Computer Networks

# Network Layer

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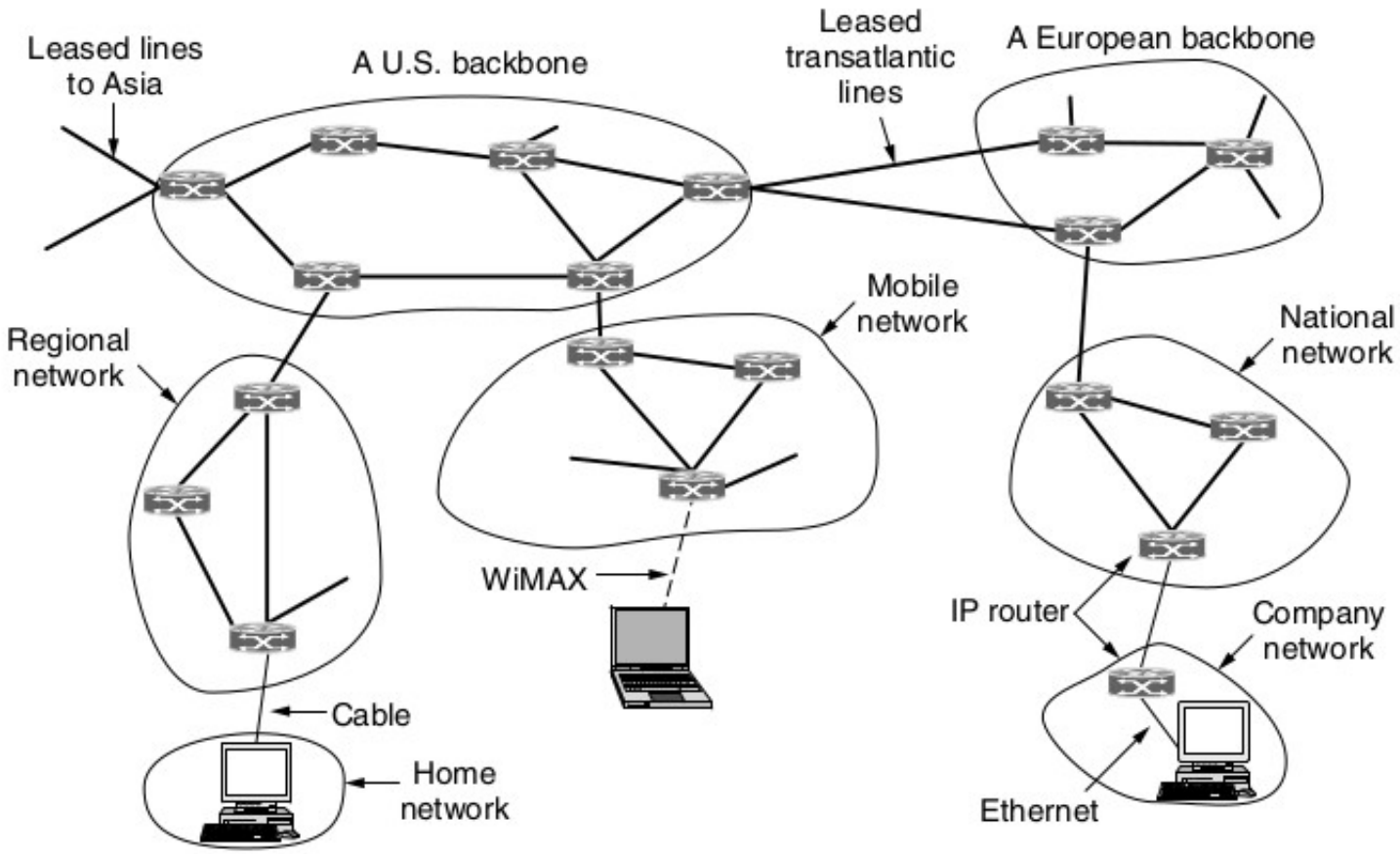
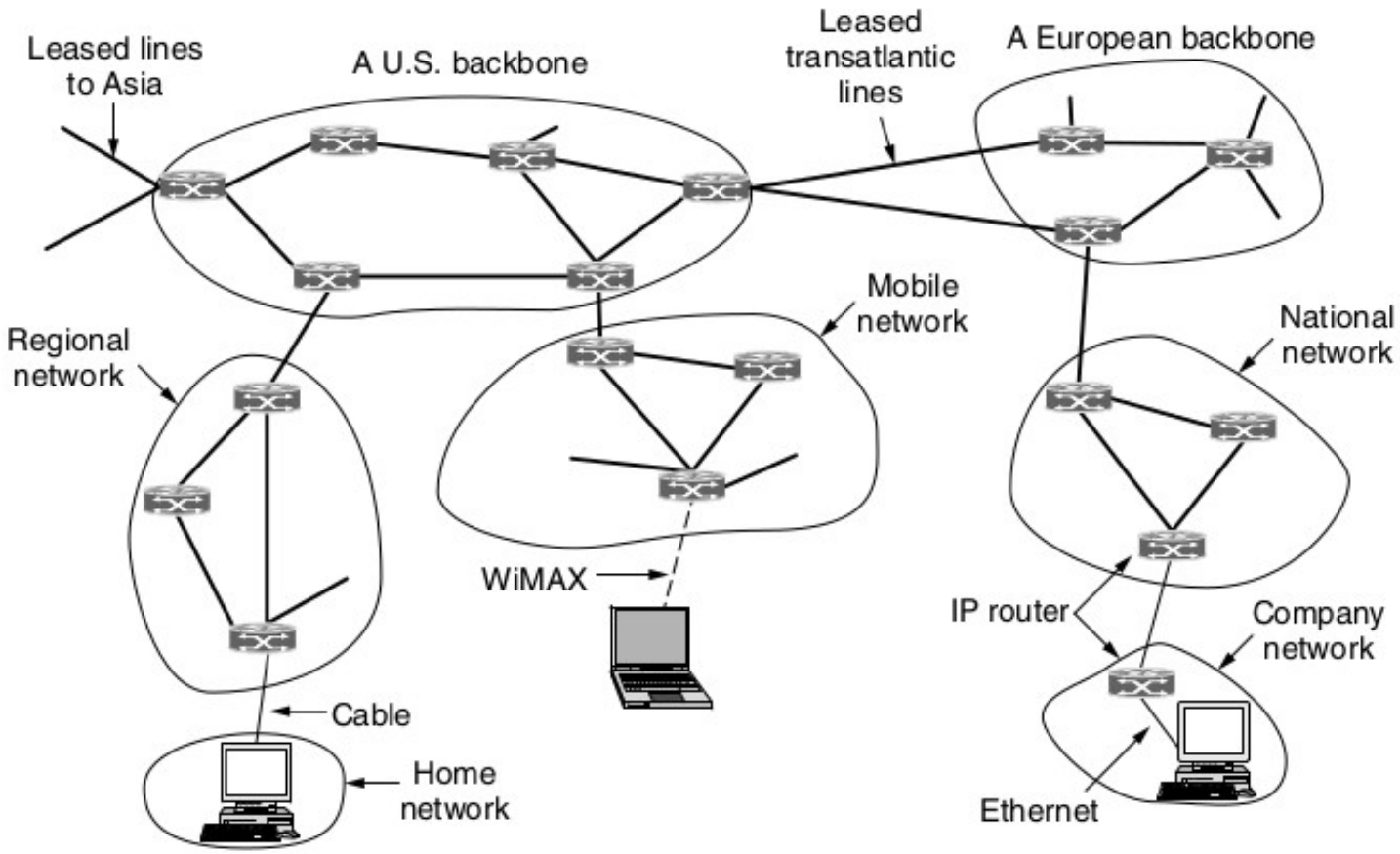
# Internetworking & Internet Protocol Suite

# Internetwork




An internetwork is a collection of individual networks, connected by intermediate networking devices, that functions as a single large network

# Internetwork (cont.)

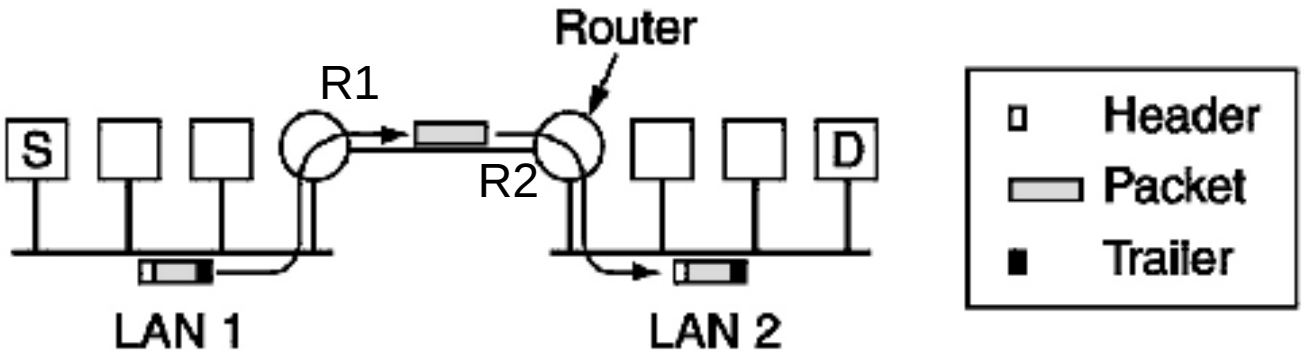



- Component networks are inhomogeneous. They are different in hardwares, softwares and protocols
- Objective of creating an internetwork is to allow a user in a network to communicate with other users in the other networks

# Levels of internetworking

- At physical layer:
  - Individual networks can be interconnected by using Repeaters or HUBs.
  - Repeaters or HIUBs simply transmit raw bits from one network segment to others network segments
- At data link layer:
  - Switches or Bridges are used. On receiving a frame, they analyze the MAC address of the frame and finally, they transmit the frame to the other network segment.
  - Reformat the frame
- At network layer: Routers are used.
- At transport layer and application layer: Gateways are used

# Internetworking at network layer




- Two routers are interconnected by a point-to-point link
- Host S wants to send a packet to host D
- S creates a frame containing the packet and sends the frame onto LAN1
- When the frame arrives at router R1, the router will
  - Unpack the frame, retrieve the packet, find the destination address of the frame, search in its routing table for the route to the destination
  - Decide to forward the packet to port connecting to R2; create a frame containing the packet and send the frame to router R2 on LAN2

# Internet Protocol Suite

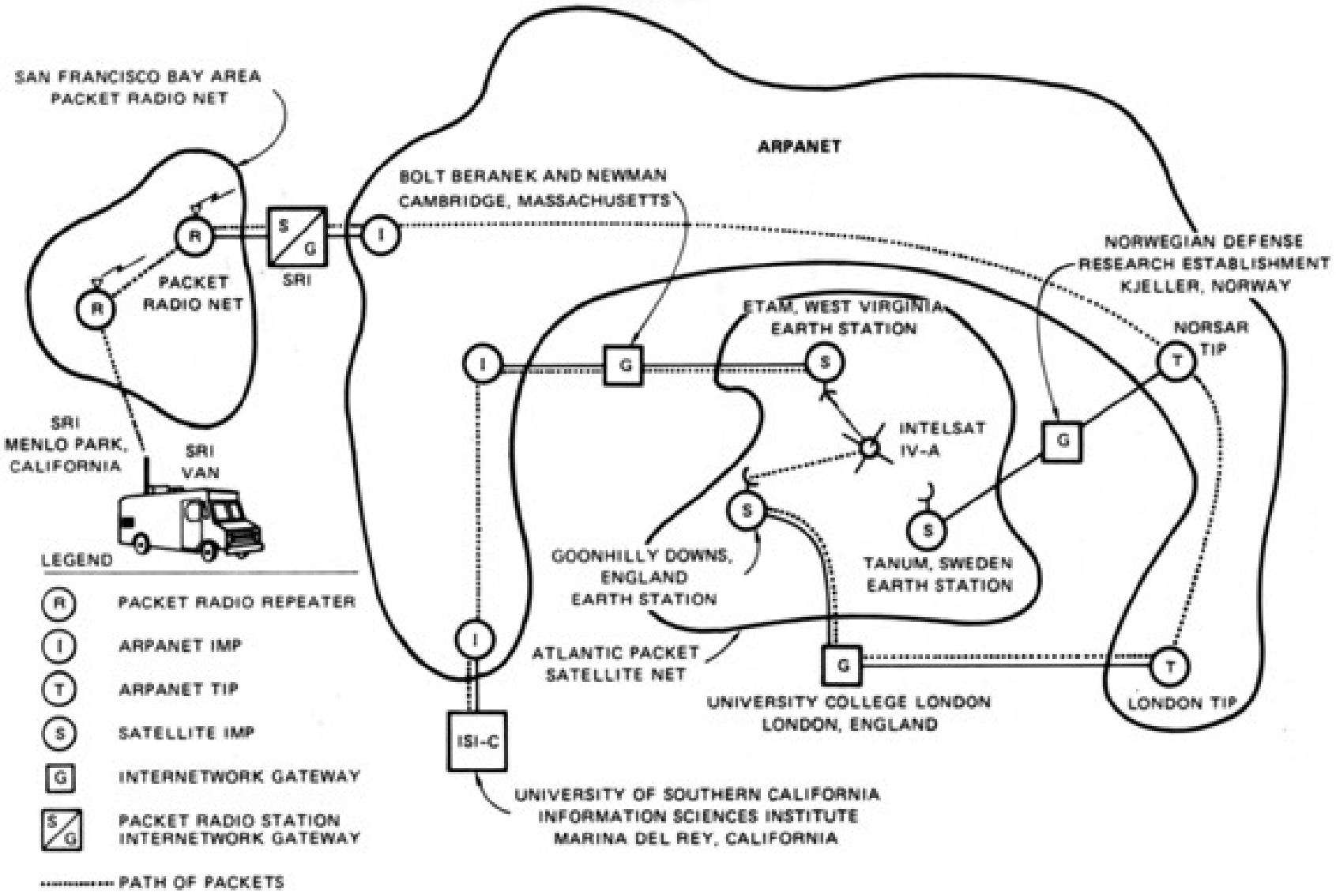
# Internet History (1)

- Internet Protocol Suite was developed in the years of the '70s of the 20th century in a project of Defense Advanced Research Projects Agency
- DARPA project led to the development of protocols for internetworking, where multiple separate networks could be joined together into a network of networks
- On 29 October 1969 : The first two nodes of what would become the ARPANET were interconnected between Leonard Kleinrock's Network Measurement Center at the University of California, Los Angeles (UCLA) Henry Samueli School of Engineering and Applied Science and Douglas Engelbart's NLS system at SRI International (SRI) in Menlo Park, California
- 1971 : Fifteen sites connected to the young ARPANET
- In December 1974, RFC 675 – Specification of Internet Transmission Control Program, term **internet** used as a shorthand for internetworking

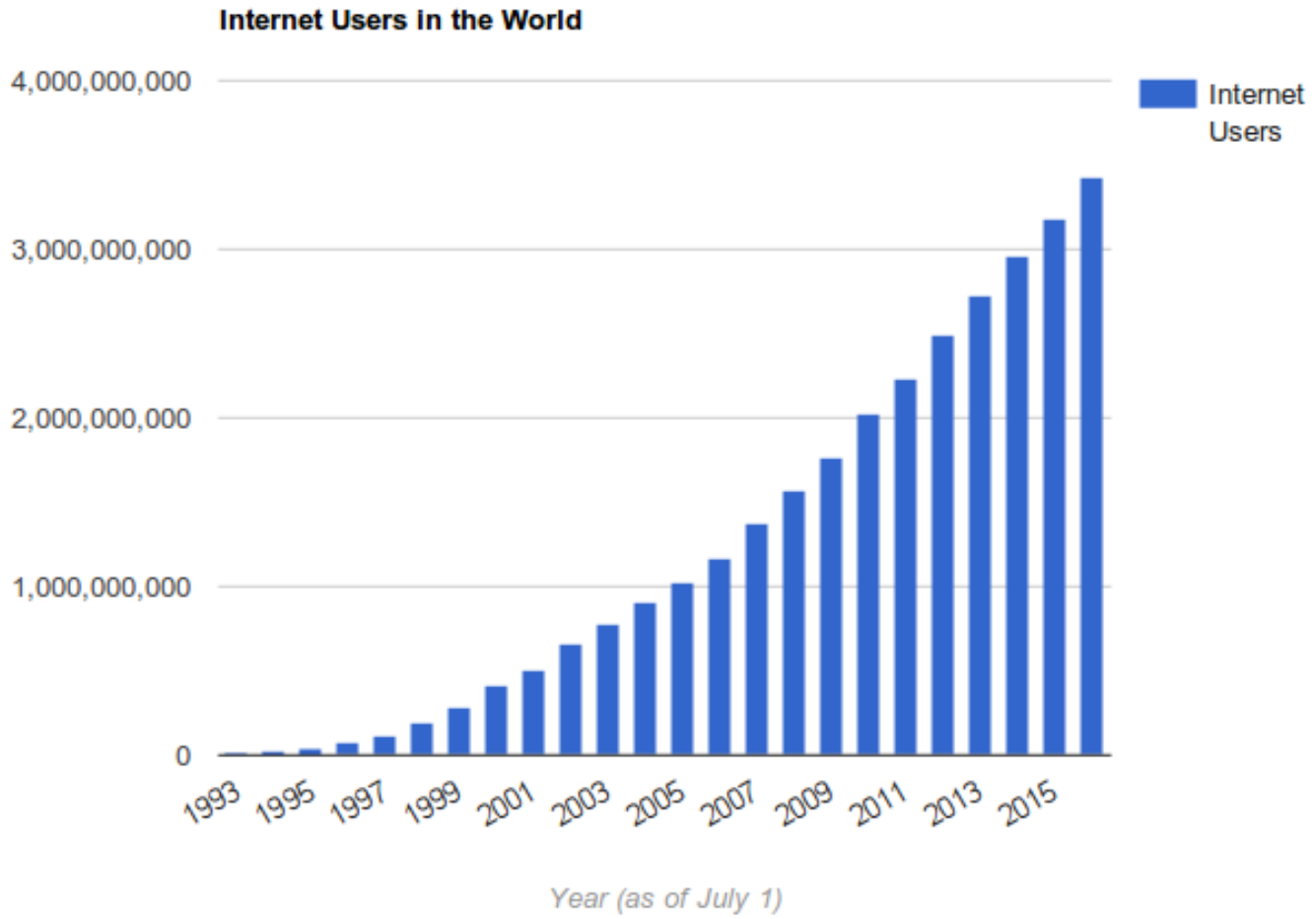
# Internet History (2)

- In 1982, the Internet Protocol Suite (TCP/IP) was standardized, which permitted worldwide proliferation of interconnected networks.
- In 1986, TCP/IP network access expanded again when the National Science Foundation Network (NSFNET) provided access to supercomputer sites in the United States from research and education organizations, first at 56 kbit/s and later at 1.5 Mbit/s and 45 Mbit/s.
- In 1990, The ARPANET was decommissioned
- By 1995, The Internet was fully commercialized in the U.S.
- In 1997, Vietnam was connected to Internet

# Internet History (3)



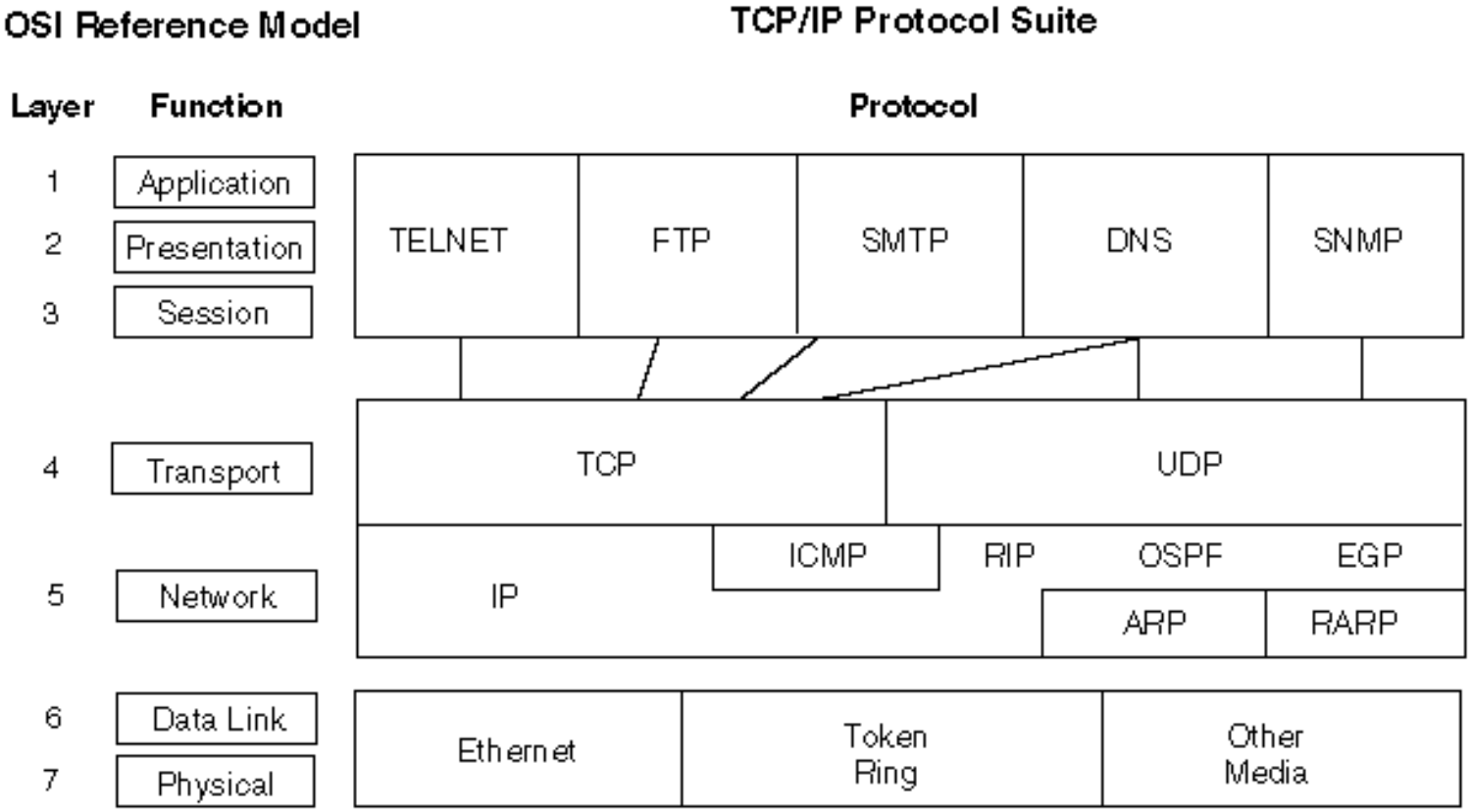
# Internet Users




| Year | Internet Users** | Penetration (% of Pop) | World Population | Non-Users (Internetless) | 1Y User Change | 1Y User Change | World Pop. Change |
|---|---|---|---|---|---|---|---|
| 2016* | **3,424,971,237** | 46.1 % | 7,432,663,275 | 4,007,692,038 | 7.5 % | 238,975,082 | 1.13 % |

# Internet Protocol Suite (IP Suite)

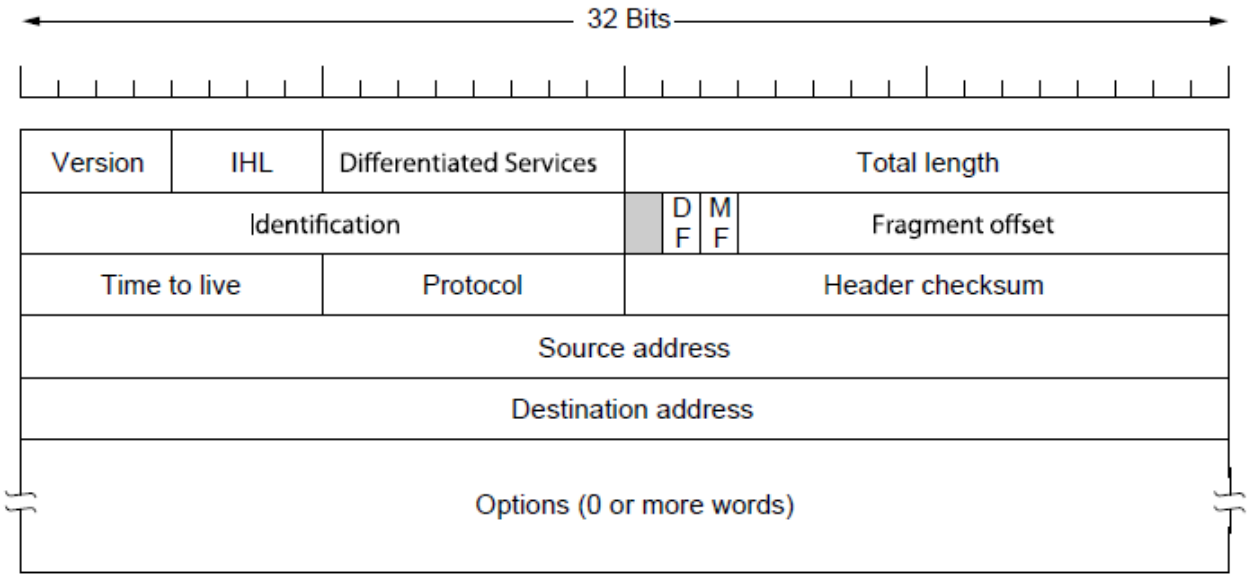
- The heart of Internet; A set of communication protocols
  - Layer 3: Internet Protocol
  - Layer 4: TCP (Transmission Control Procotol); UDP (User Datagram Protocol)
  - Layer 7: SMTP, FTP, TELNET, HTTP



# Internet Protocol (IP)

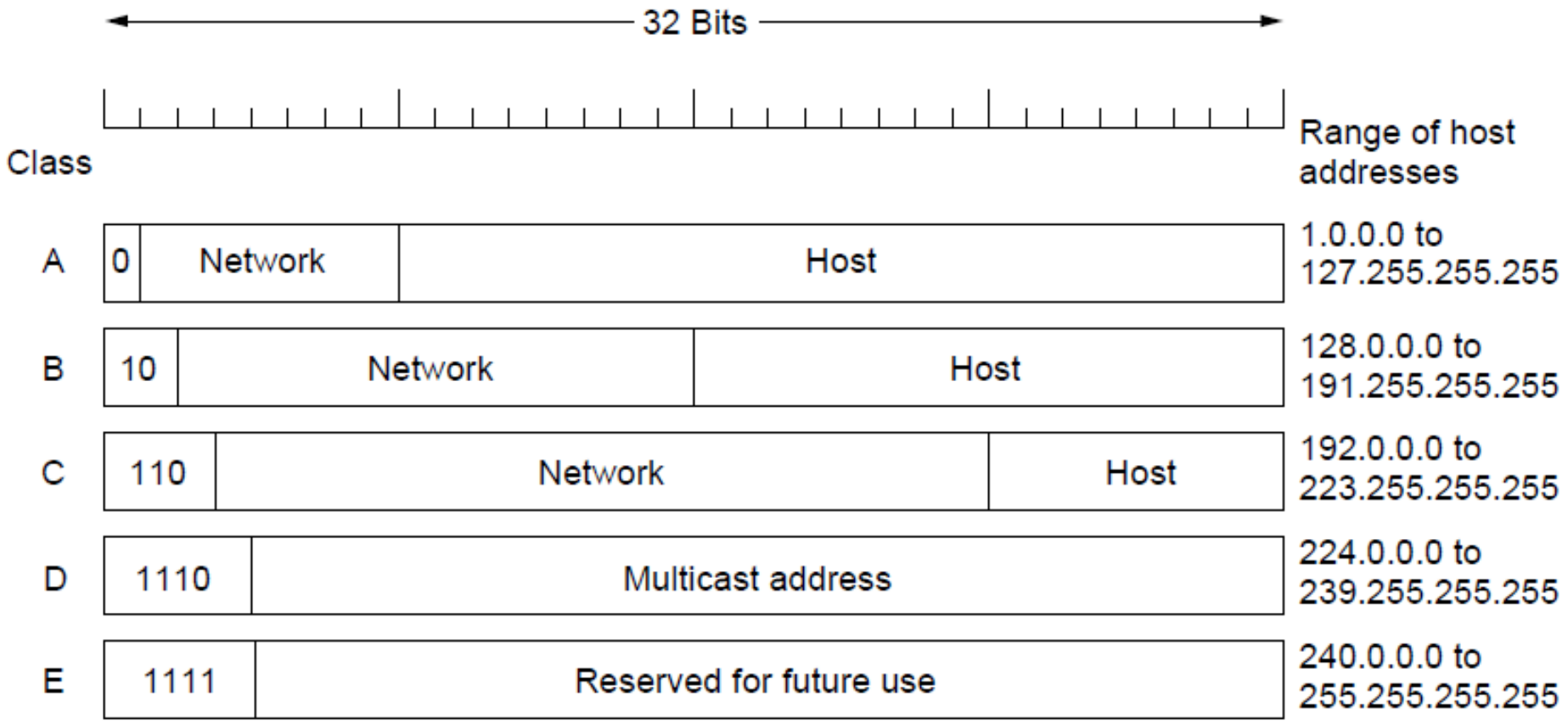
- A protocol at the Network layer
- Define the addressing scheme and packet exchange methods in an internetwork
- Specified in RFC 791 (Request For Comments)
- Two main functions
  - Providing a connectionless communication to exchange datagram packets between hosts in an internetwork
  - Breaking up packets into fragments and recombining the fragments back into original packet to support data link layer with different sizes of frames

# IP Version 4




- IHL: Internet Header Length, in 32 bits, 5 → 15
- Differentiated services: Type of service
- Total length: 65535 bytes maximum
- Identification: The same for all fragments of a packet
- DF: Don't Fragment; MF: More Fragments
- Time to live: 0 → discard the frame; 255 second in maximum
- Protocol: Protocol used in Transport layer
- Source address, Destination Address: IP address of sending and receiving hosts

# IP Address


32 Bits
Class
Range of host addresses
A
0
Network
Host
1.0.0.0 to 127.255.255.255
B
10
Network
Host
128.0.0.0 to 191.255.255.255
C
110
Network
Host
192.0.0.0 to 223.255.255.255
D
1110
Multicast address
224.0.0.0 to 239.255.255.255
E
1111
Reserved for future use
240.0.0.0 to 255.255.255.255

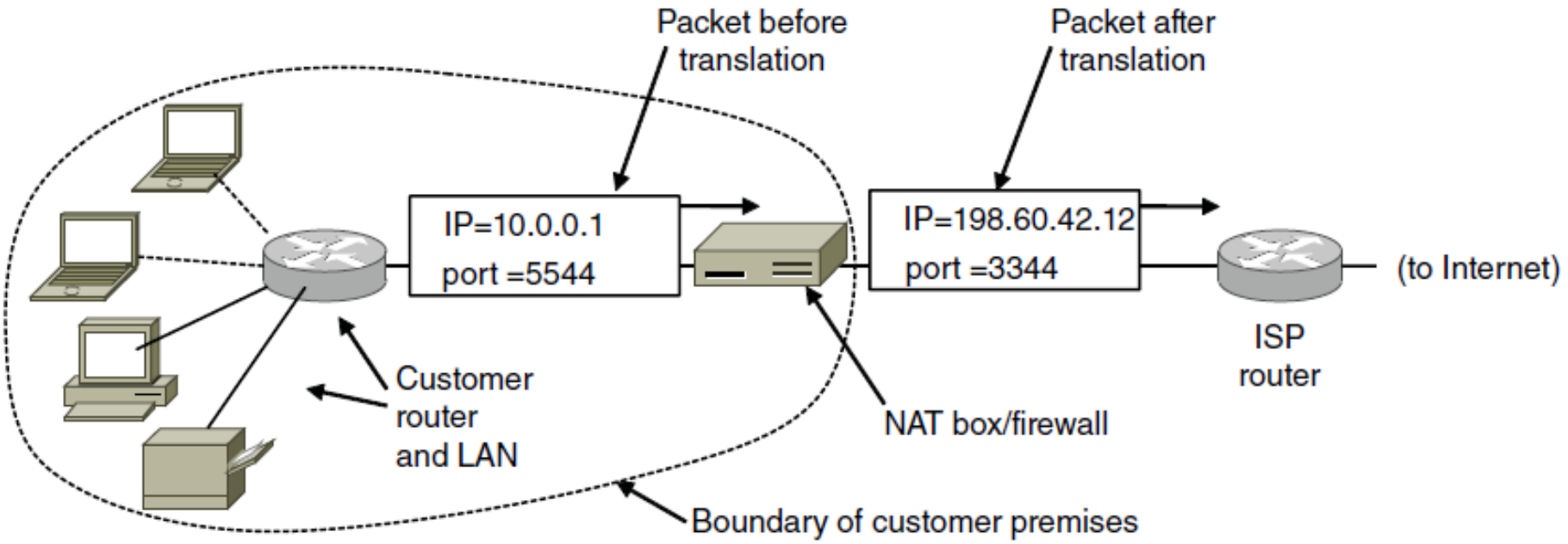
# Special IP addresses

- **Network Address**: is an IP address where all bits in host identifier part are 0, used to identify a network
  - Example: 10.0.0.0; 172.18.0.0 ; 192.1.1.0
- **Broadcast address**: is an IP address where all bits in host identifier part are 1, used to refer to all host in a network; not assigned to a host
  - Example: 10.255.255.255, 172.18.255.255, 192.1.1.255
- **Netmask**: is an IP address where all bits in network identifier part are 1 and ,all bits in host identifier part are 0. There are three standard netmasks
  - Netmask for networks of class A: 255.0.0.0
  - Netmask for networks of class B: 255.255.0.0
  - Netmask for networks of class C: 255.255.255.0

# Special IP addresses (cont.)

- **Loopback Network**:127.0.0.0 used locally in each host. Each host installed IP protocol is assigned the loopback IP address 127.0.0.1. This loopback IP address is used to check IP protocol.
- Private Network Addresses for LANs not directly connected to Internet
  - Network of class A: 10.0.0.0
  - Networks of class B: 172.16.0.0 → 172.32.0.0
  - Networks of class C: 192.168.0.0 → 192.168.254.0

# Example of an IP network



# Calculate network Address from an IP address

- Network Address = IP Address & Netmask

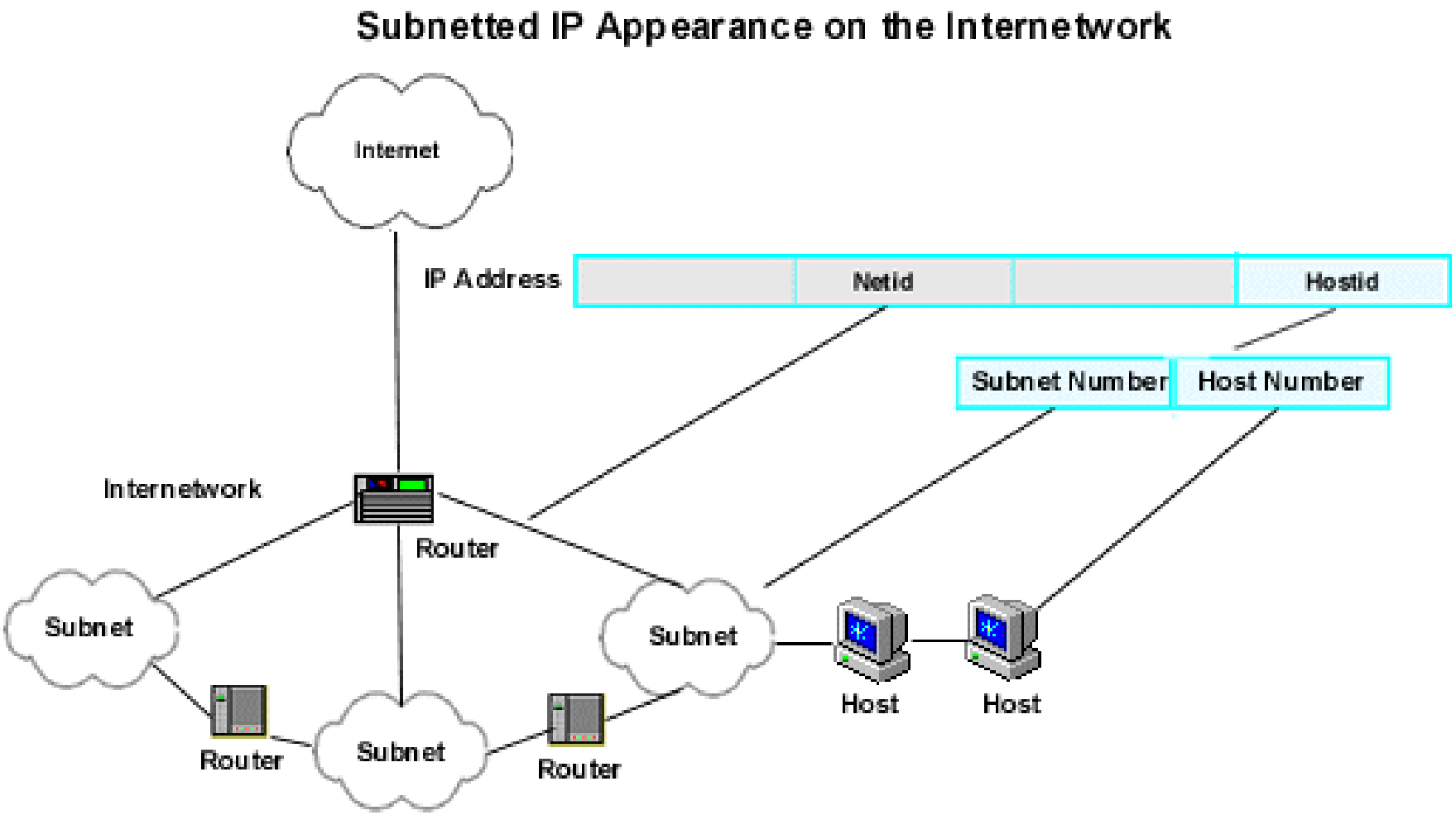
| | Biểu diễn thập phân | Biểu diễn nhị phân |
|---|---|---|
| IP Address | 198.53.147.45 | 11000110 00110101 10010011 00101101 |
| Netmask | 255.255.255.0 | 11111111 11111111 11111111 00000000 |
| Network Address | 198.53.147.0 | 11000110 00110101 10010011 00000000 |

# Subnetting

# Subnetting

- A solution allowing the block of addresses to be split into several parts for internal use as multiple networks, while still acting like a single network to the outside world.
- The networks (such as Ethernet LANs) that result from dividing up a larger network are called subnets
- Benefits
  - Simplify administration: With the help of the router, networks can be divided into multiple subnets that can be managed as independents network and more efficient
  - Be able to change the internal structure of the network without affecting the external network. An organization can continue to use the IP address was granted without having to get more new address block
  - Strengthening the security of the system: Subnetting will allow an organization to design his network as an internetwork of subnets while outside networks still feel it is a single network
  - Isolating the traffic flow on the network: With the help of the routers, network traffic can be kept to the lowest level

# Subnetting

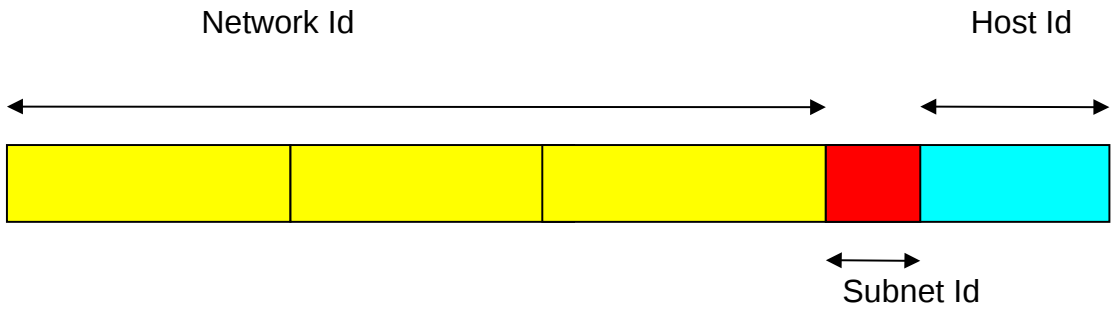

Subnetted IP Appearance on the Internetwork
Internet
IP Address
Netid
Hostid
Subnet Number
Host Number
Internetwork
Router
Subnet
Subnet
Host
Host
Router
Subnet
Router

# Methods for subnetting

- Classful standard
- CIDR (Classless Inter-Domain Routing)

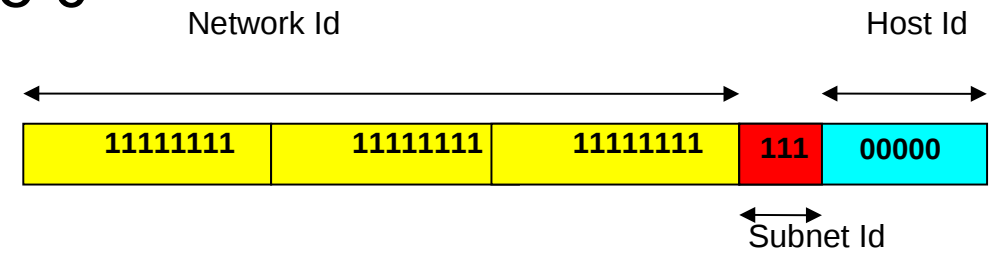
# Classful standard method

- Network Identifier of original network address remains unchanged
- Host Identifier of original network address is divided into two parts:
  - Subnet Identifier
  - Host Identifier



# Subnetmask in classful standard method

- Subnetmask is an IP address where all bits in network identifier part and all bits in subnet identifier part are 1, and all bits in host identifier are 0




- Subnetwork Address = IP & Subnetmask
- Number of bits of subnet id determines the number of subnets
  - 4 bits in subnet id → $2^4$=16 subnets
  - The subnetworks where the bits in subnet identifier are all 0 or all 1 are not used to assign to subnets because they are overlapped with the network address and the broadcast address of the original network

# Example of classful standard method

- Given a network address of class C: 192.168.1.0 / 255.255.255.0.
  - Using 2 bits for subnet identifier part
  - Subnetmask is 255.255.255.192
  - List of subnetwork addresses

| IP address | Represented in decimal | Preresented in binary | | | |
|---|---|---|---|---|---|
| Original network | 192.168.1.0 | 1100 0000 | 1010 1000 | 0000 0001 | 0000 0000 |
| Subnetmask | 255.255.255.192 | 1111 1111 | 1111 1111 | 1111 1111 | **11**00 0000 |
| Subnet 1 | 192.168.1.0 | 1100 0000 | 1010 1000 | 0000 0001 | **00**00 0000 |
| Subnet 2 | 192.168.1.64 | 1100 0000 | 1010 1000 | 0010 0001 | **01**00 0000 |
| Subnet 3 | 192.168.1.128 | 1100 0000 | 1010 1000 | 0000 0001 | **10**00 0000 |
| Subnet 4 | 192.168.1.192 | 1100 0000 | 1010 1000 | 0000 0001 | **11**00 0000 |

# Steps in classful standard method

- Determine the required number of subnets, e.g **N**
- Represent the number **(N+1)** in binary. The number of bits are used to represent **(N+1)** is also the number of bits reserved for Subnet identifier part.
  - For example, N=6 → N+1=7 ~ 111 (B) → Need 3 bits for Subnet identifier part
- Create subnetmask
- List all subnetwork addresses corresponding to the subnetmask, except the addresses where the bits in subnet identifier are all 0 or all 1 are not used to assign to subnets
- Choose N addresses from the above list to assign to N subnetworks

# Homeworks

- Cho địa chỉ mạng 192.168.1.0. Hãy phân mạng này thành 10 mạng con để gán cho 10 phòng máy tính. Định địa chỉ cho 10 máy tính của phòng 1 và phòng 2
- Cho địa chỉ mạng 172.16.0.0 được chia mạng con với subnetmask=255.255.255.0. Gán mỗi phòng 1 mạng con. Hãy định địa chỉ cho 10 máy tính ở phòng 1 và 2
- Trình bày kết quả theo dạng
  - Phân bố mạng con
    - Phong 1: Địa chỉ mạng con/subnetmask
    - ….
    - Phong 10: Địa chỉ mạng con/subnetmask
  - Phòng 1:
    - Máy 1: IP
    - Máy 2: IP
    - Máy 3: IP …
    - Máy 10: IP

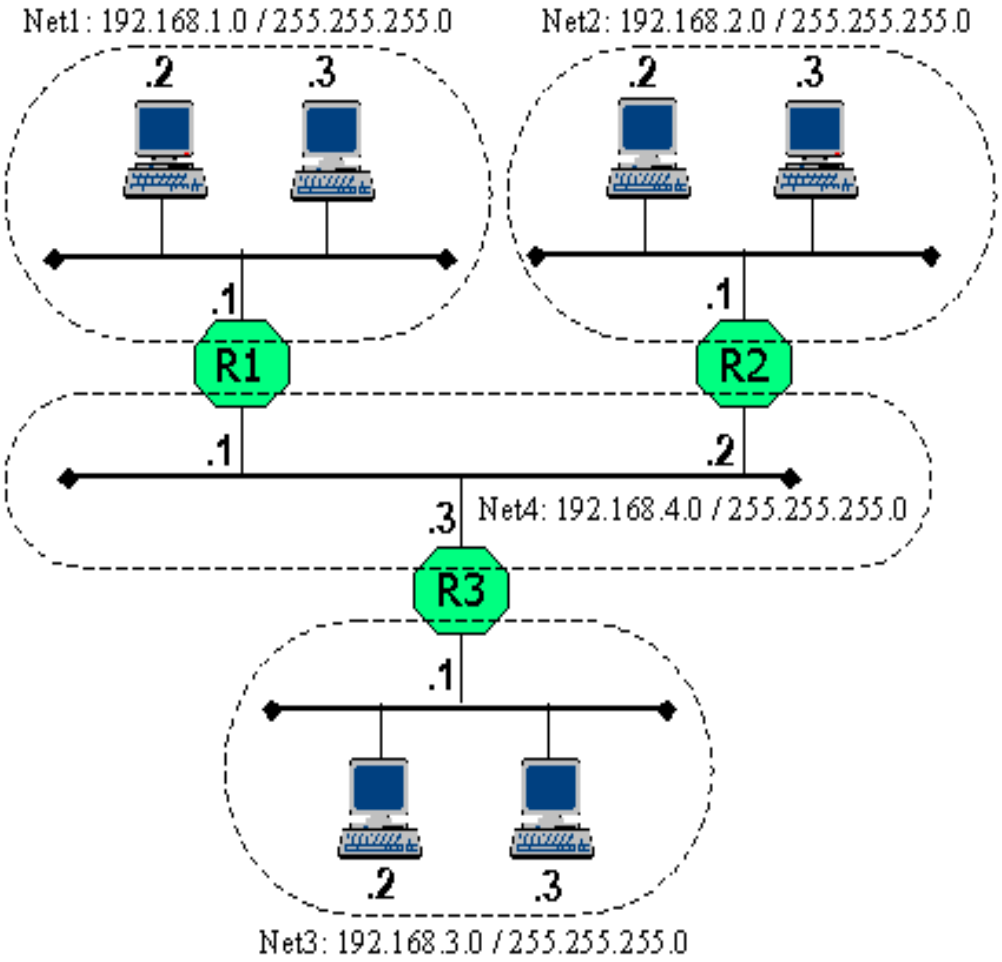
# Classless Inter-Domain Routing method (CIDR)

- Developed to resolve the lack of IP addresses
- No need to classify the networks into class A, B, or C
- Network identify part: the first 13→ 27 bits
- An IP address consists of two parts
  - 32 bits of a traditional IP address
  - Number of bits used for network identify
  - Example: 206.13.01.48/25

# Classless Inter-Domain Routing method

| Number of bits for Netword Id in CIDR | Correspondent class in classful starndart method | Number of hosts in a network |
|---|---|---|
| /27 | 1/8 class C | 32 |
| /26 | ¼ class C | 64 |
| /25 | 1/2 class C | 128 |
| /24 | 1 class C | 256 |
| /23 | 2 class C | 512 |
| /22 | 4 class C | 1.024 |
| /21 | 8 class C | 2.048 |
| /20 | 16 class C | 4.096 |
| /19 | 32 class C | 8.192 |
| /18 | 64 class C | 16.384 |
| /17 | 128 class C | 32.768 |
| /16 | 256 class C (= 1 class B) | 65.536 |
| /15 | 512 class C | 131.072 |
| /14 | 1,024 class C | 262.144 |
| /13 | 2,048 class C | 524.288 |

# Routing in IP protocol




**192.168.3.3 - Routing table**

| Network/Netmask | NextHop | Interface |
|---|---|---|
| 192.168.3.0/255.255.255.0 | local | local |
| default | 192.168.3.1 | local |

**R1-Routing table**

| Network/Netmask | NextHop | Interface |
|---|---|---|
| 192.168.1.0/255.255.255.0 | local | local |
| 192.168.2.0/255.255.255.0 | 192.168.4.2 | 192.168.4.1 |
| 192.168.3.0/255.255.255.0 | 192.168.4.3 | 192.168.4.1 |
| 192.168.4.0/255.255.255.0 | local | local |

**R2-Routing table**

| Network/Netmask | NextHop | Interface |
|---|---|---|
| 192.168.1.0/255.255.255.0 | 192.168.4.1 | 192.168.4.2 |
| 192.168.2.0/255.255.255.0 | local | local |
| 192.168.3.0/255.255.255.0 | 192.168.4.3 | 192.168.4.2 |
| 192.168.4.0/255.255.255.0 | local | local |

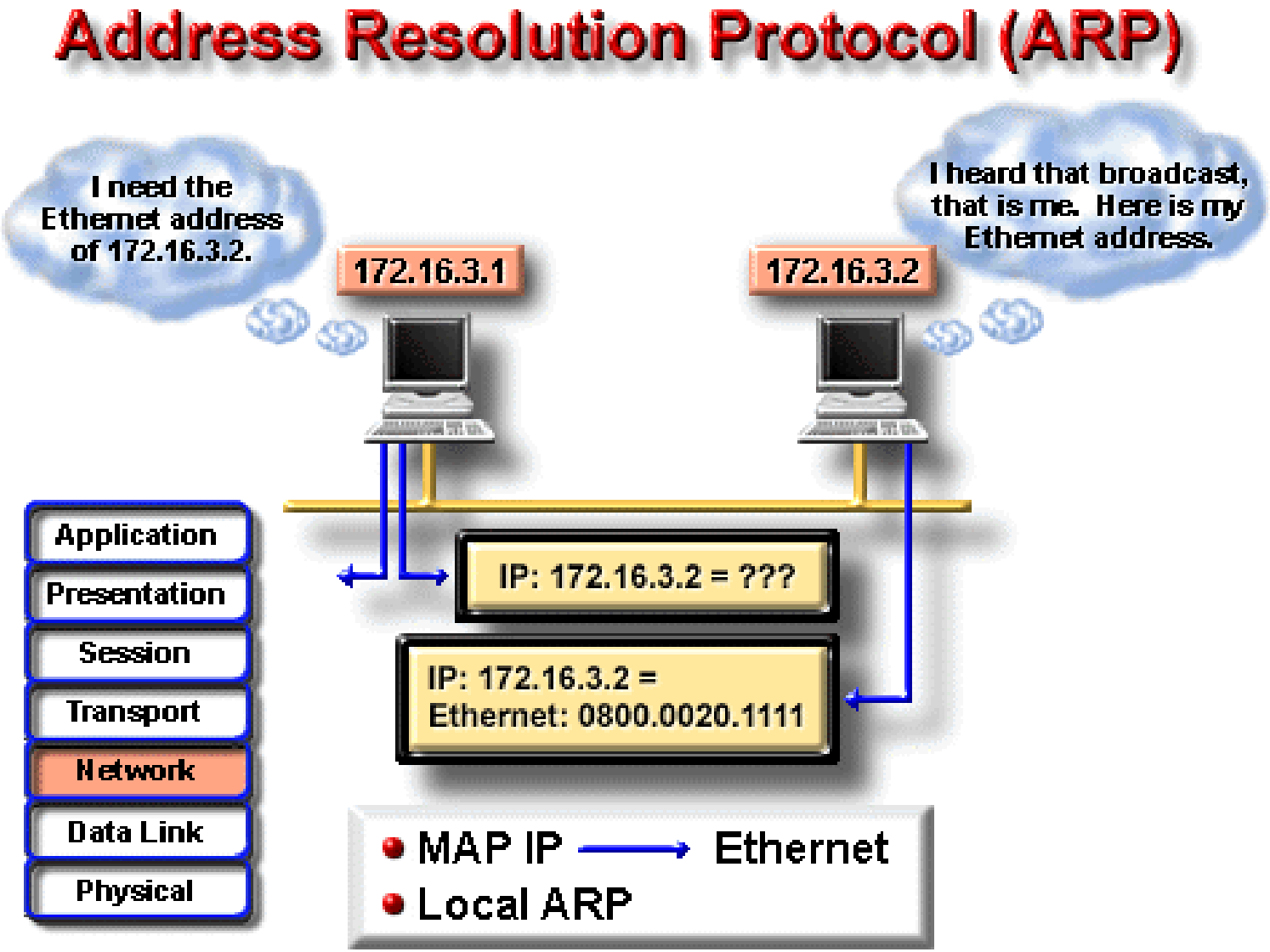
**R3-Routing table**

| Network/Netmask | NextHop | Interface |
|---|---|---|
| 192.168.1.0/255.255.255.0 | 192.168.4.1 | 192.168.4.3 |
| 192.168.2.0/255.255.255.0 | 192.168.4.2 | 192.168.4.3 |
| 192.168.3.0/255.255.255.0 | local | local |
| 192.168.4.0/255.255.255.0 | local | local |

# Homeworks

- Trang bị router cho bài tập phần trước.
- Vẽ sơ đồ thiết kế và xây dựng bảng chọn đường để các máy tính ở phòng 1 và phòng 2 giao tiếp được với nhau

# Address Resolution Protocol



# Reverse Address Resolution Protocol

- Mapping MAC addresses to IP addresses
- Used in systems supporting diskless workstations
- Diskless workstations need to get IP addresses to communicate with the server
- The server maintains a table mapping MAC addresses to IP addresses
- On receiving an RARP request, the server searches in mapping table for the IP address correspond to the MAC address in RARP request and return the address to the workstation

# Internet Control Message Protocol (ICMP)

- Messages of ICMP are transmitted in IP packets
- Used to transmit error messages or control information
- Message types
  - Destination Unreachable
  - Echo Request and Reply
  - Redirect
  - Time Exceeded
  - Router Advertisemen
  - Router Solicitation