification, the computer can supply a dummy value of an address containing all 0s to mean “this computer”. Consequently, an IP address containing all 0s is reserved.

Loopback Address

- Loopback address – used to test and debug network application programs.
- Consider two application programs that are developed to communicate over the network. To test these programs without running them on two different hosts, it is possible to run the two application programs on the same host and use the loopback address to communicate.
- When data from one application program travels down the protocol stack and reaches the IP software, the packet is forwarded back up through the protocol stack to the second application program.

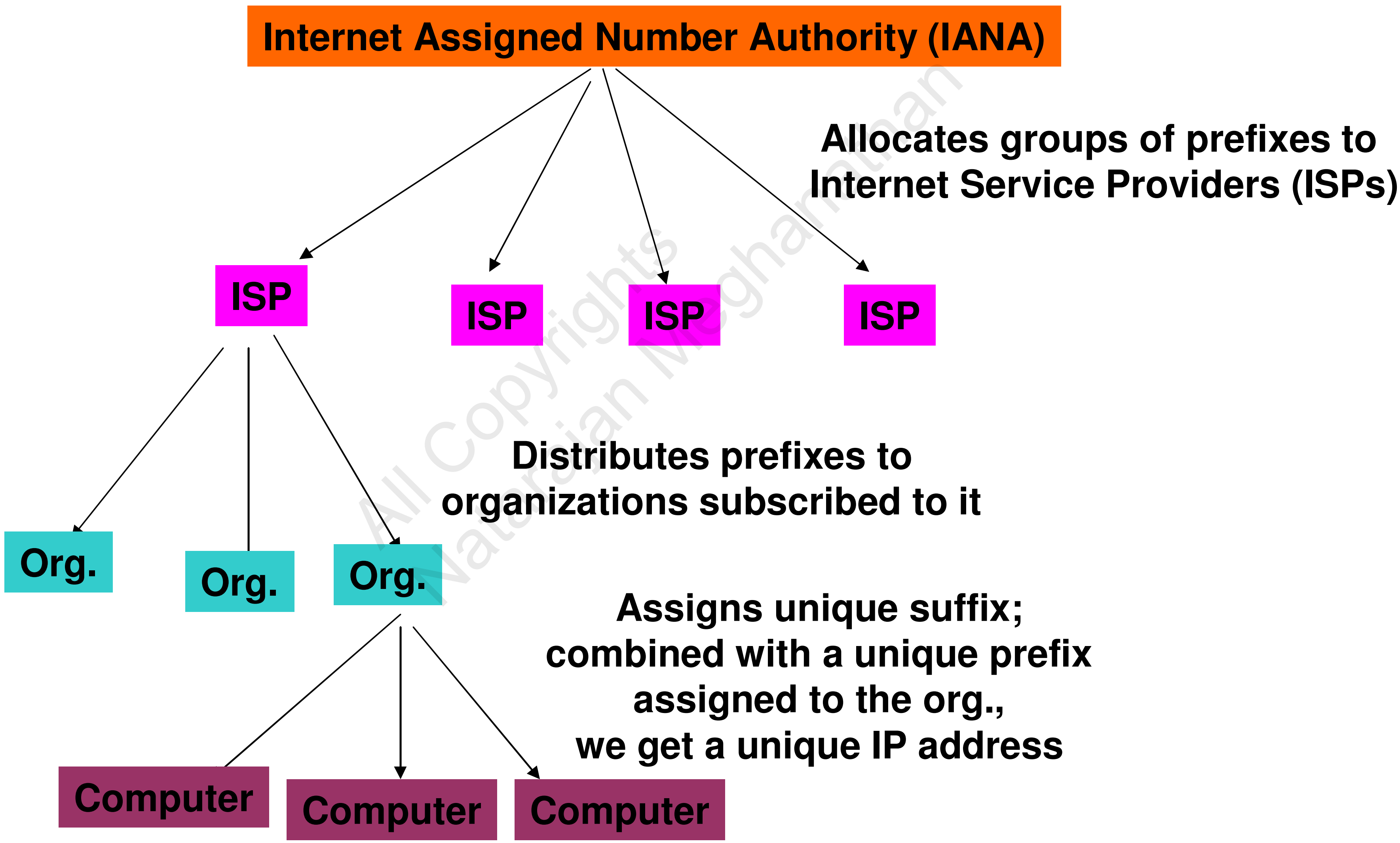
- The advantage of loopback testing is that no packets leave the computer.
- Note that the loopback address never appears on a packet traveling in a network.

- IP reserves the network prefix 127/8 for use with loopback.
- Commonly used loopback address: 127.0.0.1/8

Summary of Special IP Address Forms

Prefix	Suffix	Type Of Address	Purpose
all-0s	all-0s	this computer	used during bootstrap
network	all-0s	network	identifies a network
network	all-1s	directed broadcast	broadcast on specified net
all-1s	all-1s	limited broadcast	broadcast on local net
127	any	loopback	testing

Authority for Addresses



Private IP Addresses

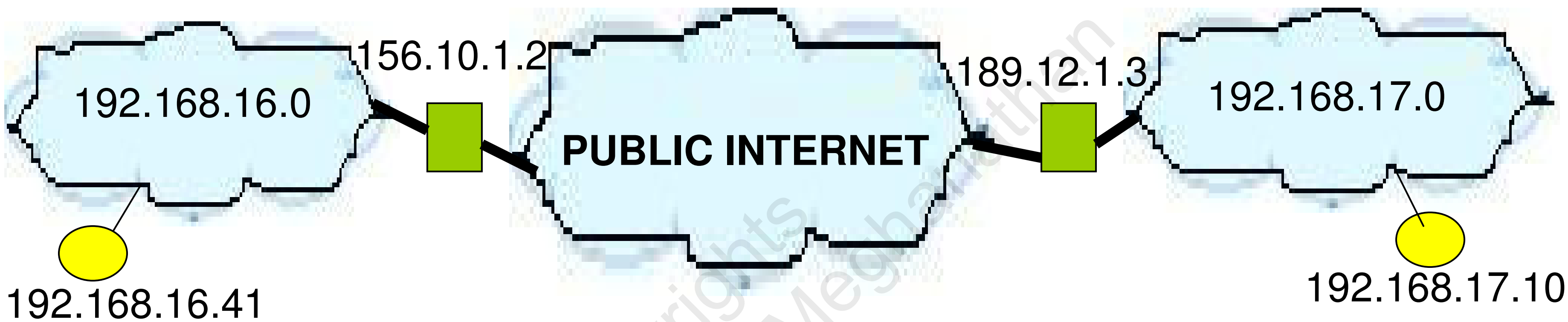
- IANA reserves certain blocks of IP addresses (called private IP address) for use by the private internets. The **private ip address blocks are:**

  10.0.0.0 - 10.255.255.255
  172.16.0.0 - 172.31.255.255
  192.168.0.0 - 192.168.255.255

- The same set of private IP addresses can be used at different organizations (i.e., a private IP address has to be only locally unique); where as a public IP address (all IP addresses other than the above blocks of private IP addresses) has to be globally unique.
- Private IP addressing is one of the solutions to reduce the exhaustion of IP address space.
- **The private ip addresses are not routable in the public internet** (i.e., packets bearing private ip addresses are not forwarded by routers in the Internet). We need to through a public gateway and use its IP address.

- For networks connected to the public internet, the service provider makes the class of IP address to be assigned to an organization's network; where as in a private internet, the local administrator selects the class.

Communication between Two Private IP Addresses



Public IP Header		Private IP Header		
156.10.1.2	**189.12.1.3**	**192.168.16.41**	**192.168.17.10**	**IP Payload**
Gateway IP addresses		**Encapsulated Private IP Datagram**		

IP-in-IP Encapsulation

Sample Question: IP Addresses

- Identify whether the following is a network address, broadcast IP address, unicast IP address, multicast IP address or a private IP address:
  - a) 143.132.10.1 – unicast IP address for a class B network
  - b) 229.0.1.2 – multicast IP address
  - c) 16.1.255.255 – unicast IP address for a class A network
  - d) 10.1.1.1 – private IP address
  - e) 172.18.12.34 – private IP address
  - f) 202.14.12.255 – broadcast IP address for a class C network
  - g) 156.25.32.0 – unicast IP address for a class B network
  - h) 202.45.69.0 – network address for a class C network

1.3 Subnetting and CIDR

Subnet/ Classless Addressing

- As the Internet grows rapidly, the IP address space gets exhausted quickly.
- Also, since there are only three distinct possible choices for the maximum number of hosts per network, most of the allocated addresses are unused.

- Example: Consider a network that contains 9 hosts.
- If we have to use classful addressing, we might end up choosing a class C address with 8 bits for the suffix, making it possible to support 254 hosts while we need a network that can support only 9 hosts.
- It would be enough to assign 4 bits of host suffix to represent all possible host values.
- With classless addressing, it is possible to subdivide a single class C address into 16 addresses such that each have a 28-bit prefix and a 4-bit suffix. Thus, it is possible to create 16 networks such that each can support a maximum of 14 hosts.

- **Generalization:** Instead of having three distinct classes, the division between prefix and suffix must be allowed to be made on an arbitrary bit boundary.

Address Masks

- To specify the exact boundary between the prefix and suffix, IP address are supplemented with a 32-bit binary value called the subnet mask or address mask.
- A sequence of 1 bits in the subnet mask represent the network portion and is followed by a sequence of 0 bits representing the host portion.
- Given an IP address, D and its address mask M, a bitwise AND operation applied over D and M, yields the network prefix portion of the address D. The rest of the bits in D then represent the host portion of the address.
- Example: D = 128.10.2.3 and M = 255.255.0.0

  D 1000000 00001010 00000010 00000011

  M 1111111 11111111 00000000 00000000

  D&M 1000000 00001010 00000000 00000000

  D&M=128.10.0.0, the network prefix for D.

Sample Question 1: Subnetting

- Assume there are three Departments P, Q and R in an organization XYZ. Each of the department needs a separate subnet. The number of computers in Departments P, Q and R are 30, 10 and 47 respectively. Assume organization XYZ got a class C network prefix 212.46.98.0. Derive the following for each of the Departments P, Q and R:
  - i) The subnet prefix
  - ii) The subnet mask
  - iii) The directed broadcast IP address for each subnet
  - iv) The valid range of IP addresses for each subnet

Question 1 Solution

Subnet Part	Subnet	# hosts	#bits for host part
0 0	P	30	5
0 1	Q	10	4
1 0	R	47	6

We need two bits for the subnet part and Max(5, 4, 6) = 6 bits for the host part. Hence, we need to have at least 2 + 6 = 8 bits that can be used in the host part of a class-based Address space. We will use the class-C Address space: 212.46.98.0.

212 . 46 . 98 . | x x | x x x x x x |

Subnet Part – 2 bits   Host part – 6 bits

Subnet Mask: Sequence of 32 – 6 = 26 1s, followed by 6 0s

11111111 . 11111111 . 11111111 . 11000000

255 . 255 . 255 . 192

Subnet P

Subnet address	212 . 46 . 98 . | 0 0 | 0 0 0 0 0 0 |	**212.46.98.0 / 26**
Broadcast address	212 . 46 . 98 . | 0 0 | 1 1 1 1 1 1 |	**212.46.98.63 / 26**

Question 1 Solution (continued…)

Subnet P	212 . 46 . 98 . 0 0 0 0 0 0 0 1	**212.46.98.1 / 26**
Range of Valid IP Addresses 62 addresses		
	212 . 46 . 98 . 0 0 1 1 1 1 1 0	**212.46.98.62 / 26**
Subnet Q		
Subnet address	212 . 46 . 98 . 0 1 0 0 0 0 0 0	**212.46.98.64 / 26**
Broadcast address	212 . 46 . 98 . 0 1 1 1 1 1 1 1	**212.46.98.127 / 26**
	212 . 46 . 98 . 0 1 0 0 0 0 0 1	**212.46.98.65 / 26**
Range of Valid IP Addresses 62 addresses		
	212 . 46 . 98 . 0 1 1 1 1 1 1 0	**212.46.98.126 / 26**

Subnet R

Subnet address	212 . 46 . 98 . 1 0 | 0 0 0 0 0 0	**212.46.98.128 / 26**
Broadcast address	212 . 46 . 98 . 1 0 | 1 1 1 1 1 1	**212.46.98.191 / 26**
Range of Valid IP Addresses 62 addresses	212 . 46 . 98 . 1 0 | 0 0 0 0 0 1	**212.46.98.129 / 26**
	212 . 46 . 98 . 1 0 | 1 1 1 1 1 0	**212.46.98.190 / 26**

Subnet	Subnet Mask	Subnet Prefix (Subnet Address)	Broadcast IP Address	Range of Valid IP Addresses
P	255.255.255.192	212.46.98.0 / 26	212.46.98.63 / 26	212.46.98.1 / 26 to 212.46.98.62 / 26
Q	255.255.255.192	212.46.98.64 / 26	212.46.98.127 / 26	212.46.98.65 / 26 to 212.46.98.126 / 26
R	255.255.255.192	212.46.98.128 / 26	212.46.98.191 / 26	212.46.98.129 / 26 to 212.46.98.190 / 26

Efficiency of IP Address Assignment: $\dfrac{30\ (P) + 10\ (Q) + 47\ (R)}{62 + 62 + 62} = 46.8\%$

Sample Question 2: Subnetting

- Assume there are five units A, B, C, D and E in an organization. Each of the units needs a separate subnet. The number of computers in units A, B, C, D and E are 10, 15, 20, 25 and 30 respectively. Assume the organization got a class B network prefix 202.45.80.0. Derive the following for each of the units A, B, C, D and E:
  – The subnet prefix
  – The subnet mask
  – The directed broadcast IP address for each subnet.
  – The valid range of IP addresses for each subnet

Question 2 Solution

Subnet Part	Subnet	# hosts	#bits for host part
0 0 0	A	10	4
0 0 1	B	15	5
0 1 0	C	20	5
0 1 1	D	25	5
1 0 0	E	30	5

We need two bits for the subnet part and Max(5, 4) = 5 bits for the host part. Hence, we need to have at least 3 + 5 = 8 bits that can be used in the host part of a class-based Address space. We will use the class-C Address space: 202.45.80.0.

202 . 45 . 80 . x x x x x x x x

Subnet Part – 3 bits

Host part – 5 bits

Subnet Mask: Sequence of 32 – 5 = 27 1s, followed by 5 0s

11111111 . 11111111 . 11111111 . 11100000

255 . 255 . 255 . 224

Subnet A

Subnet address	202 . 45 . 80 . 0 0 0 0 0 0 0 0	**202.45.80.0 / 27**
Broadcast address	202 . 45 . 80 . 0 0 0 1 1 1 1 1	**202.45.80.31 / 27**
Range of Valid IP Addresses 30 addresses	202 . 45 . 80 . 0 0 0 0 0 0 0 1	**202.45.80.1 / 27**
	202 . 45 . 80 . 0 0 0 1 1 1 1 0	**202.45.80.30 / 27**

Subnet B

Subnet address	202 . 45 . 80 . 0 0 1 0 0 0 0 0	**202.45.80.32 / 27**
Broadcast address	202 . 45 . 80 . 0 0 1 1 1 1 1 1	**202.45.80.63 / 27**
Range of Valid IP Addresses 30 addresses	202 . 45 . 80 . 0 0 1 0 0 0 0 1	**202.45.80.33 / 27**
	202 . 45 . 80 . 0 0 1 1 1 1 1 0	**202.45.80.62 / 27**

Subnet C

Subnet address	202 . 45 . 80 .	0 1 0	0 0 0 0 0	**202.45.80.64 / 27**
Broadcast address	202 . 45 . 80 .	0 1 0	1 1 1 1 1	**202.45.80.95 / 27**
Range of Valid IP Addresses 30 addresses	202 . 45 . 80 .	0 1 0	0 0 0 0 1	**202.45.80.65 / 27**
	202 . 45 . 80 .	0 1 0	1 1 1 1 0	**202.45.80.94 / 27**

Subnet D

Subnet address	202 . 45 . 80 .	0 1 1	0 0 0 0 0	**202.45.80.96 / 27**
Broadcast address	202 . 45 . 80 .	0 1 1	1 1 1 1 1	**202.45.80.127 / 27**
Range of Valid IP Addresses 30 addresses	202 . 45 . 80 .	0 1 1	0 0 0 0 1	**202.45.80.97 / 27**
	202 . 45 . 80 .	0 1 1	1 1 1 1 0	**202.45.80.126 / 27**

Subnet E

Subnet address	202 . 45 . 80 .	1 0 0	0 0 0 0 0	**202.45.80.128 / 27**
Broadcast address	202 . 45 . 80 .	1 0 0	1 1 1 1 1	**202.45.80.159 / 27**
Range of Valid IP Addresses 30 addresses	202 . 45 . 80 .	1 0 0	0 0 0 0 1	**202.45.80.129 / 27**
	202 . 45 . 80 .	1 0 0	1 1 1 1 0	**202.45.80.158 / 27**

Efficiency of IP Address Assignment: $\frac{10 + 15 + 20 + 25 + 30}{30 + 30 + 30 + 30 + 30} = 66.7\%$

Question 3: Subnetting

- Consider an organization that needs to host the following three divisions A, B and C to support 200, 400 and 700 hosts. Implement subnetting by choosing a proper class-based address space. Determine the following for each division/subnet:
  - Subnet mask
  - Subnet prefix
  - Subnet broadcast address
  - Valid range of unicast IP addresses for each subnet
  - Efficiency of IP address assignment.

Question 3 Solution

Subnet Part	Subnet	# hosts	#bits for host part
0 0	A	200	8
0 1	B	400	9
1 0	C	600	10

We need two bits for the subnet part and 10 bits for the host part. Hence, we need to have at least 2 + 10 = 12 bits that can be used in the host part of a class-based Address space. We will use a class-B Address space: 170.40.0.0.

170 . 40 . 0 0 0 0 x x x x . x x x x x x x x

Subnet Part – 2 bits (x x); Host part – 10 bits (x x . x x x x x x x x)

Subnet Mask: Sequence of 32 – 10 = 22 1s, followed by 10 0s

11111111 . 11111111 . 11111100 . 00000000

255 . 255 . 252 . 0

Subnet A

Subnet address	170 . 40 . 0 0 0 0 0 0 0 0 . 0 0 0 0 0 0 0 0	**170.40.0.0 / 22**
Broadcast address	170 . 40 . 0 0 0 0 0 0 1 1 . 1 1 1 1 1 1 1 1	**170.40.3.255 / 22**

Question 3 Solution (continued…)

Subnet A

Range of Valid IP Addresses

170 . 40 . 0 0 0 0 0 0 0 0 . 0 0 0 0 0 0 0 1 — **170.40.0.1 / 22**

170 . 40 . 0 0 0 0 0 0 0 0 . 0 0 0 0 0 0 1 0 — **170.40.0.2 / 22**

.
.
.

170 . 40 . 0 0 0 0 0 0 1 1 . 1 1 1 1 1 1 1 0 — **170.40.3.254 / 22**

255 (0.1 .. 0.255)
256 (1.0 .. 1.255)
256 (2.0 .. 2.255)
255 (3.0 .. 3.254)

1022 IP addresses

Subnet B

Subnet address 170 . 40 . 0 0 0 0 0 1 0 0 . 0 0 0 0 0 0 0 0 — **170.40.4.0 / 22**

Broadcast address 170 . 40 . 0 0 0 0 0 1 1 1 . 1 1 1 1 1 1 1 1 — **170.40.7.255 / 22**

Question 3 Solution (continued...)

Subnet B

Range of Valid IP Addresses

255 (4.1 .. 4.255)
256 (5.0 .. 5.255)
256 (6.0 .. 6.255)
255 (7.0 .. 7.254)

1022 IP addresses

170 . 40 . 0 0 0 0	0 1	0 0 . 0 0 0 0 0 0 0 1	**170.40.4.1 / 22**
170 . 40 . 0 0 0 0	0 1	0 0 . 0 0 0 0 0 0 1 0	**170.40.4.2 / 22**
.			
.			
.			
170 . 40 . 0 0 0 0	0 1	1 1 . 1 1 1 1 1 1 1 0	**170.40.7.254 / 22**

Subnet C

Subnet address	170 . 40 . 0 0 0 0	1 0	0 0 . 0 0 0 0 0 0 0 0	**170.40.8.0 / 22**
Broadcast address	170 . 40 . 0 0 0 0	1 0	1 1 . 1 1 1 1 1 1 1 1	**170.40.11.255 / 22**

Question 3 Solution (continued…)

Subnet B

Range of Valid IP Addresses

255 (8.1 .. 8.255)
256 (9.0 .. 9.255)
256 (10.0 .. 10.255)
255 (10.0 .. 10.254)

1022 IP addresses

170 . 40 . 0 0 0 0 | 1 0 | 0 0 . 0 0 0 0 0 0 0 1 — **170.40.8.1 / 22**

170 . 40 . 0 0 0 0 | 1 0 | 0 0 . 0 0 0 0 0 0 1 0 — **170.40.8.2 / 22**

.
.
.

170 . 40 . 0 0 0 0 | 1 0 | 1 1 . 1 1 1 1 1 1 1 0 — **170.40.11.254 / 22**

Efficiency of IP Address Assignment: $\frac{200\ (A) + 400\ (B) + 700\ (C)}{1022 + 1022 + 1022} = 42.4\%$

Classless Interdomain Routing (CIDR)

- With class A, B and C addresses, we are forced to hand out network address space in fixed-sized chunks of three very different sizes.
- Even though subnetting helps us to assign addresses carefully, it does not get around the fact that any autonomous system with more than 255 hosts, wants a class B address.
- Unless any domain shows a need for something close to 64K addresses, we should not assign them a class B address and instead assign an appropriate number of class C addresses to cover the expected number of hosts. The drawback with this approach would be that we will require more entries in the routing tables to handle the multiple class C network addresses.
- CIDR tries to balance the desire to minimize the number of routes that a router needs to know against the need to assign addresses efficiently. CIDR does this by aggregating routes.

Classless Interdomain Routing (CIDR)

- Suppose we need 16 class C network numbers for an AS. Instead of assigning 16 random network numbers, we can assign the class C network numbers from 192.4.16 to 192.4.31.
- The first 20 bits of all the addresses in the above range would be the same.
- Subnetting is used to share one address among multiple physical networks, CIDR aims to collapse the multiple addresses that would be assigned to a single AS onto one address.

Sample Question: CIDR

Consider the use of the Classless Interdomain Routing (CIDR). Let there be a network PQR that requires the support of 700 hosts and we assign three contiguous class C network address space 212.45.16.0, 212.45.17.0 and 212.45.18.0. Compute the following for network PQR:

- (1) Subnet mask
- (2) Network address
- (3) Broadcast address
- (4) Range of valid IP addresses
- (5) Efficiency of IP address assignment.
- (6) Identify the class C network address spaces required.

Solution for CIDR

212.45. 0 0 0 1 0 0 0 0. 0

212.45. 0 0 0 1 0 0 0 1. 0

212.45. 0 0 0 1 0 0 1 0. 0

212.45. 0 0 0 1 0 0 0 0 . 0 / 22 ← Network Prefix/ Network Address

212.45.0 0 0 1 0 0 0 0 .0
212.45.16.0 / 22

Broadcast IP Address:
212.45.0 0 0 1 0 0 11 .255
212.45.19.255/ 22

Subnet Mask:
255.255.11111100.00000000
255.255.252.0

Range of Valid IP Addresses:
212.45.16.1/22 to
212.45.19.254/22

Note: With the above assignment, we can support 255 + 256 + 256 + 255 = 1022 unique IP addresses. <u>Efficiency of address assignment = 700/1022 = 68.5%.</u>

<u>We need to purchase 4 class C address spaces:</u>

212.45.16.0; 212.45.17.0; 212.45.18.0 and 212.45.19.0

Identifying the type of classless address

- Consider the following IP addresses in the context of classless addressing (subnetting and CIDR). Identify whether the following is a subnet/network address, broadcast IP address or a unicast IP address:
  - 212.40.90.63 / 26
  - 156.23.80.0 / 20
  - 199.34.56.32 / 27
  - 213.45.1.12 / 28
  - 143.132.7.255 /21

Identify the type of classless address

- 212.40.90.63 / 26

  212.40.90.01 111111

  All six bits of the host part are 1s. Hence, it is a **broadcast IP address**

- 156.23.80.0 / 20

  156.23.0101 0000.00000000

  All 12 bits of the host part are 0s. Hence, it is a **Subnet address**

- 199.34.56.32 / 27

  199.34.56.001 00000

  All five bits of the host part are 0s. Hence, it is a **Subnet address**

- 213.45.1.12 / 28

  213.45.1.0000 1100

  All the four bits of the host part are neither 0s nor 1s. Hence, it is a **unicast IP address**

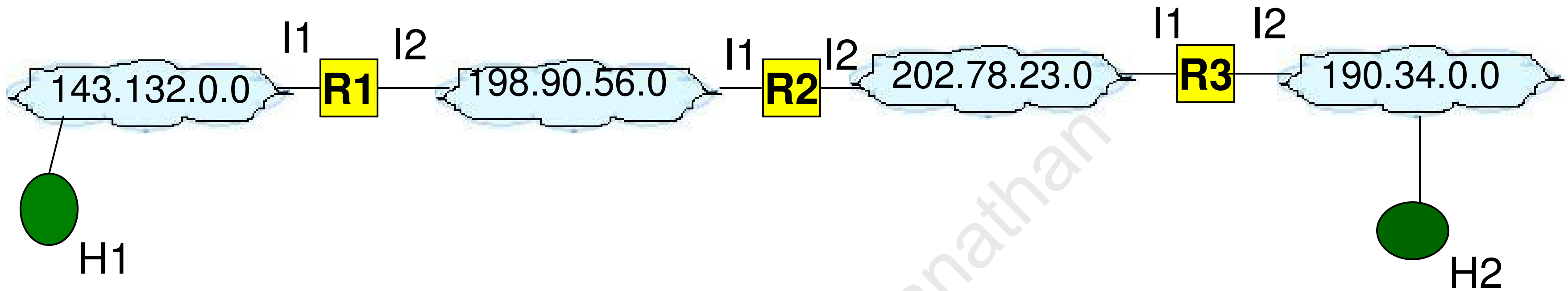
- 143.132.7.255 /21

  143.132.00000 111.11111111

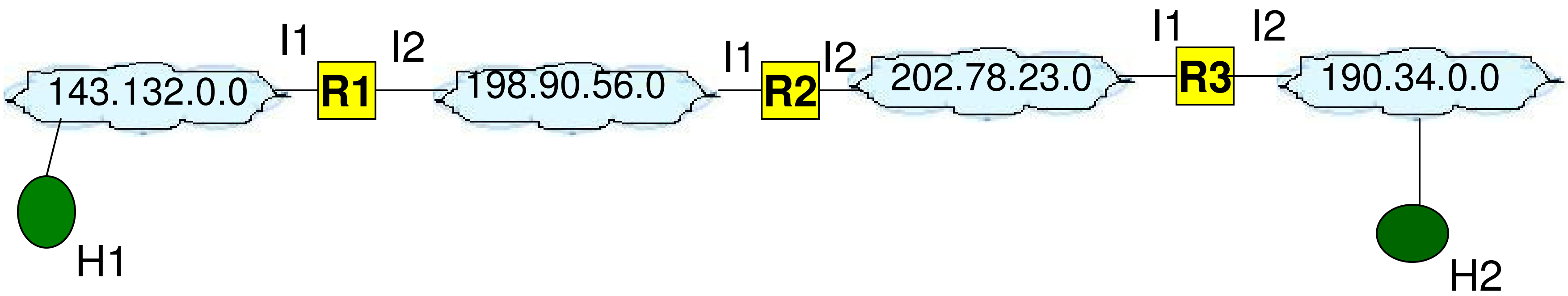
  All the 11 bits of the host part are 1s. Hence, it is a **broadcast IP address**

1.4 End-to-End Packet Transmission across the Internet

Example for End-to-End Packet Transmission across the Internet

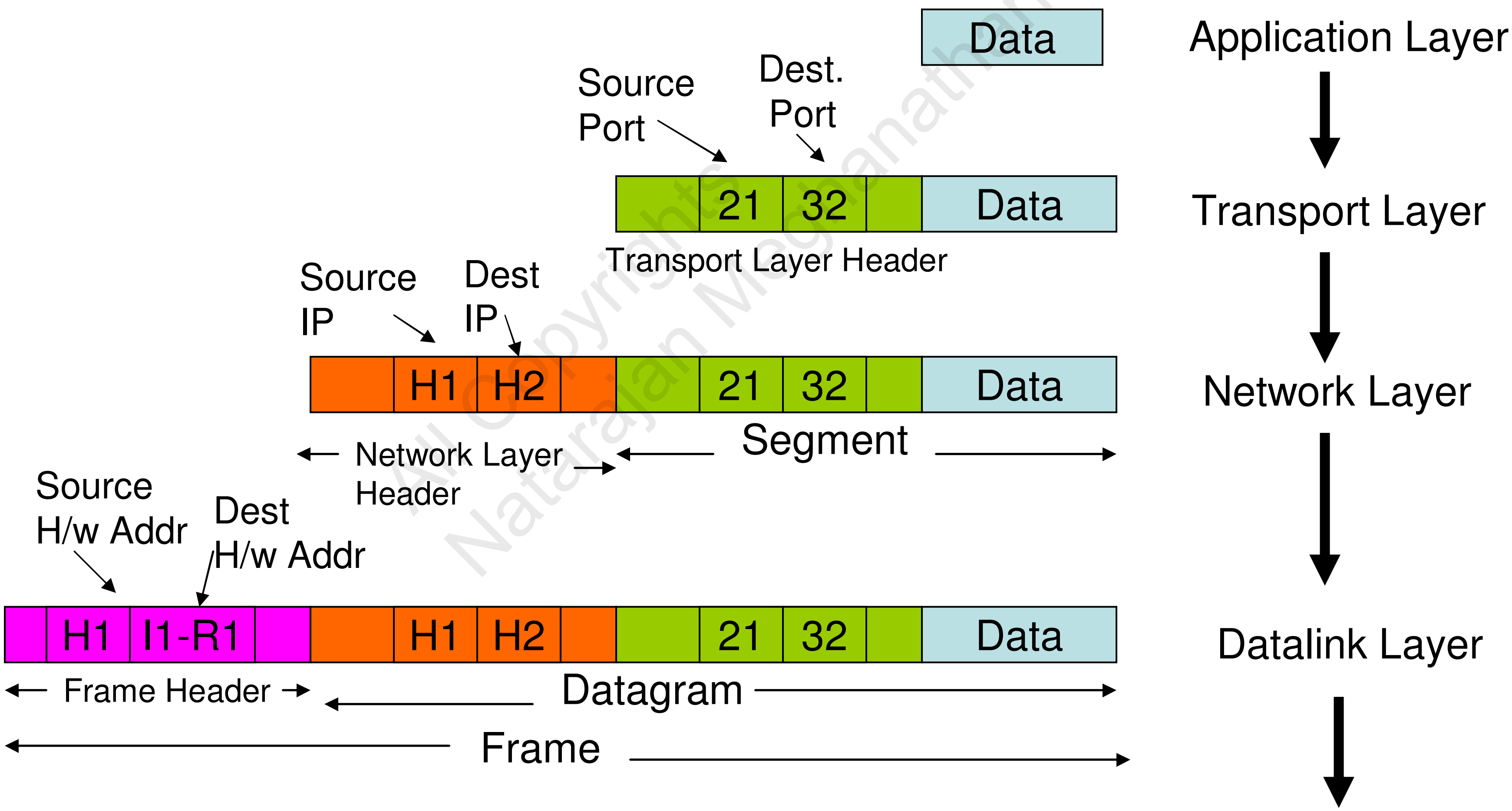


Host/ Router	IP address	Hardware address
H1	143.132.0.1	34:12:45:AB:CD:EF
Interface 1 of R1	143.132.90.2	38:45:A9:E2:B5:C3
Interface 2 of R1	198.90.56.1	4C:9A:3B:54:DF:12
Interface 1 of R2	198.90.56.2	24:3B:1C:4A:52:CD
Interface 2 of R2	202.78.23.1	9C:12:AB:89:CF:33
Interface 1 of R3	202.78.23.2	BC:32:11:A2:45:23
Interface 2 of R3	190.34.0.1	28:12:AB:45:69:12
H2	190.34.0.2	30:90:CD:EF:AB:43

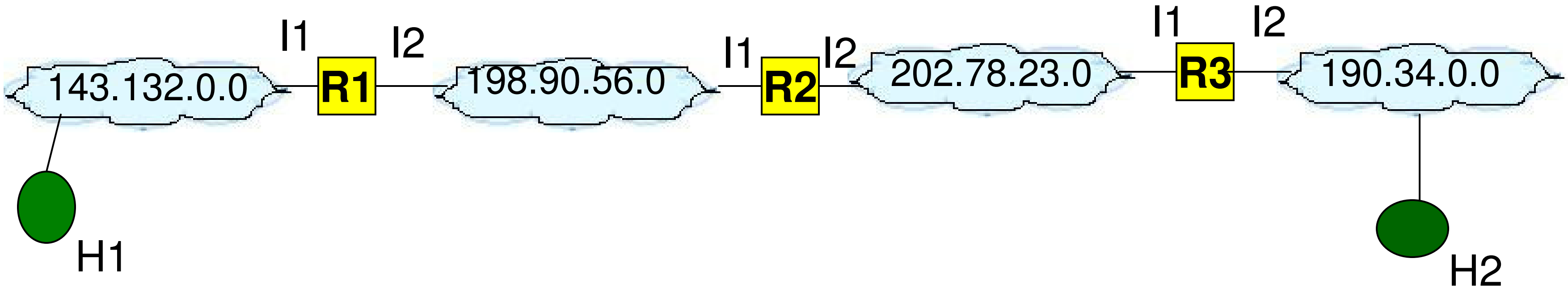


143.132.0.0
I1
R1
I2
198.90.56.0
I1
R2
I2
202.78.23.0
I1
R3
I2
190.34.0.0
H1
H2

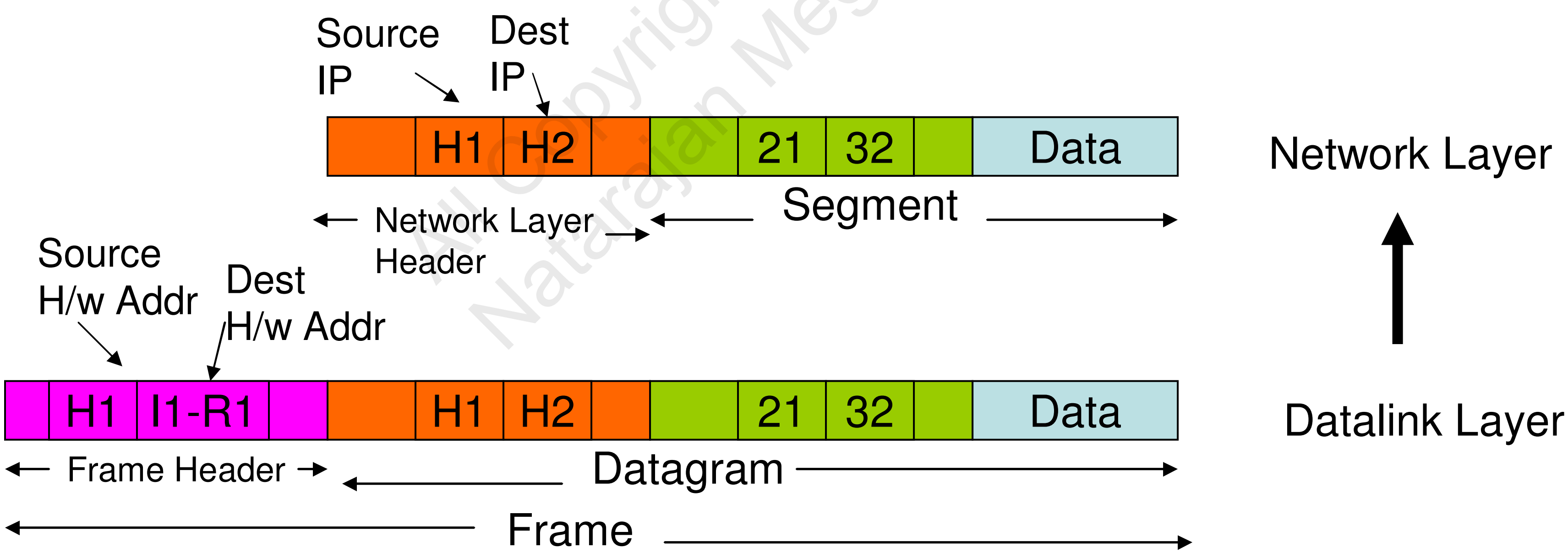
At H1

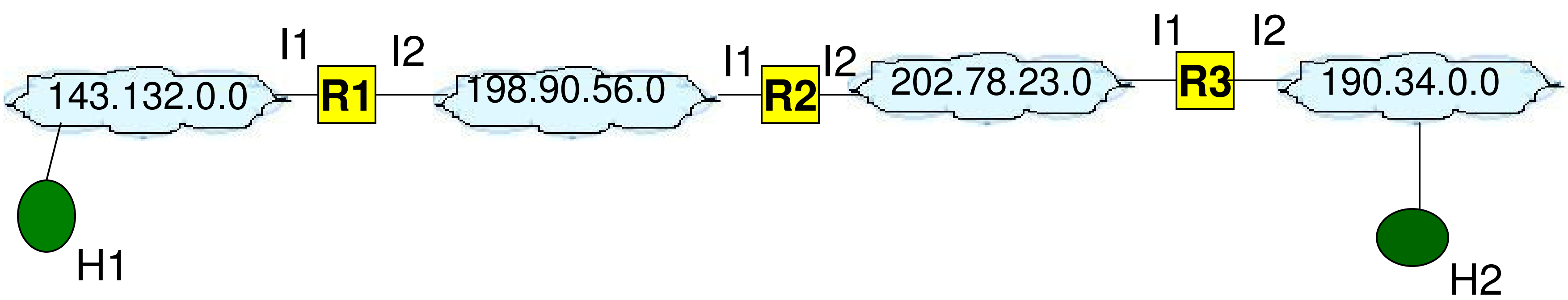


Data
Application Layer
Source Port
Dest. Port
21
32
Data
Transport Layer
Transport Layer Header
Source IP
Dest IP
H1
H2
21
32
Data
Network Layer
Network Layer Header
Segment
Source H/w Addr
Dest H/w Addr
H1
I1-R1
H1
H2
21
32
Data
Datalink Layer
Frame Header
Datagram
Frame

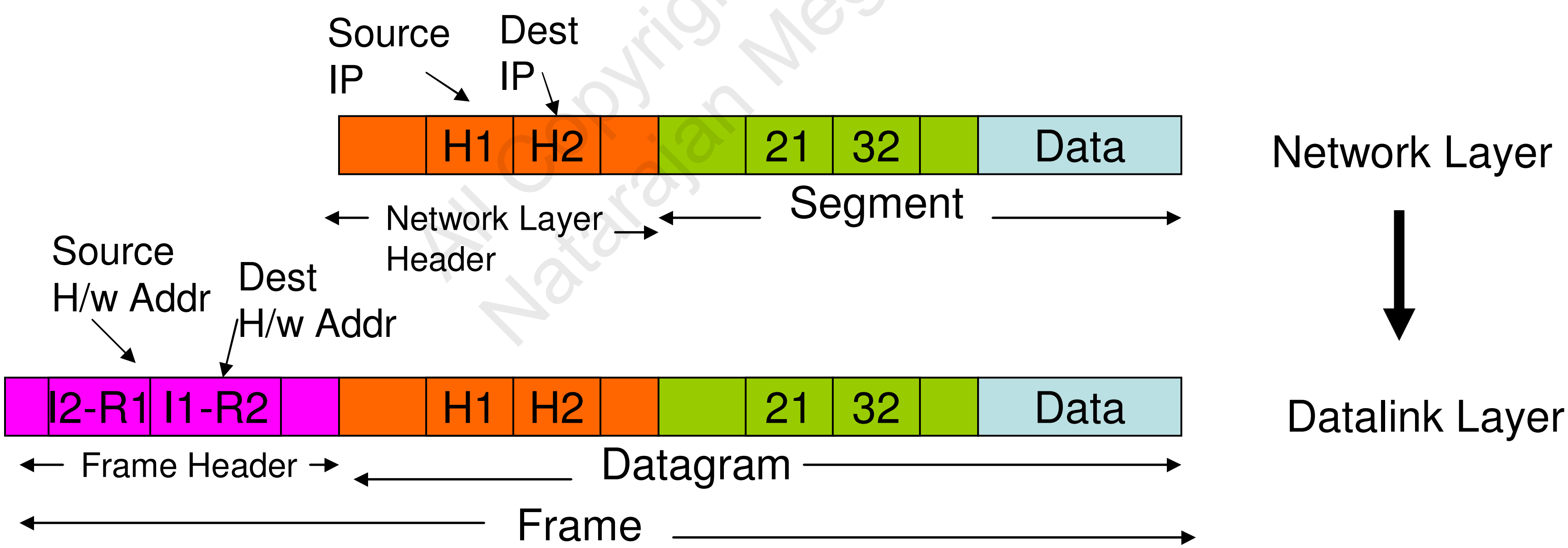


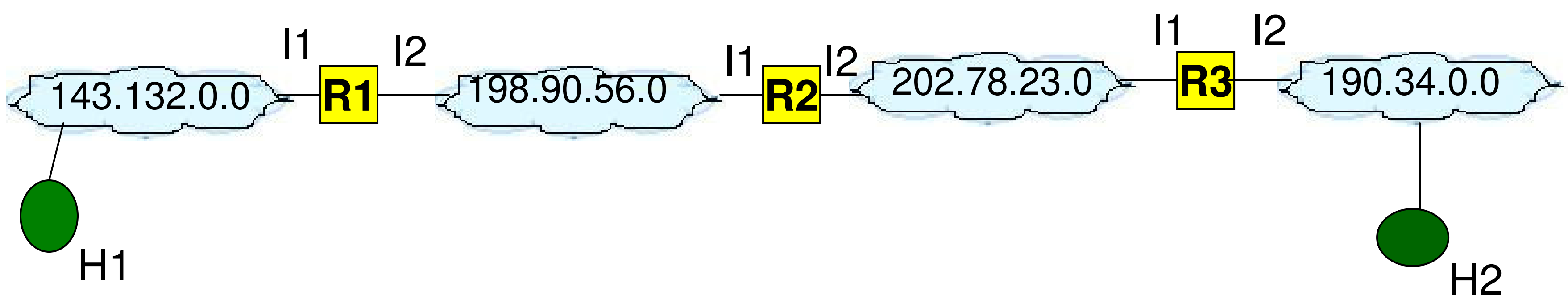
At Interface 1 of R1



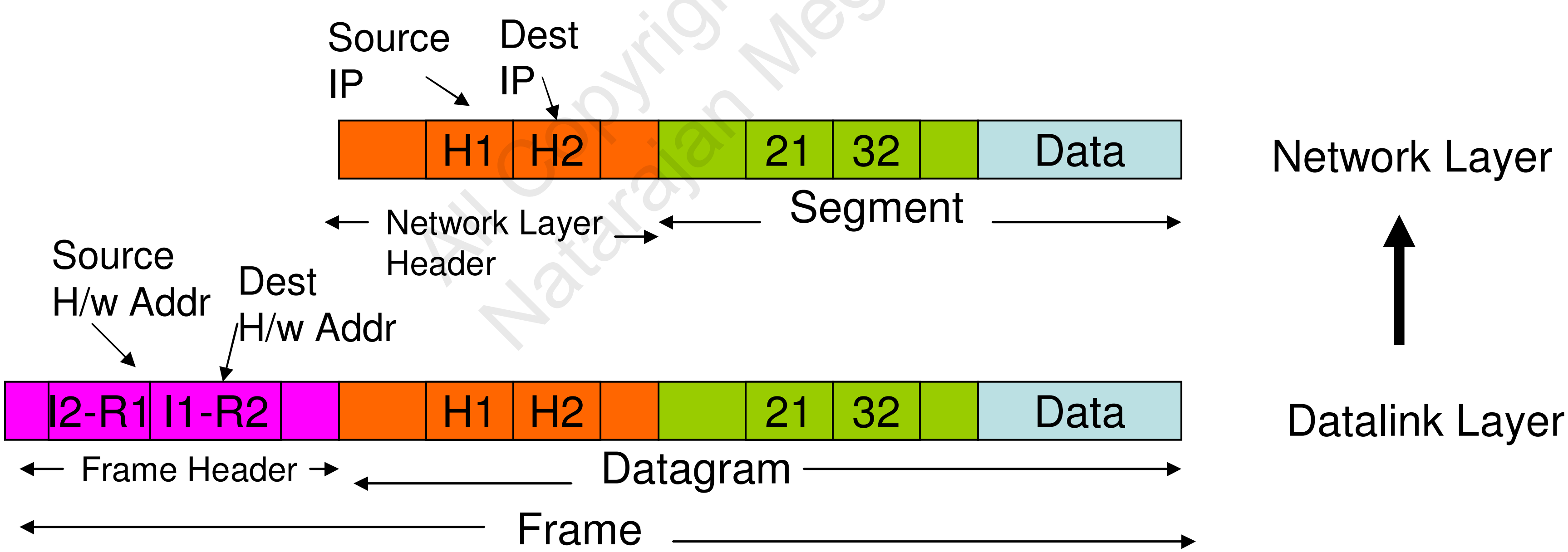


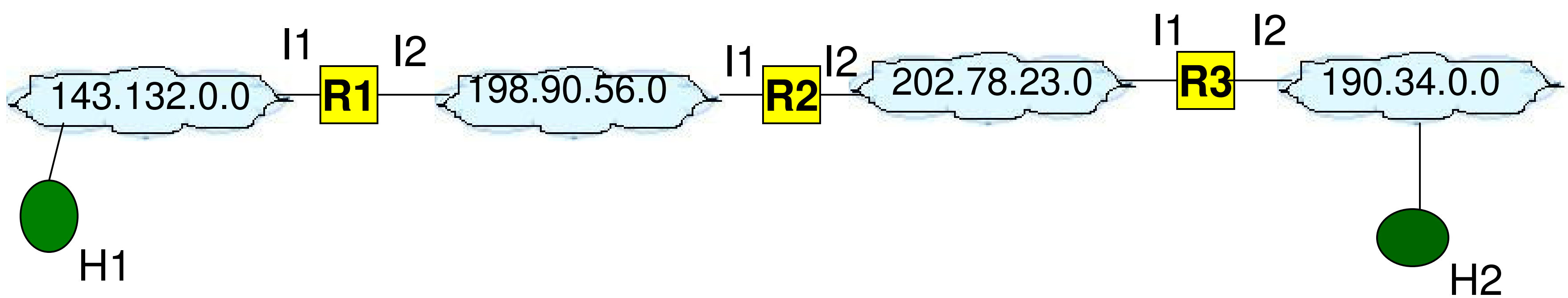
At Interface 2 of R1



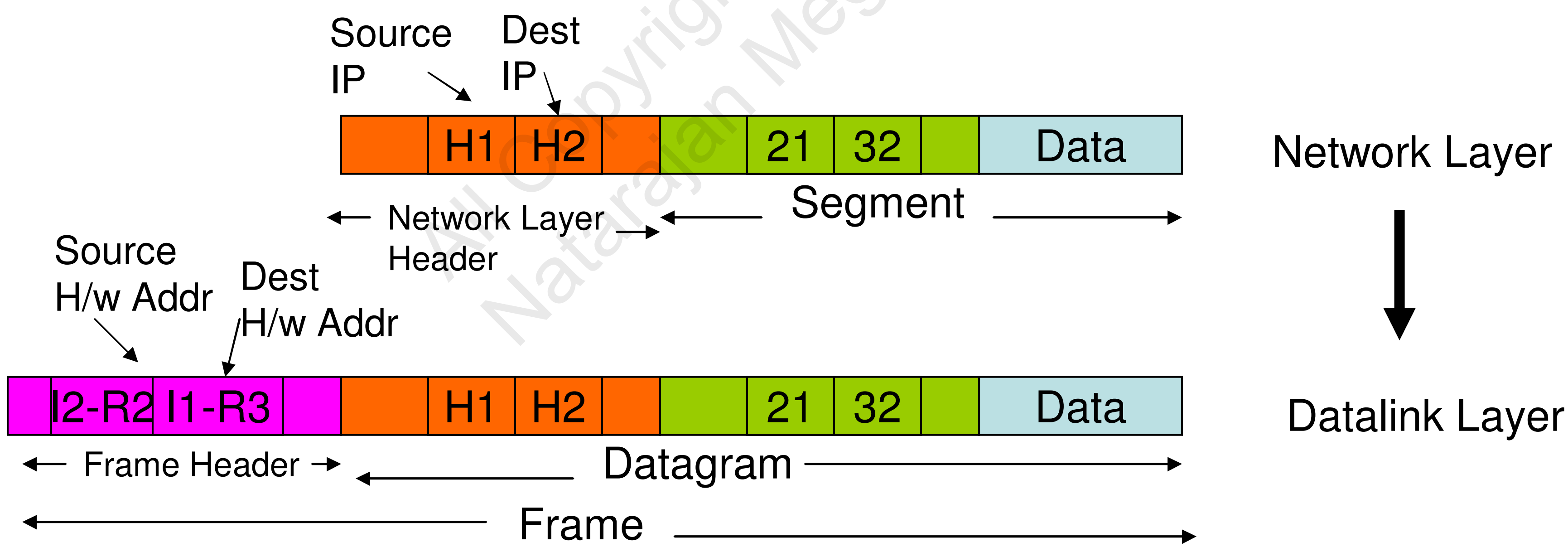


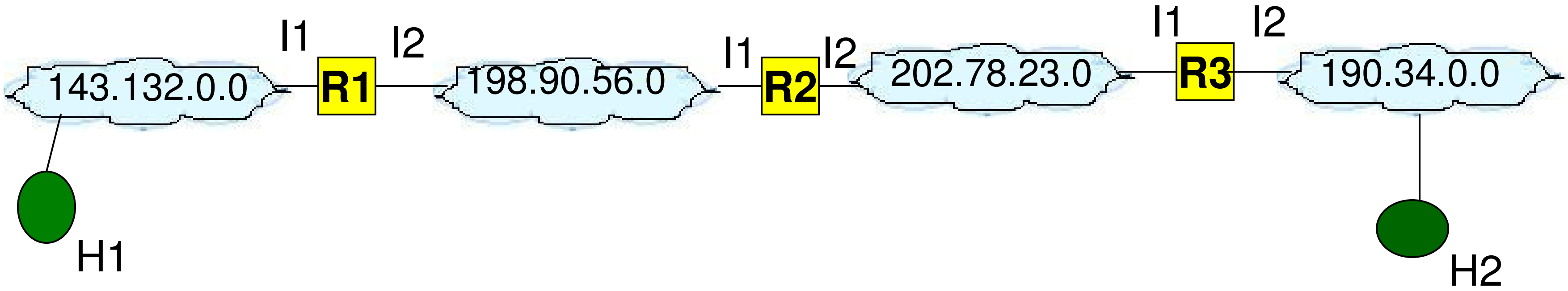
At Interface 1 of R2



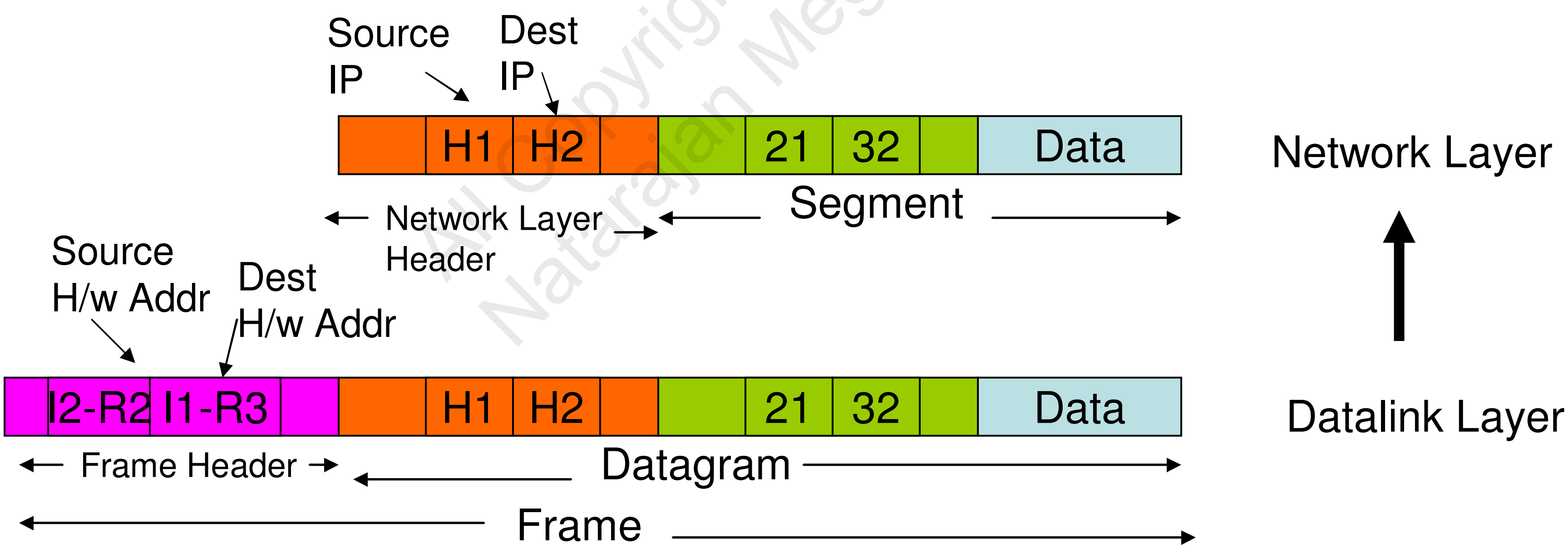


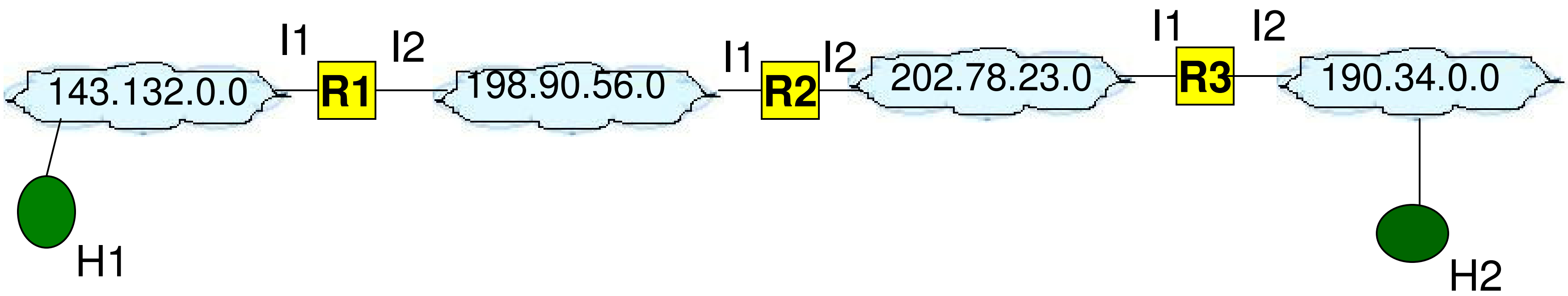
At Interface 2 of R2



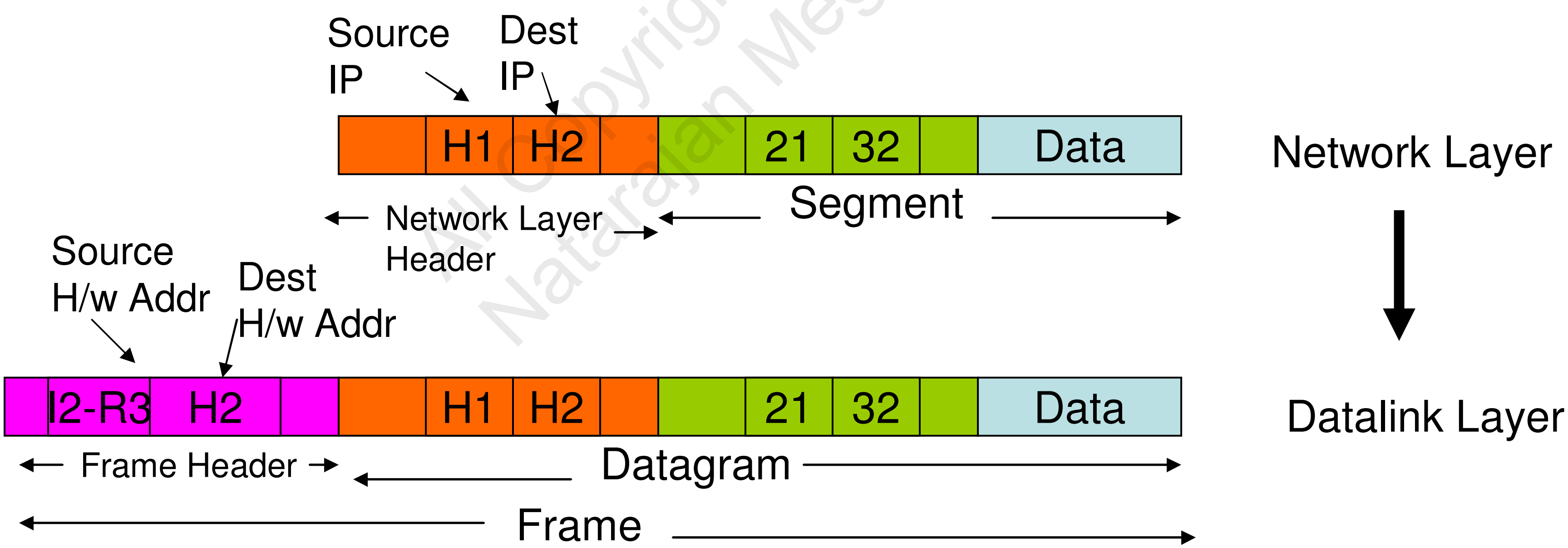


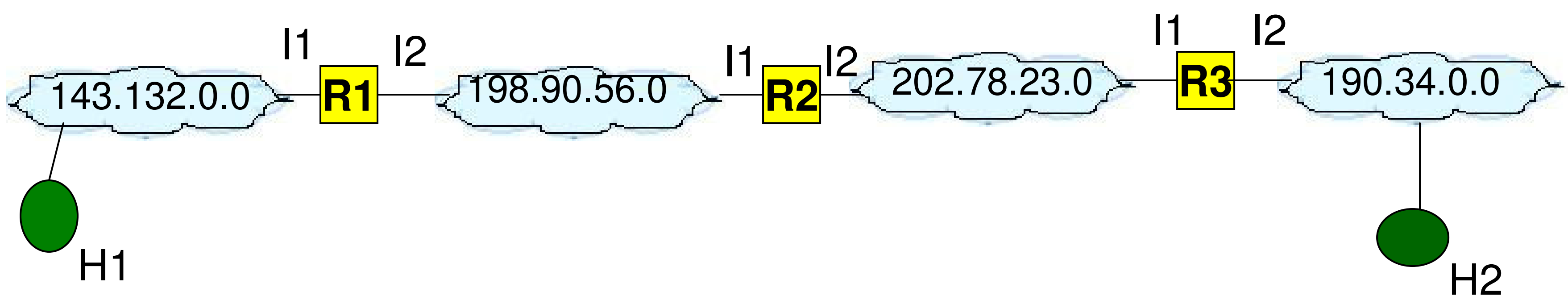
At Interface 1 of R3



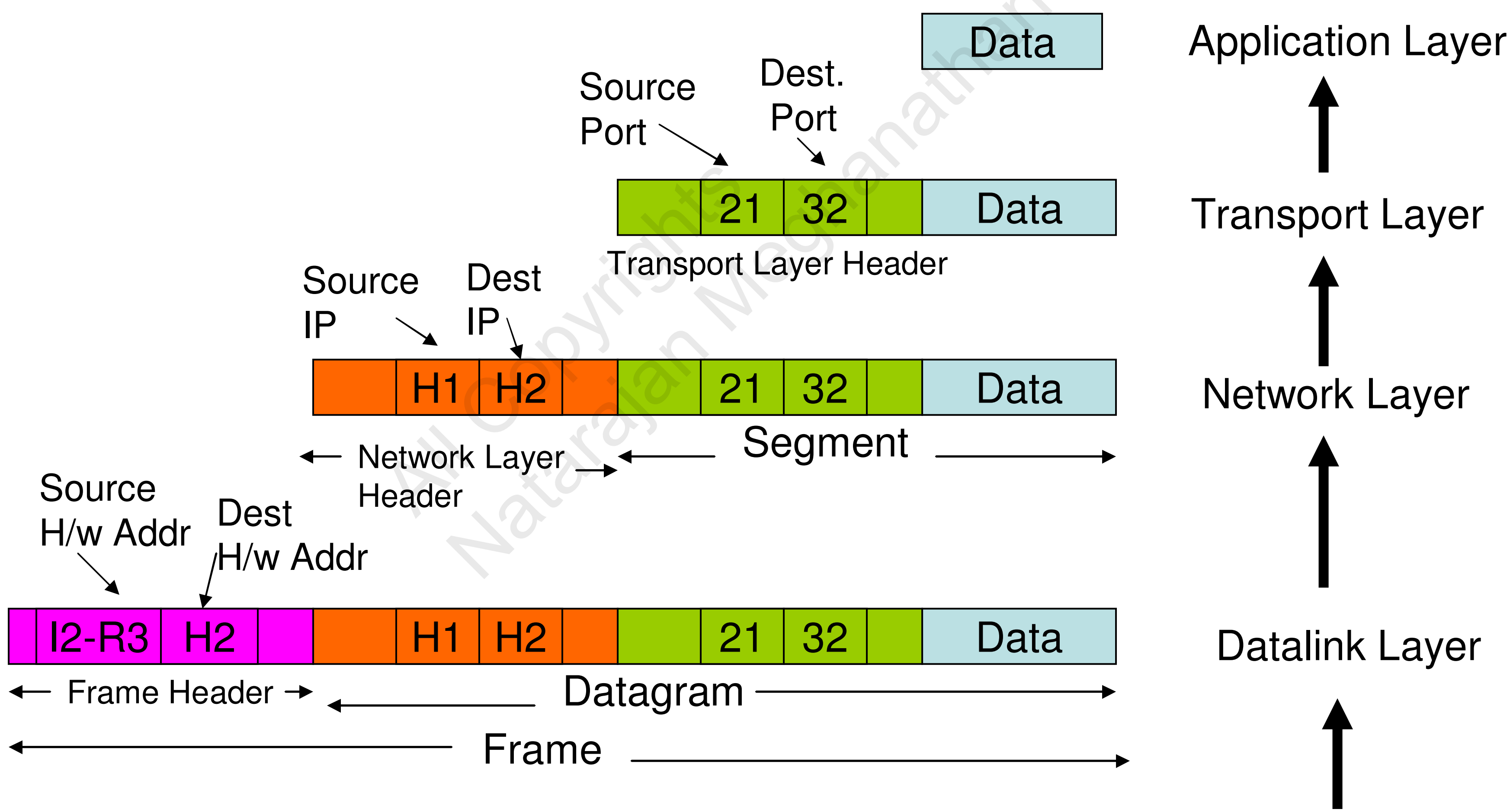


At Interface 2 of R3



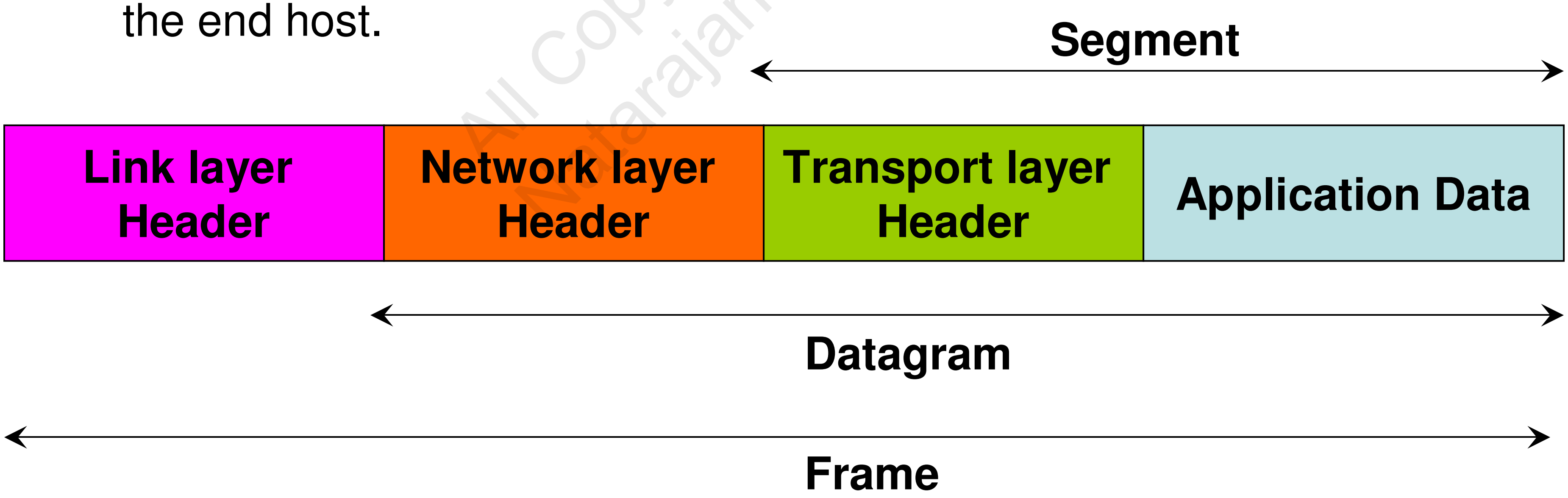

143.132.0.0
I1
R1
I2
198.90.56.0
I1
R2
I2
202.78.23.0
I1
R3
I2
190.34.0.0
H1
H2

At H2


Data
Application Layer
Source Port
Dest. Port
21
32
Data
Transport Layer
Transport Layer Header
Source IP
Dest IP
H1
H2
21
32
Data
Network Layer
Network Layer Header
Segment
Source H/w Addr
Dest H/w Addr
I2-R3
H2
H1
H2
21
32
Data
Datalink Layer
Frame Header
Datagram
Frame

Segment, Datagram and Frame

- Segment – Transport layer (TCP or UDP) header + Application Data
- Datagram – Network layer (IP) header + Segment
- Frame – Link layer (frame) header + Datagram
- The physical layer, network interface and Internet layers are called the <u>host-to-host</u> layers as the headers corresponding to these layers are exposed at each intermediate; whereas, the transport and application layers are called as the <u>end-to-end</u> layers as the header and application data corresponding to these layers are seen only at the end host.



1.5 ISO/OSI Model and TCP/IP Model

ISO 7-Layer Reference Model

1. Physical layer: Corresponds to the basic network hardware- transmission of data as a sequence of bits of 1s and 0s

E.g., RS-232 specification

2. Data Link layer: Deals with organization of data into frames and transmission of frames over a network.

E.g., frame format, byte/bit stuffing, checksum computation

3. Network layer: Deals with the specifics of address assignment and packet forwarding from one end of the network to another.

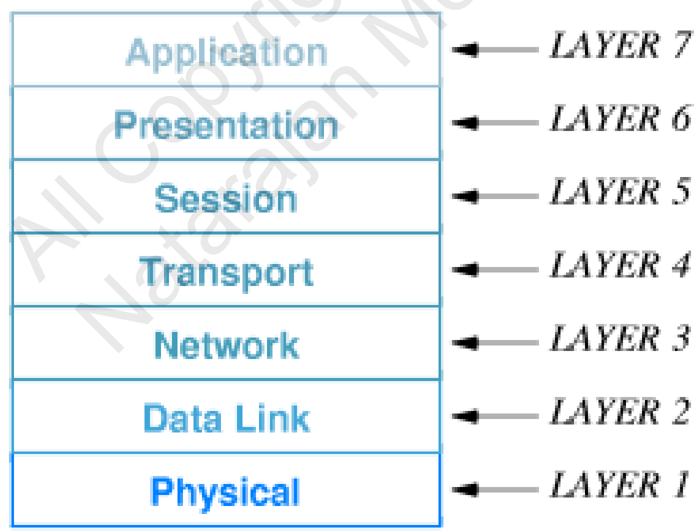
4. Transport layer: Specifies the details of handling reliable data transfer.

5. Session layer: Deals with establishing a communication session with a remote system. Security aspects of connecting to a remote system like authentication using password are dealt in this layer.

ISO 7-Layer Reference Model

6. Presentation layer: Deals with the translation of representation of data on one computer to the representation on another.

7. Application layer: Specifies how one particular application uses a network and contacts the application program running on a remote machine.

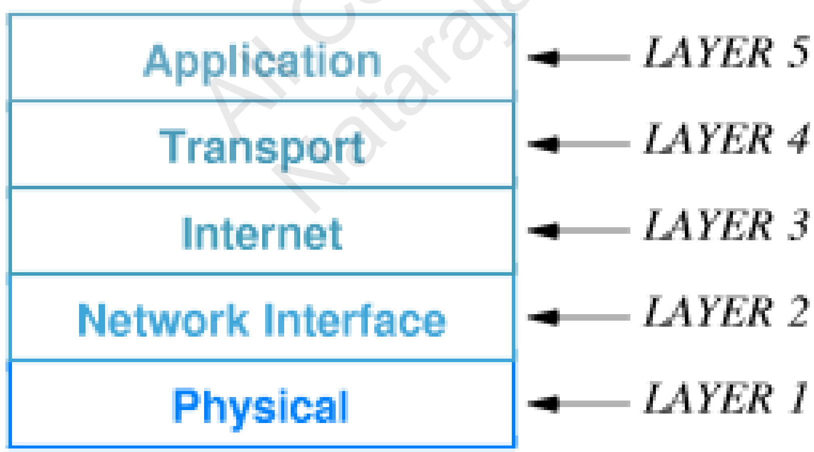


ISO 7-Layer Reference Model

TCP/IP Protocol Stack

Motivation

- The ISO 7-layer model was developed before the idea of internetworking was conceived and hence the model does not have an Internet layer to take care of communication across different heterogeneous networks.
- The session layer in the 7-layer model has become less important in present day computer systems that are mostly private workstations and not timesharing systems.



TCP/IP Protocol Stack

1. Physical Layer: Corresponds to the ISO 7-layer model's physical layer.

2. Network Interface Layer: Specifies organization of data into frames and transmission of frames over a network; similar to the ISO 7-layer model's data link layer.

3. Internet Layer: Specifies the format of packets sent across an internet and mechanisms to forward packets from a source computer through one or more routers to a final destination.

4. Transport Layer: Similar to the ISO model's transport layer, specifying reliable transfer.

5. Application Layer: Corresponds to the presentation and application layer of the ISO model; TCP/IP's application layer protocols specify how an application uses an internet.