Chapter 9

The Internet

9.1 Introduction

- Internet
  - Internet protocol
  - Internet address or IP address

Internet Technology

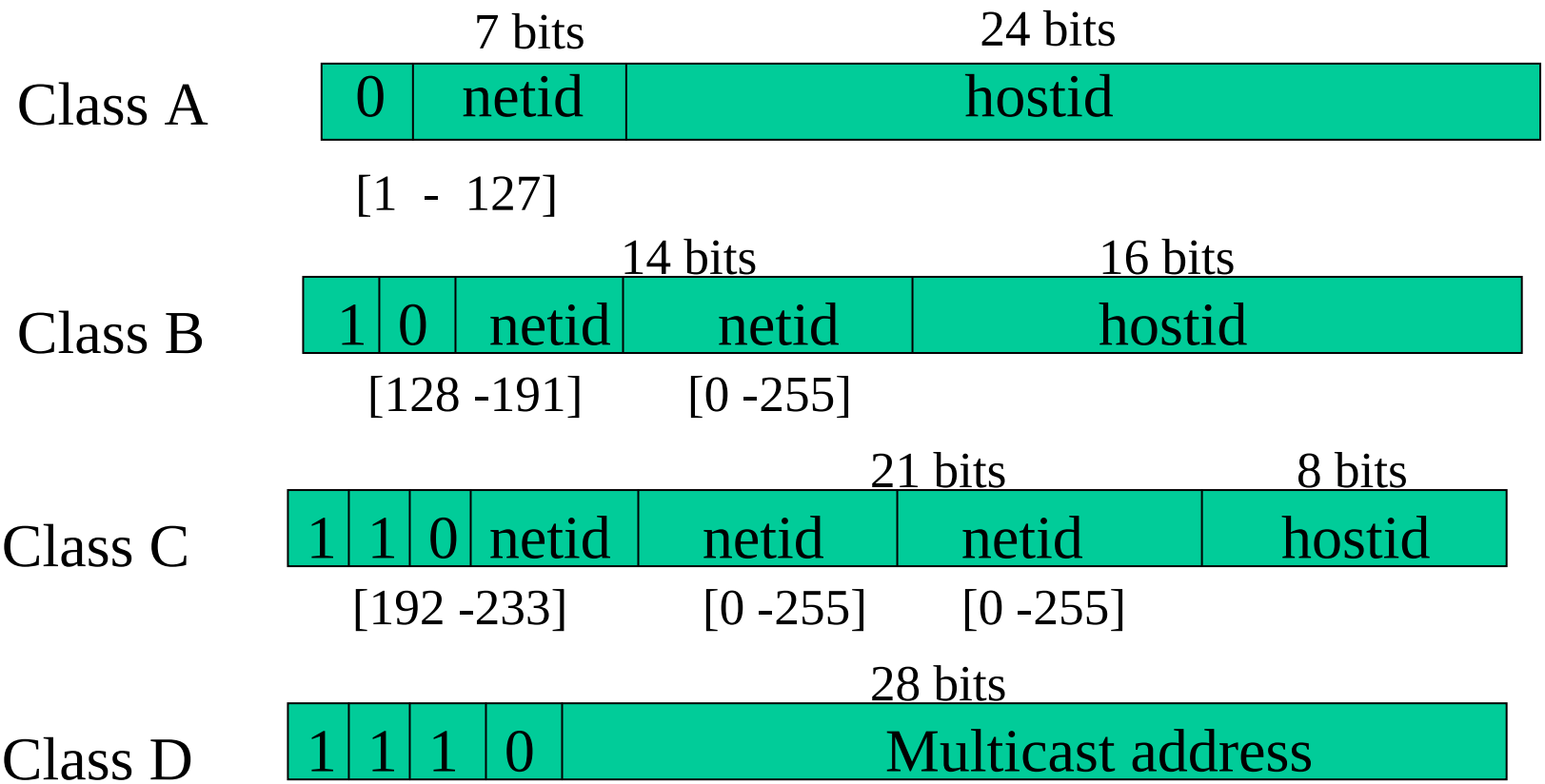
- Internet Packets are like Postcards
  - To/From addresses
  - Finite but variable content
  - Delivery failures
  - Duplication (not normally a postal service)
  - Disorderly arrival
  - Variable delays
  - Alternate routes/carriers

IP Addresses

- Assigned by the NIC (Network Information Center)
- 호스트의 인터넷 주소에 대응하는 숫자 주소
- 4개의 숫자와 마침표로 구성
  - 203.252.192.1
- 구성
  - 네트웍 주소
  - 호스트 주소
- 세계적으로 고유함
  - NIC (NIDA: National Internet Development Agency) 에 등록
  - 국제적 협조 필요

IP Address Format

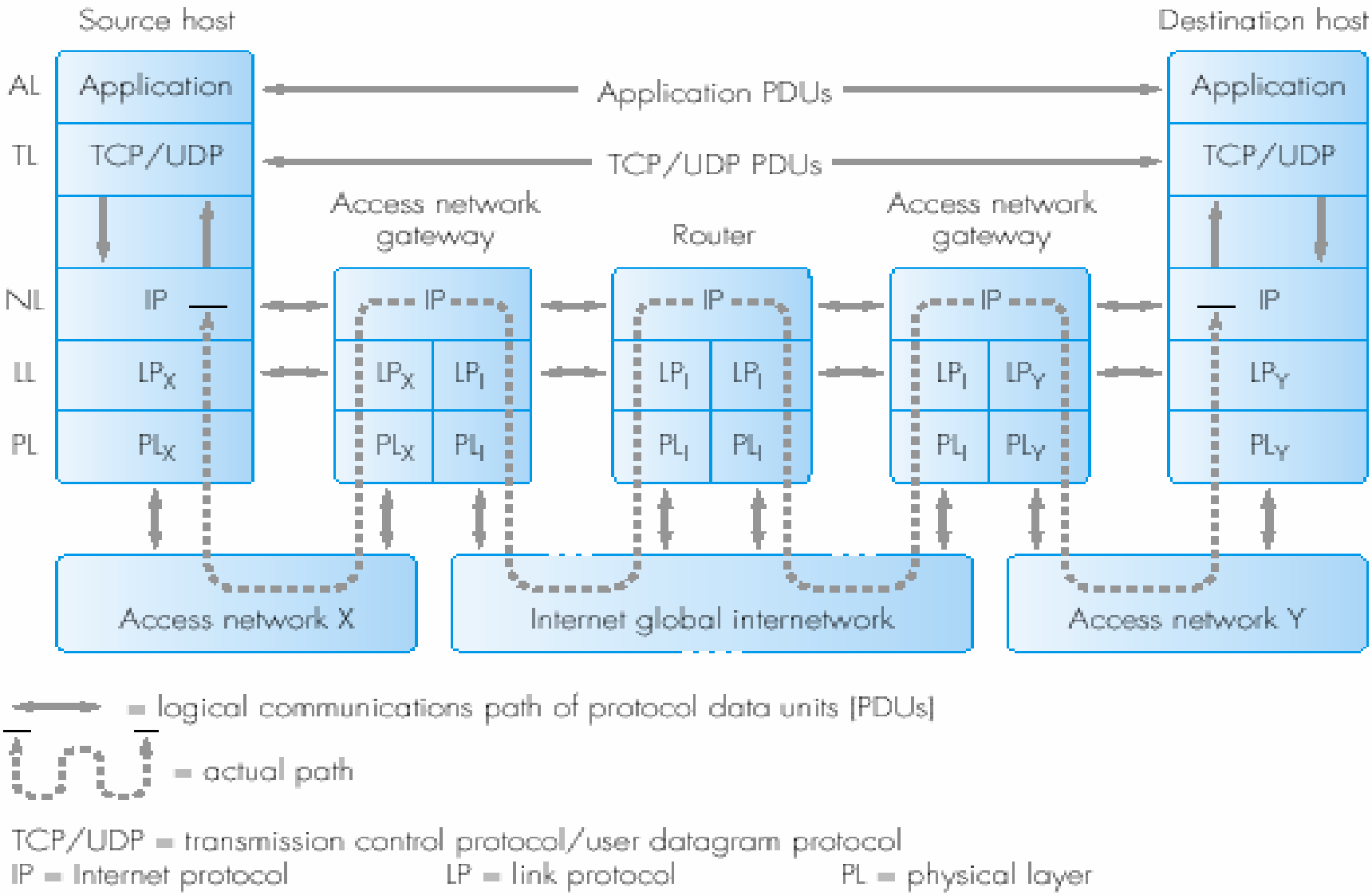
- IP 주소 유형



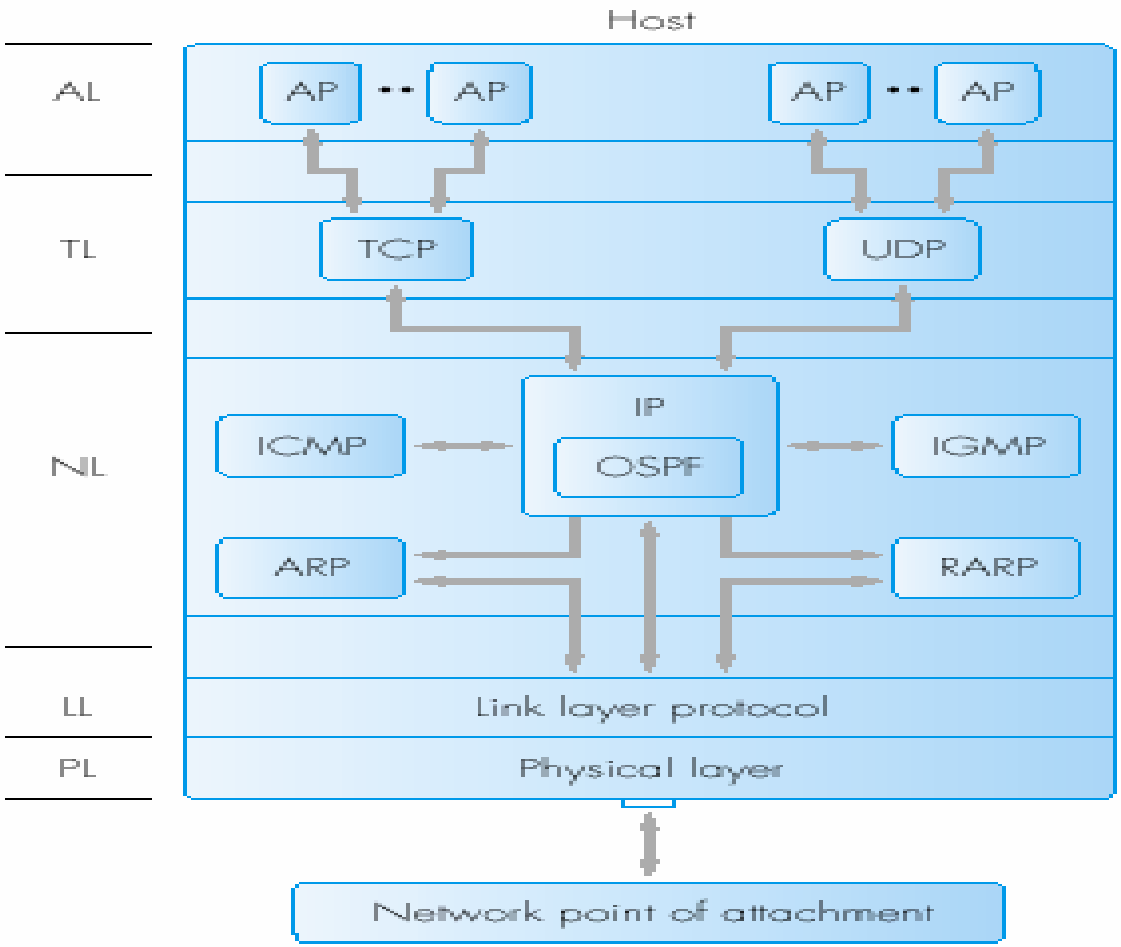
Domain of IP

- 인터넷 호스트의 지정방식
  - userid@host-name.domain-name
- 계층적으로 구성
  - Top-level domain
    - 국가별
    - 기관별
  - Sub Domain
  - eg) sookmyung.ac.kr

Internet networking components and protocols



IP Adjunct protocols



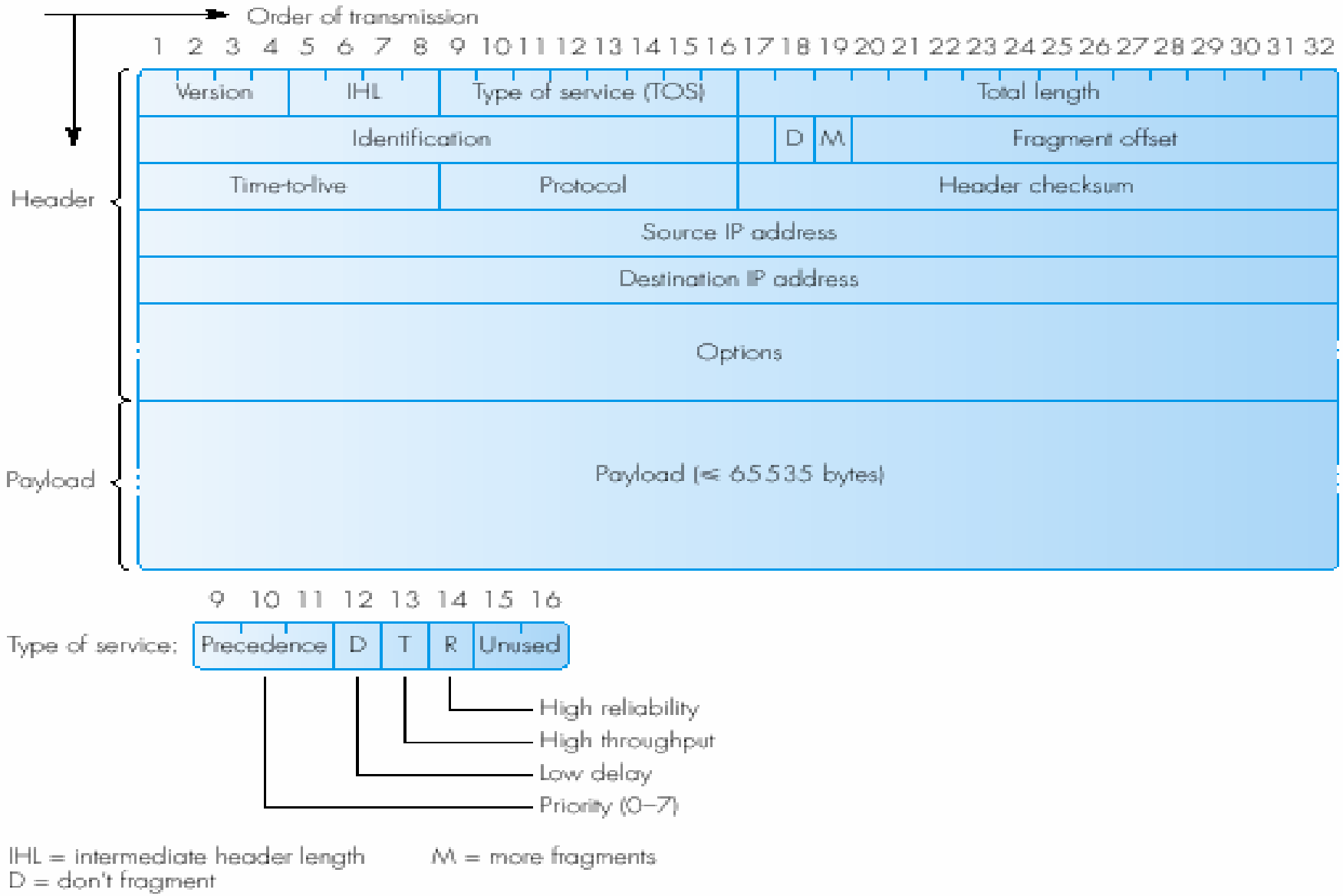
AP = application protocol/process
IP = Internet protocol
ARP = address resolution protocol
RARP = reverse ARP

ICMP = Internet control message protocol
IGMP = Internet group message protocol
OSPF = open shortest path first

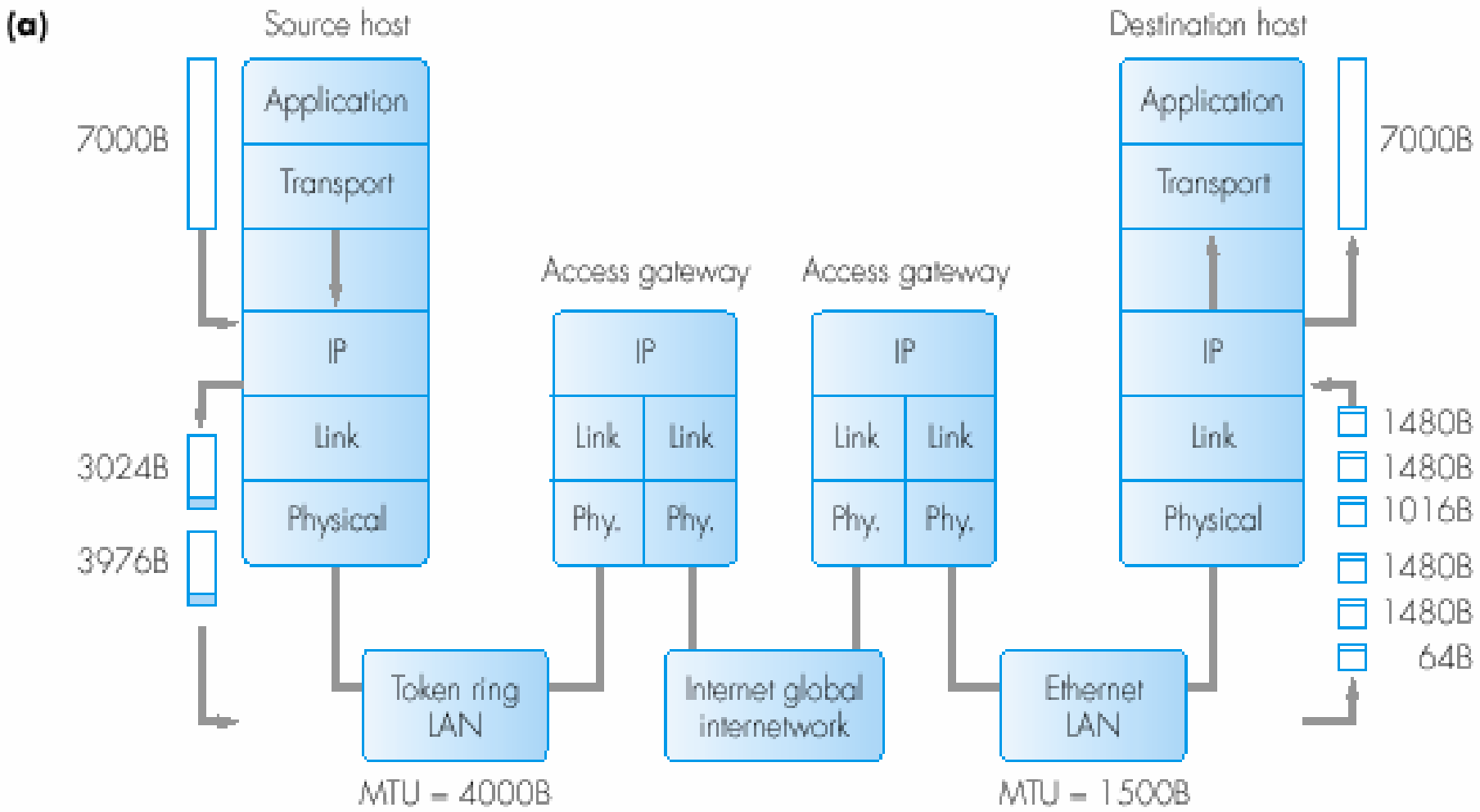
9.2 IP Datagrams

- Basic unit of Internet transfer
- Analogous to physical network packet
- Composed of
  - Header that contains source and destination Internet addresses, datagram type field, etc.
  - Data area that contains data being carried
- Encapsulation
  - IP datagram travels in physical network packet or frame
  - Complete datagram is treated as data by the hardware
  - TCP/IP defines standards for encapsulation on most network hardware

IP datagram Format



9.3 Fragmentation and reassembly



Note: All values shown are the amounts of user data in each packet/frame in bytes

Network MTU

- Each network h/w technology imposes a fixed limit on the maximum size of a packet
- Size limit called Maximum Transmission Unit (MTU)
- Encapsulated datagram must be less than network MTU

Datagram Fragmentation

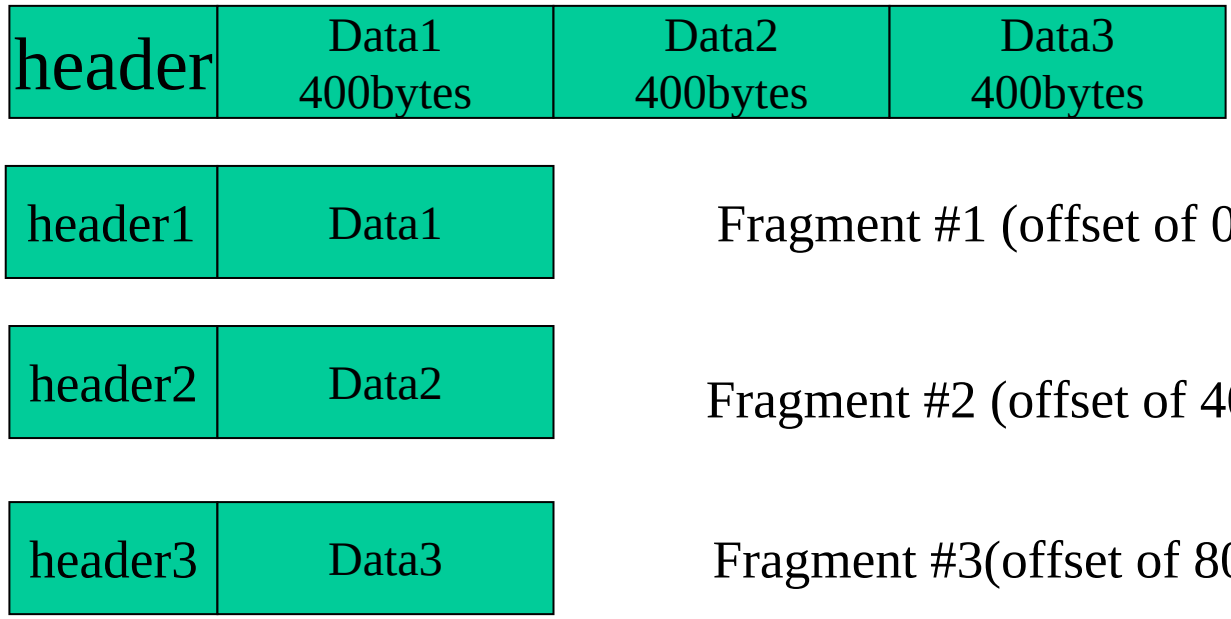
- Needed when datagram larger than network MTU over which it must travel
- Performed by routers
- Divides datagram into several, smaller datagrams called fragments
- Each fragment routed as independent datagram
- Final destination reassembles fragments

Datagram Fragmentation Details

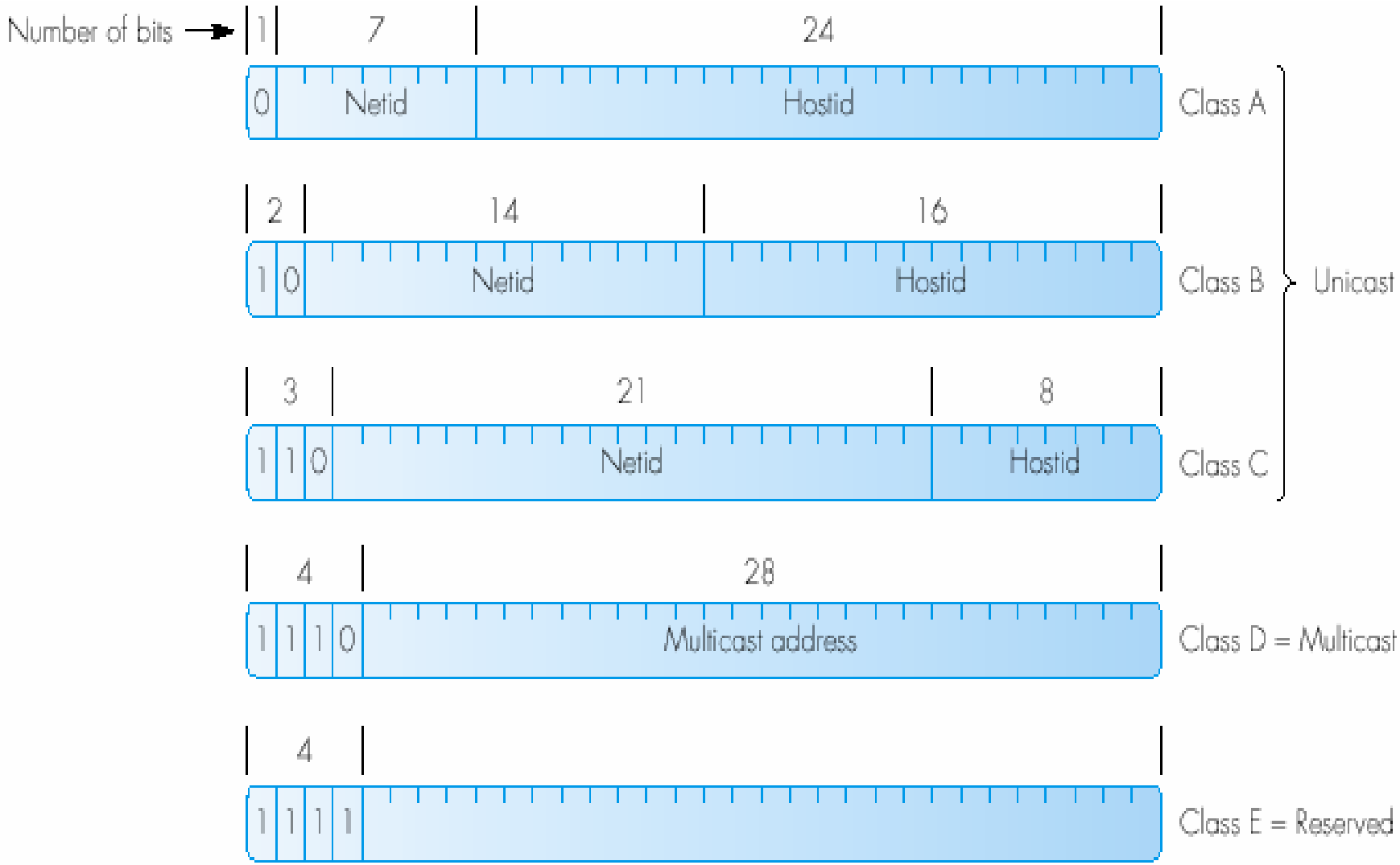
- Each fragment is a datagram
- Router replicates initial datagram header for all fragments
- Offset field in header gives offset in original datagram for data in this fragment
- Fragment bit in header indicates this is a fragment
- Additional bit set in header to indicate last fragment

Example of Fragmentation

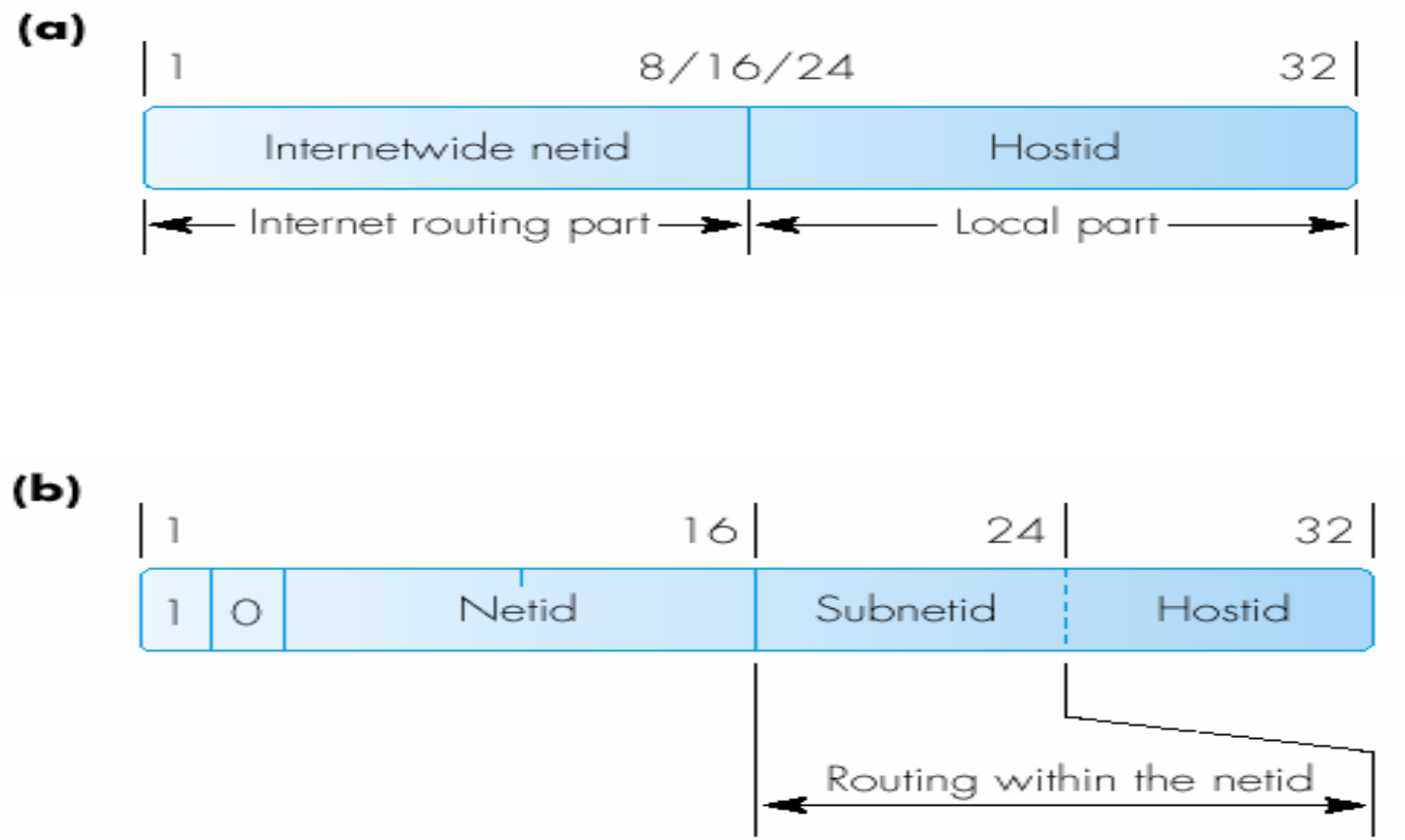
- Original datagram



9.4 IP address

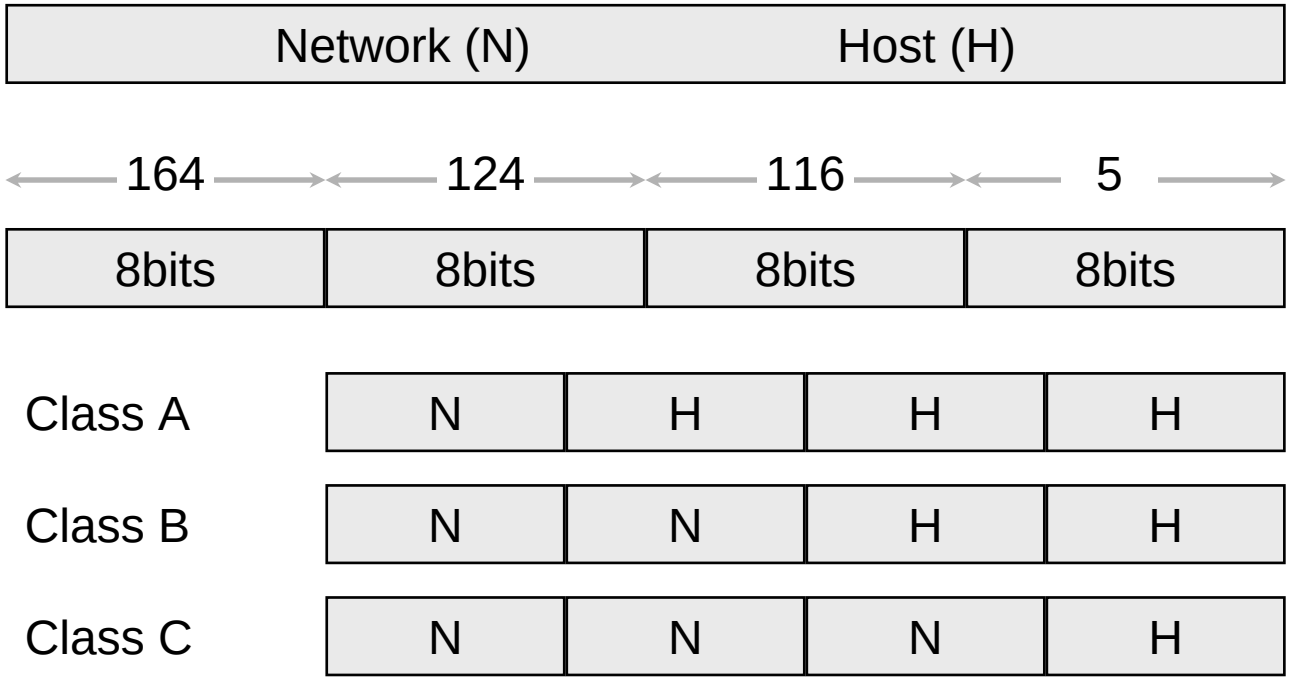


Subnet addressing

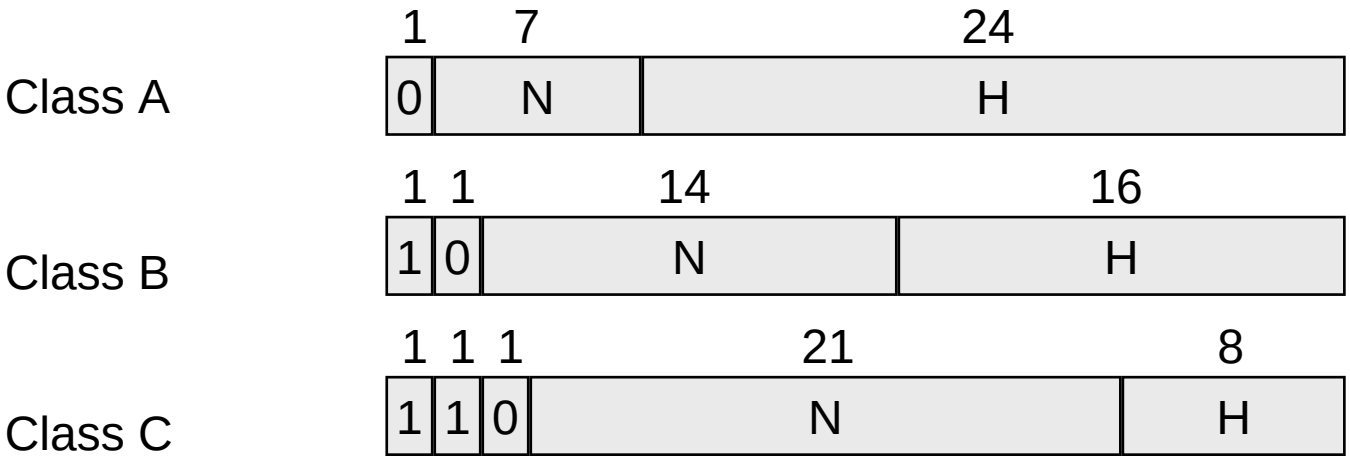


IP Address(1)

- 32bits 구성됨. Class A, Class B, Class C가 있음
- 인터넷을 위한 IP Address는 공인기관으로부터 할당 받아야 하며, Network Number만을 할당 받음
- Host Number는 네트웍관리자가 원하는 대로 활용 가능



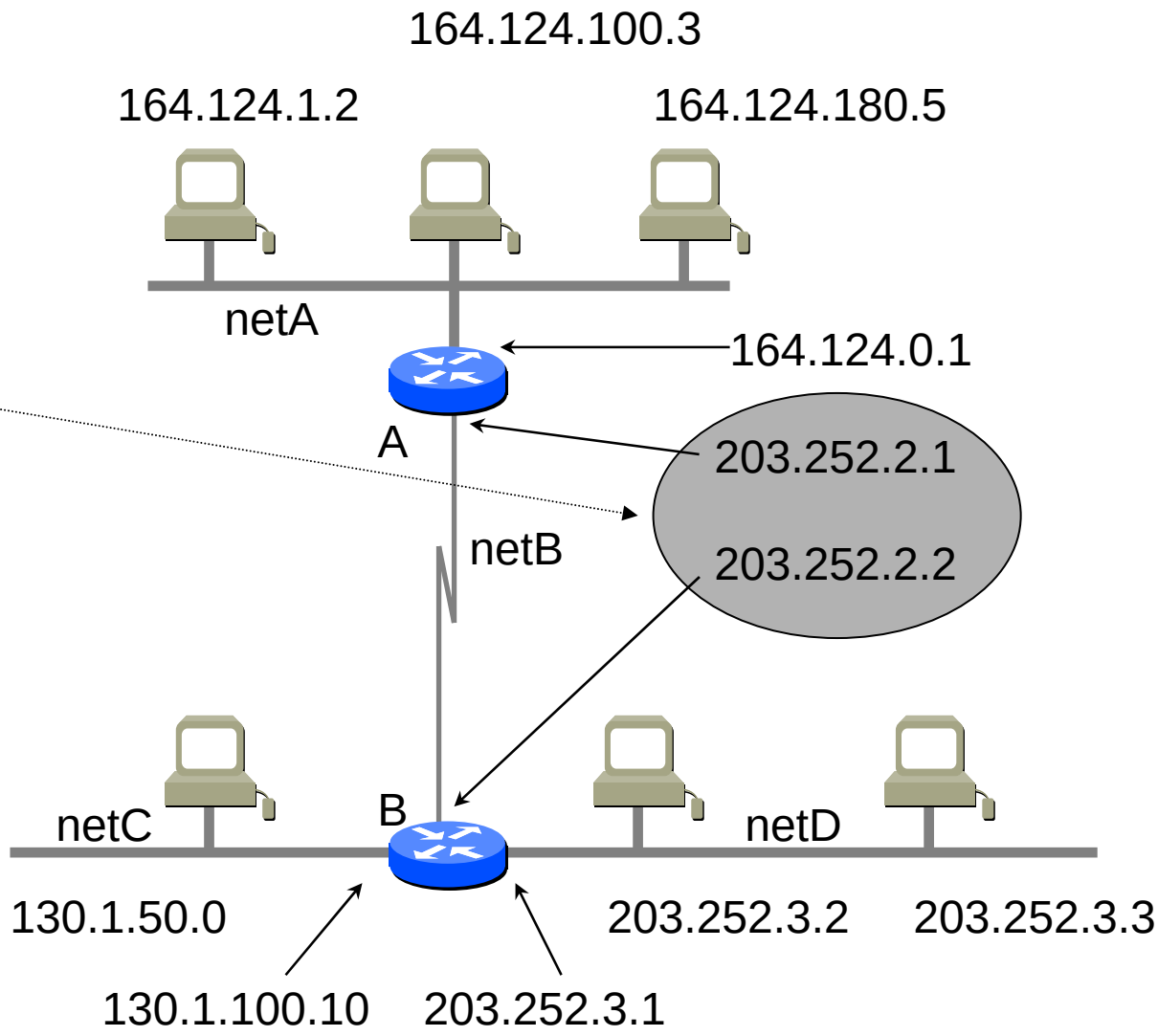
IP Address(2)



	Network # 갯수	1개의 Network #내의 이용가능한 Host Number 수	첫 1Byte의 십진수 범위
Class A	1 ~ 126 (126개)	16777214개 (256^3-2)	1 ~ 126
Class B	128.1 ~ 191.254 (32766개)	65534개 (256^2-2)	128 ~ 191
Class C	192.0.1 ~ 223.255.254.0 (2097150개)	254개 (256^1-2)	192 ~ 223

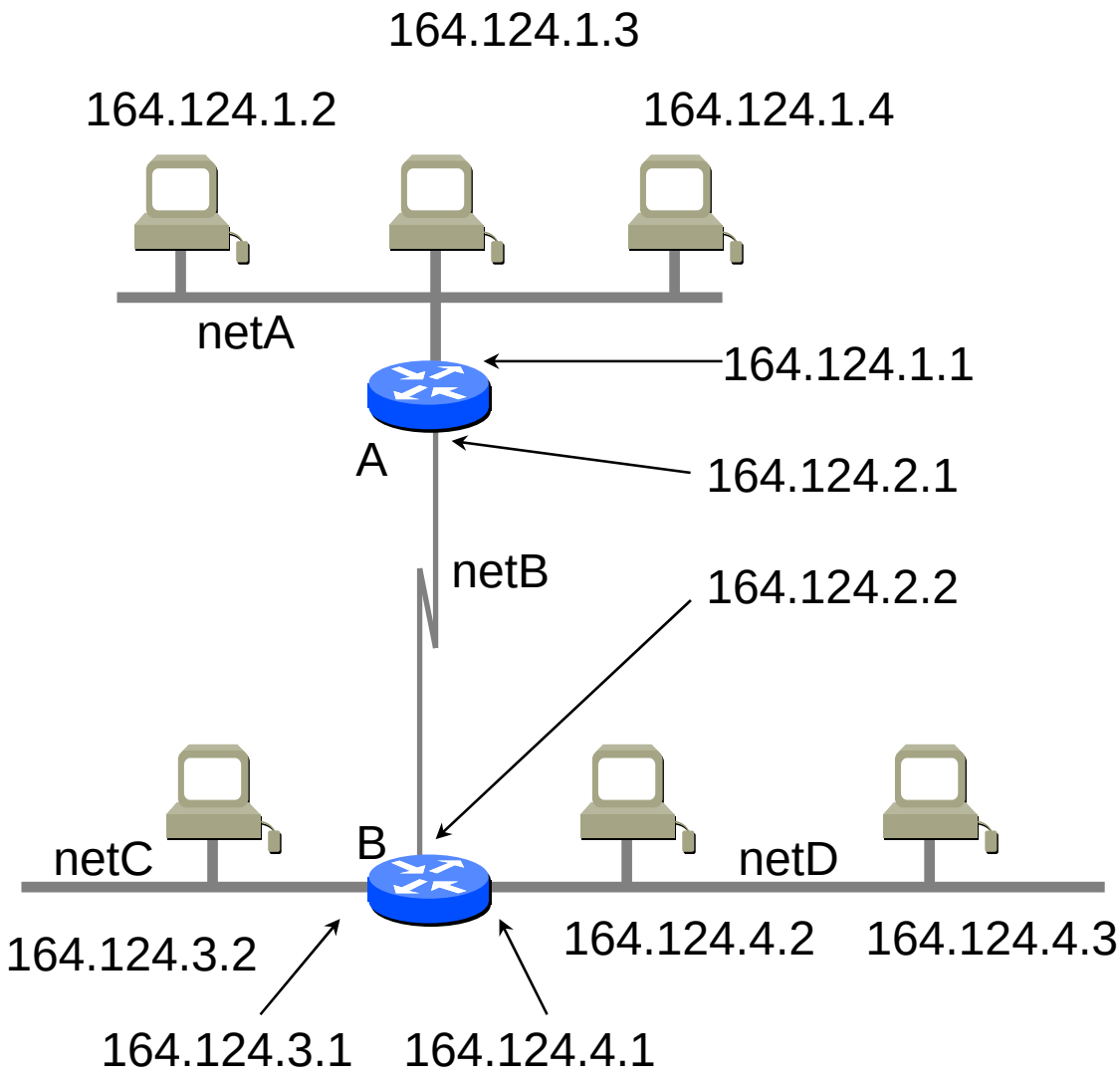
Network별 Network Number 할당

- LAN, WAN별로 동일한 Network Number를 이용함
- WAN (serial link)에서는 2개의 Host Number만 이용하며 나머지는 모두 사용하지 못함
- 시스템의 Interface별로 Host Number를 이용함



Sub Network Number 할당

- 4개의 네트웍을 위해 1개의 Class B Network Number 164.124 만을 이용함
- 네트웍별로 다른 Network Number를 가져야 된다는 것과 상충함
- Subnetmask로 해결
- 시스템수가 적을 경우는 Class C의 Sub Network Number 를 할당하는 것이 바람직



Subnetmask

Class A IP Addr	N	H	H	H
	60	1	2	3
본래 netmask	255	0	0	0
masking	60	0	0	0

Class A IP Addr	N	H	H	H
	60	1	2	3
new netmask	255	255	0	0
masking	60	1	0	0

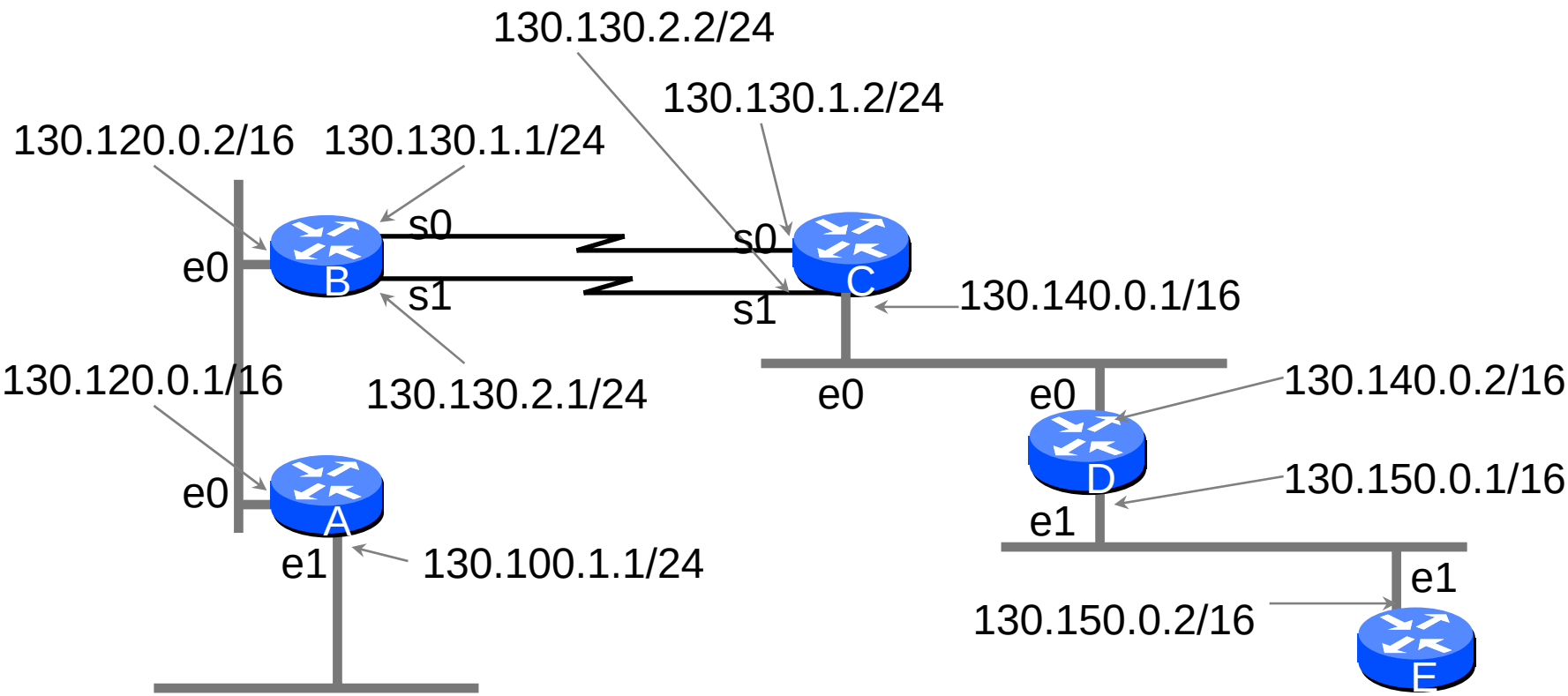
Class B IP Addr	N	N	H	H
	164	124	116	5
본래 netmask	255	255	0	0
masking	164	124	0	0

Class B IP Addr	N	N	H	H
	164	124	116	5
new netmask	255	255	255	0
masking	164	124	116	0

Class C IP Addr	N	N	N	H
	203	252	3	1
본래 netmask	255	255	255	0
masking	203	252	3	0

Class C IP Addr	N	N	N	H
	203	252	3	66
new netmask	255	255	255	192
masking	203	252	3	64

Basic Network Configuration



/16은 subnetmask가 1bit~16bit까지 1임을 의미하므로 255.255.0.0을 의미
/24은 subnetmask가 1bit~24bit까지 1임을 의미하므로 255.255.255.0을 의미

e0는 interface ethernet 0를 의미, s0는 interface serial 0를 의미

IP Address 설정 (in Router)

- global config mode에서 특정 interface를 지정한 후 IP Address 및 netmask 입력
- description은 생략되어도 되지만 ip-address는 꼭 지정되어야 함
- shutdown이 선언되어 있는 경우 no shutdown을 입력해야 함

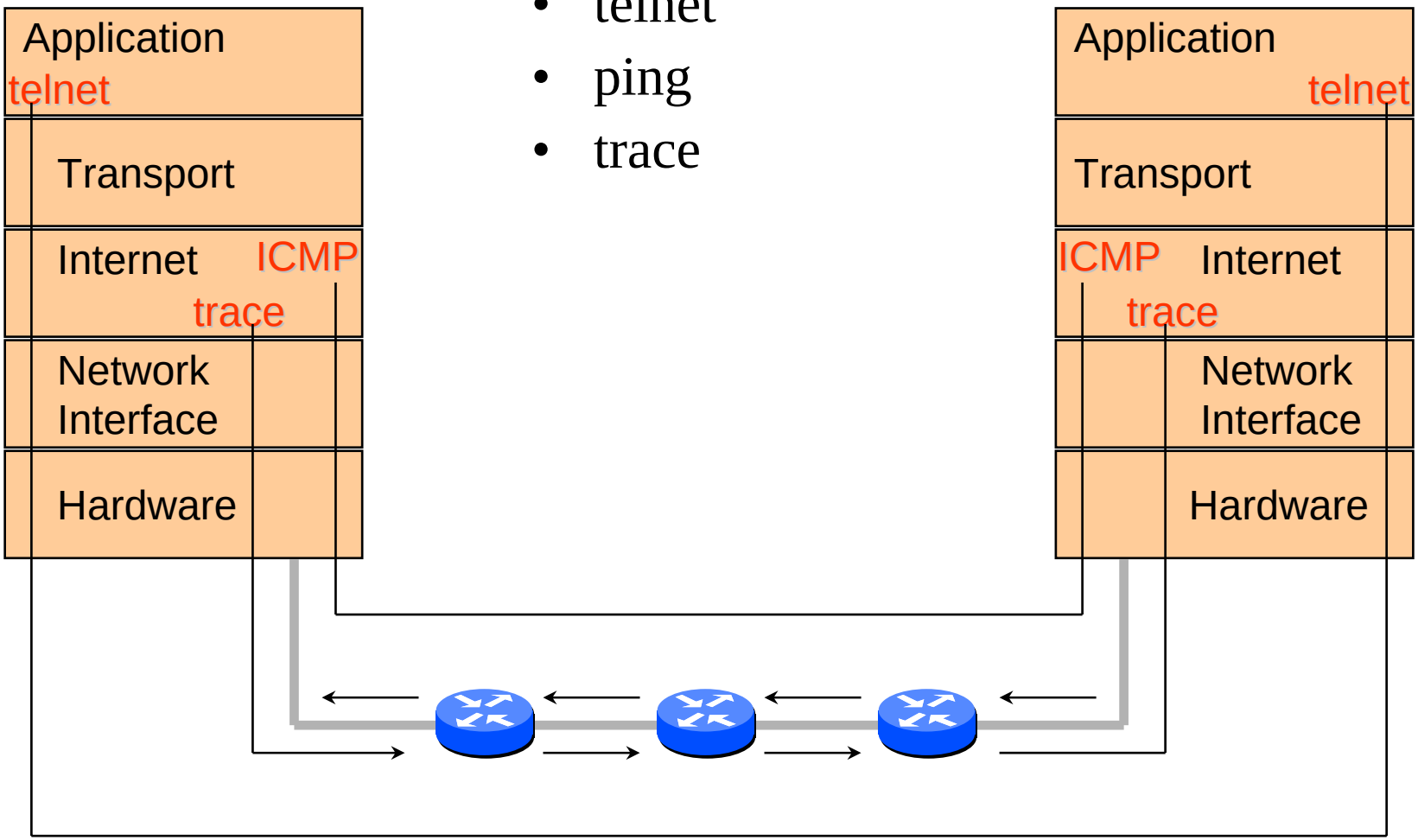
```
Router(config)# interface interface-type [slot/]port
Router(config-if)# description description-for-this-interface
Router(config-if)# ip address ip-address netmask
Router(config-if)# no shutdown
Router(config-if)# Ctrl-Z
Router#
```

Data Link Protocol 설정

- LAN용 Interface에는 별도로 data link protocol을 설정하지 않아도 되지만 WAN용 Interface에는 IP Address와 함께 data link protocol을 설정해야 함
- 대응하는 라우터의 Interface에서도 동일한 datalink protocol을 지정해야 함
- HDLC, PPP, X25, Frame-Relay등을 지정할 수 있음
- CISCO 라우터에서는 default로 HDLC를 이용함
- PPP는 표준이므로 CISCO 제품이 아닌 라우터와 연결할때에는 PPP를 이용할 것을 권장

Address 설정 확인

- telnet
- ping
- trace



Internet Address Resolution Protocol (ARP)

- Internet standard for dynamic address binding
- Allows machine A to find machine B's physical address knowing only B's Internet address
- Uses hardware broadcast
- ARP only used to map addresses within a single physical network, never across multiple networks

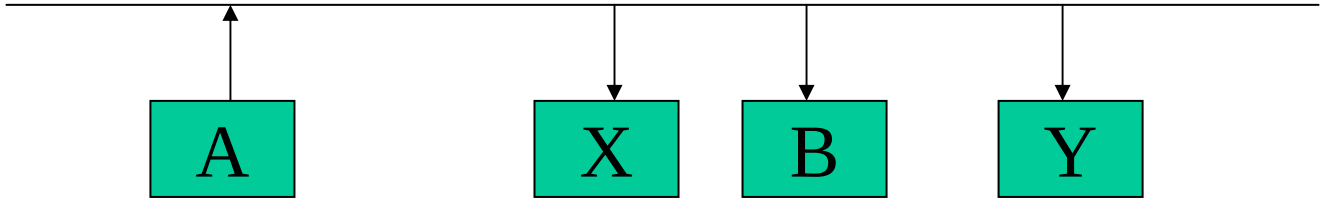
- ARP details
  - ARP table is merely a cache
  - Entries should time out and be invalidated
  - Machine can broadcast new binding when it boots

ARP request and reply messages (2)

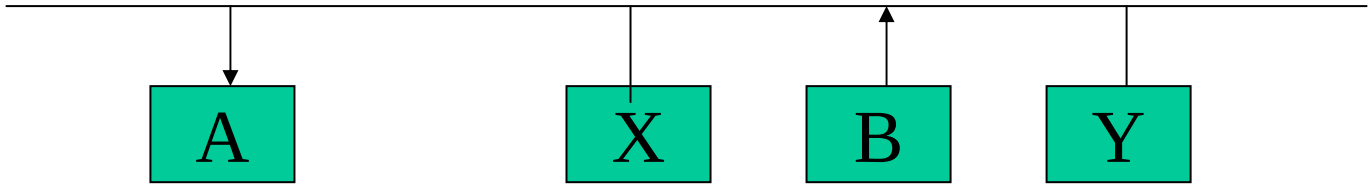
- Machine A broadcasts ARP request with B's IP address
- All machines on local net receive broadcast
- Machine B replies with its physical address
- Machine A adds B's address information to its table
- Machine A delivers packet directly to B

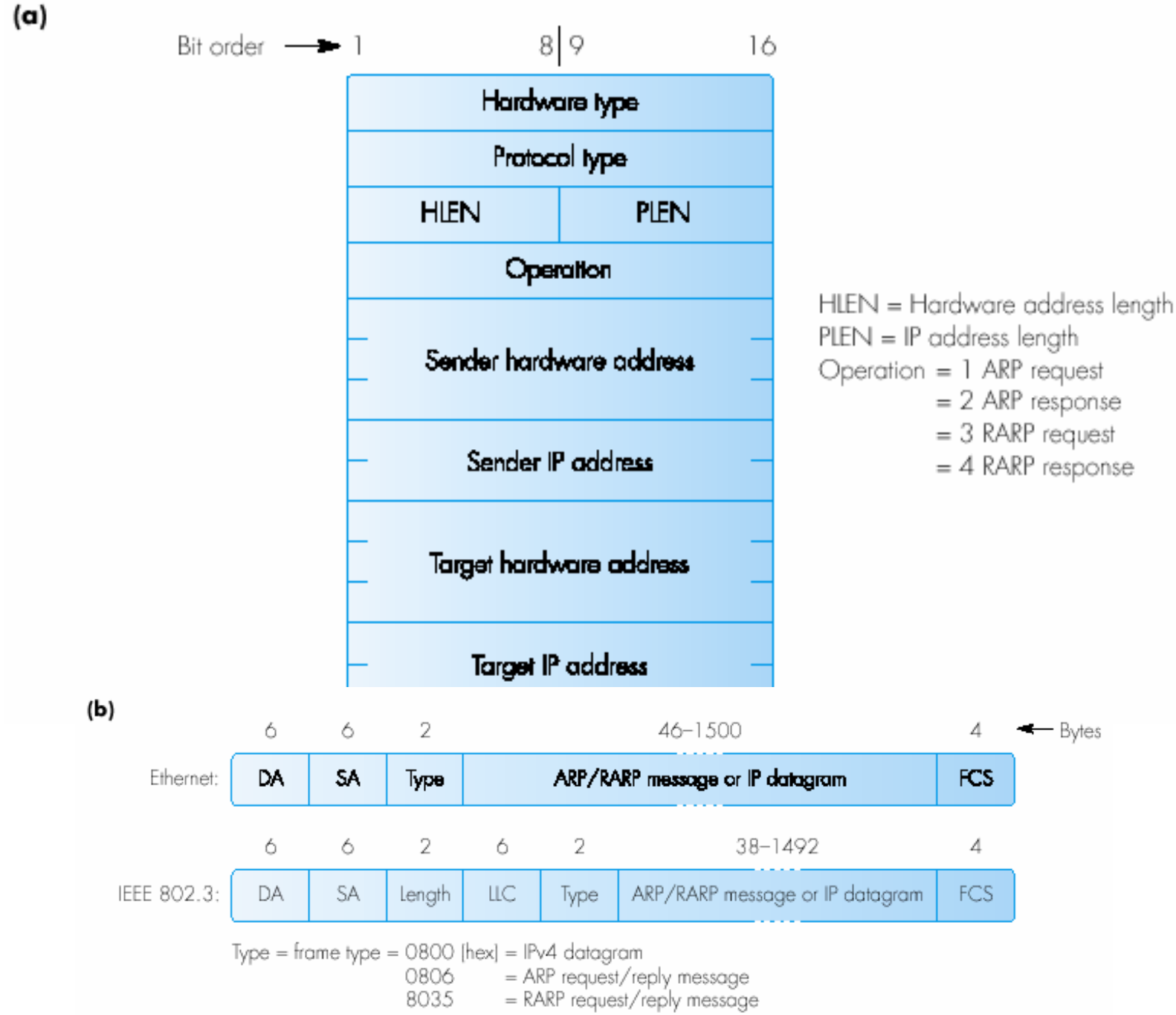
ARP request and reply messages (2)

A broadcasts request for B (across local net only)



B replies to request



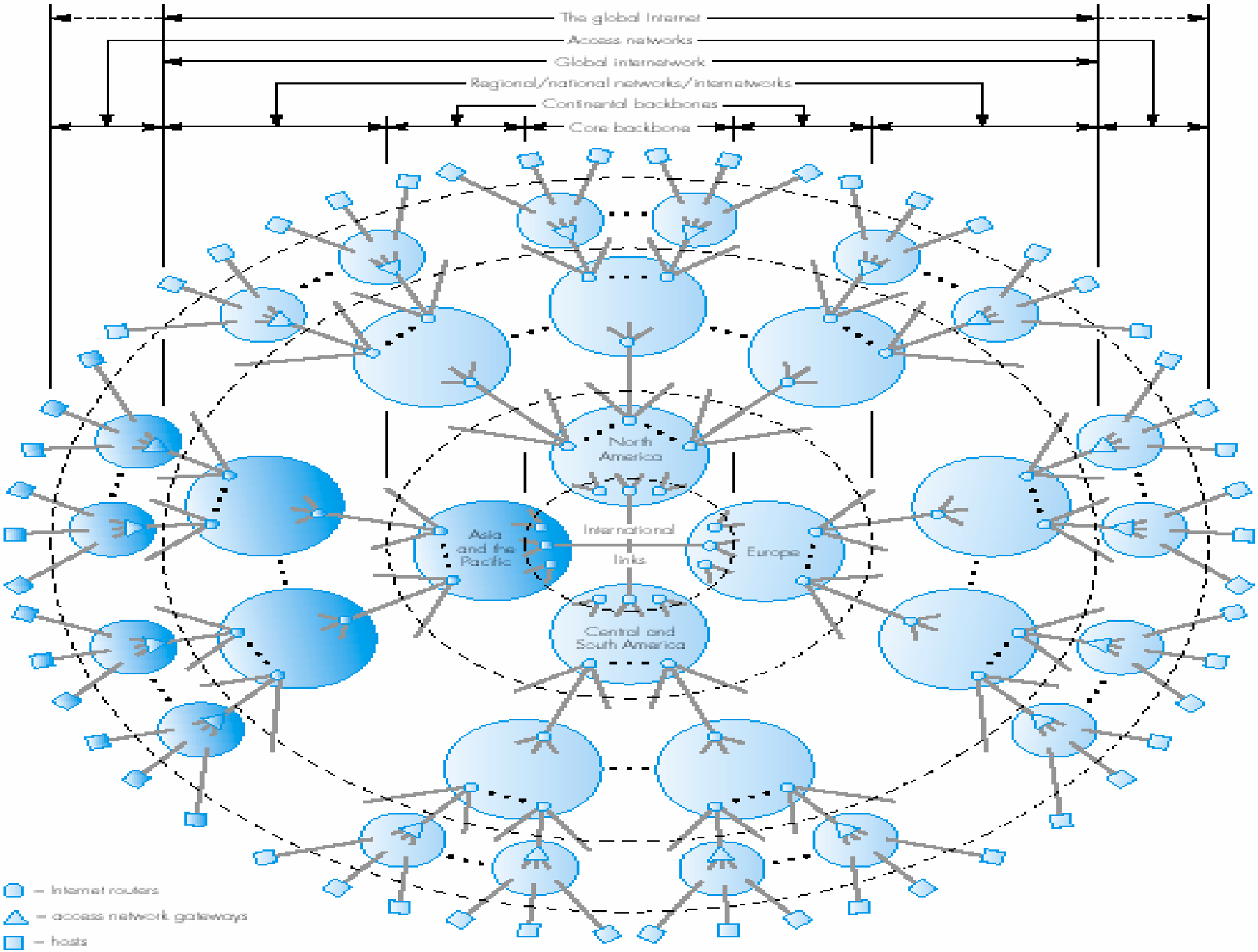

(a)
Bit order → 1
8 | 9
16
Hardware type
Protocol type
HLEN
PLEN
Operation
Sender hardware address
Sender IP address
Target hardware address
Target IP address
HLEN = Hardware address length
PLEN = IP address length
Operation = 1 ARP request
= 2 ARP response
= 3 RARP request
= 4 RARP response
(b)
6
6
2
46–1500
4
Bytes
Ethernet:
DA
SA
Type
ARP/RARP message or IP datagram
FCS
6
6
2
6
2
38–1492
4
IEEE 802.3:
DA
SA
Length
LLC
Type
ARP/RARP message or IP datagram
FCS
Type = frame type = 0800 (hex) = IPv4 datagram
0806 = ARP request/reply message
8035 = RARP request/reply message

Algorithm for Processing ARP Requests

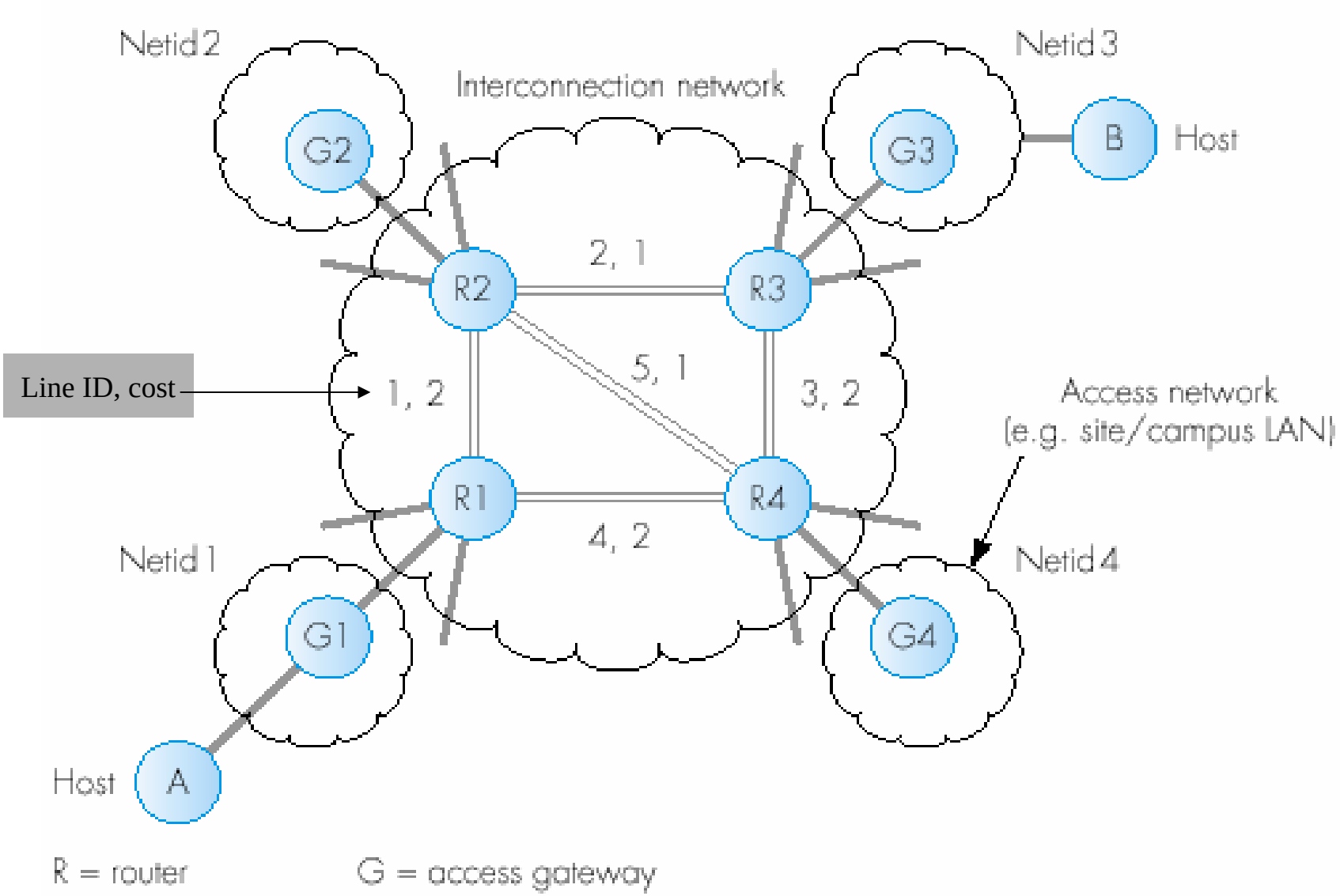
- Extract sender's pair, (Ia, Ha) and update local ARP table
- If this is a request and the target is "me"
  - Fill in target h/w address
  - Exchange sender and target entries
  - Set operation to reply
  - Send reply back to requester

9.6 Routing algorithm

- Routing in an Internet
  - Host delivers datagrams to directly connected machines
  - Host sends datagrams that can not be delivered directly to router
  - Routers forward datagrams to other routers
  - Final router delivers datagram directly
- Routing protocol
  - 데이타를 encapsulation해서 전달하기 위한 protocol로 IP, IPX, Appletalk등이 이에 해당된다. routing protocol이라는 것은 IP packet, IPX packet, Appletalk packet등을 전달할때 경로정보를 교환, 관리하기 위한 protocol이다. IP는 routing protocol로 RIP, IGRP, OSPF, BGP등을, IPX는 Novell RIP, NLSP등을, Appletalk은 RTMP를 이용한다.

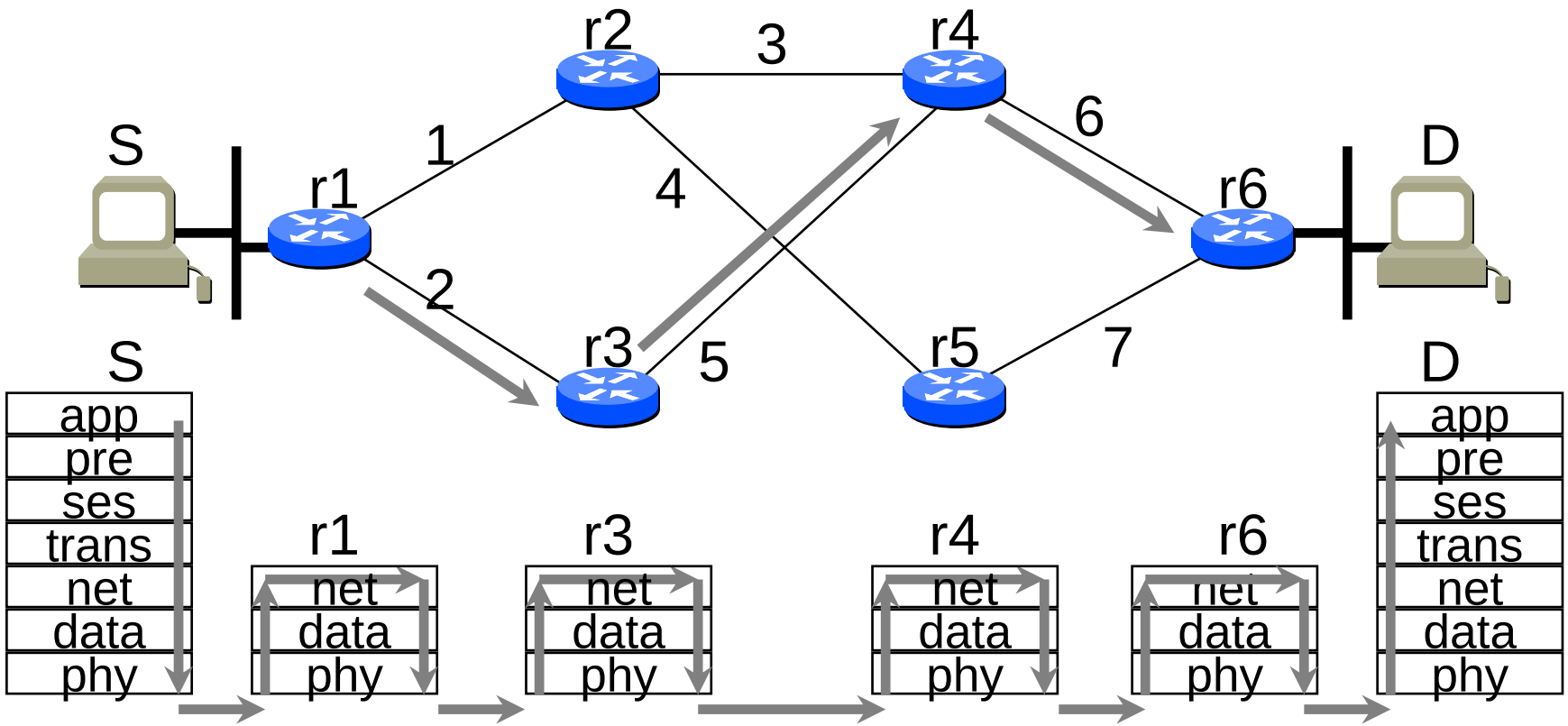

The global Internet
Access networks
Global internetwork
Regional/national networks/internetworks
Continental backbones
Core backbone
North America
Asia and the Pacific
International links
Europe
Central and South America
= Internet routers
= access network gateways
= hosts

Example internetwork topology



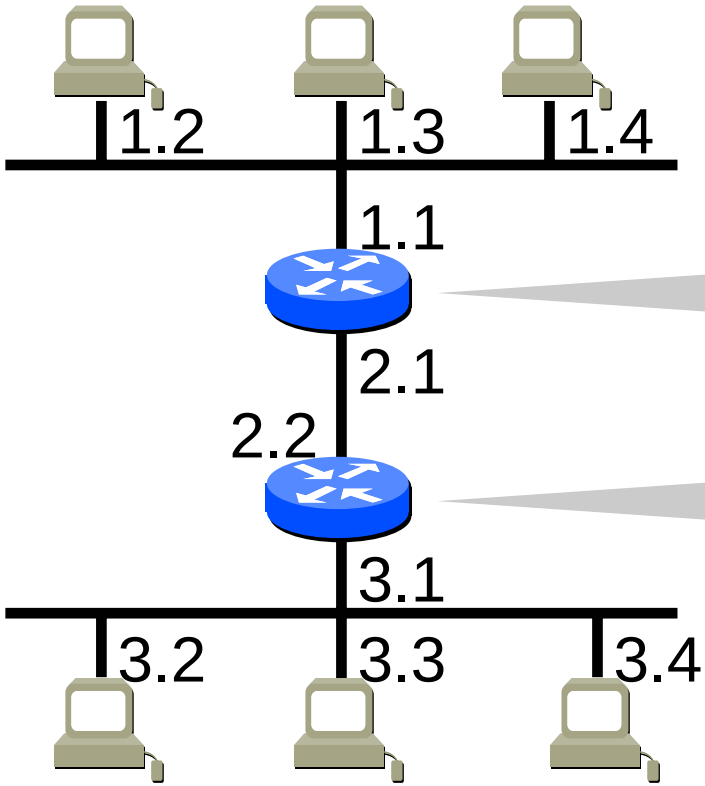
Network Layer & Routing Protocol

- Network Layer는 시작(source)에서부터 목적지(destination)까지 Packet을 전달
- Routing Protocol은 라우터간에 경로정보를 주고 받는 Protocol



Addressing & Network-level Routing

Network	Node
1	1,2,3,4
2	1,2
3	1,2,3,4



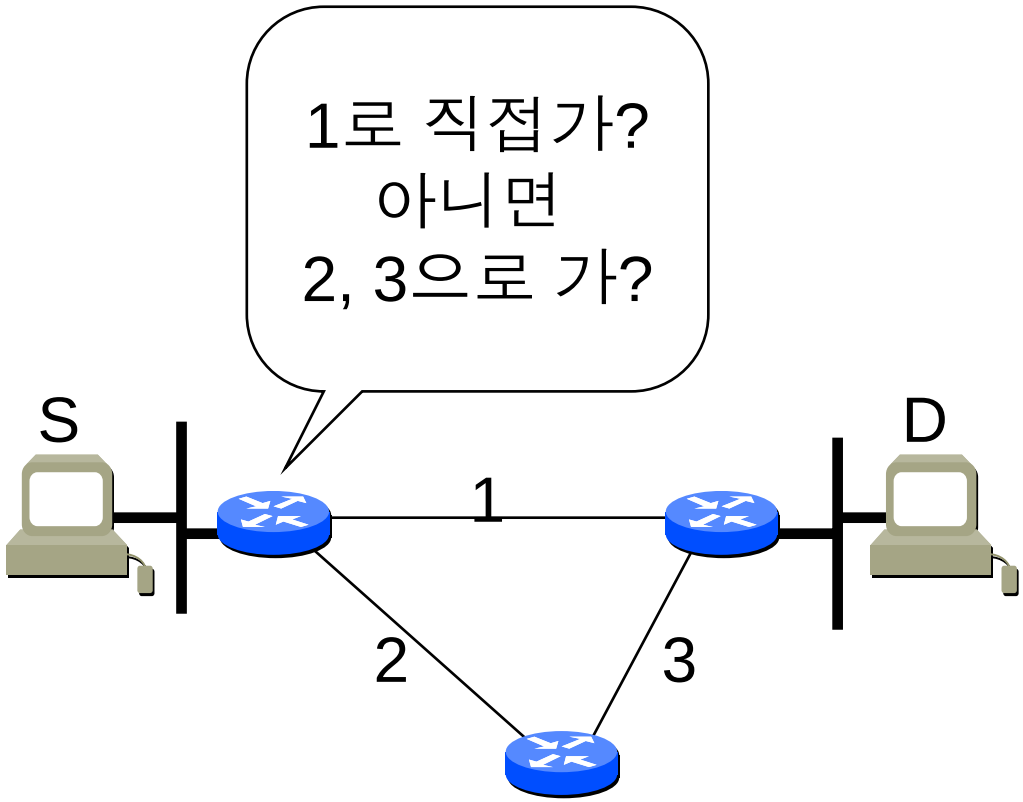
Detination Network	Router Port
1.0	1.1
2.0	2.1
3.0	2.1
1.0	2.2
2.0	2.2
3.0	3.1

Efficient Routing

- Routing decisions based on table lookup
- Routing tables keep only network portion of addresses
  - size proportional to number of networks
  - not number of hosts
- Algorithm is efficient and “easy” to understand
- Easy to automate routing table update

경로결정 영향요소

- Bandwidth
- Delay
- Reliability
- Load
- MTU
- Hop Count
- money



- OSPF : Bandwidth
- RIP : hop count
- IGRP : Bandwidth, Delay, Reliability, Load, MTU

Routing관련 Keyword

- advertising 혹은 announcement
- neighbor
- next hop
- 주기적 update
- partial update 및 full update
- metric factor 및 metric | cost
- Autonomous System Number (AS Number, ASN)

cost = function (metric factors)

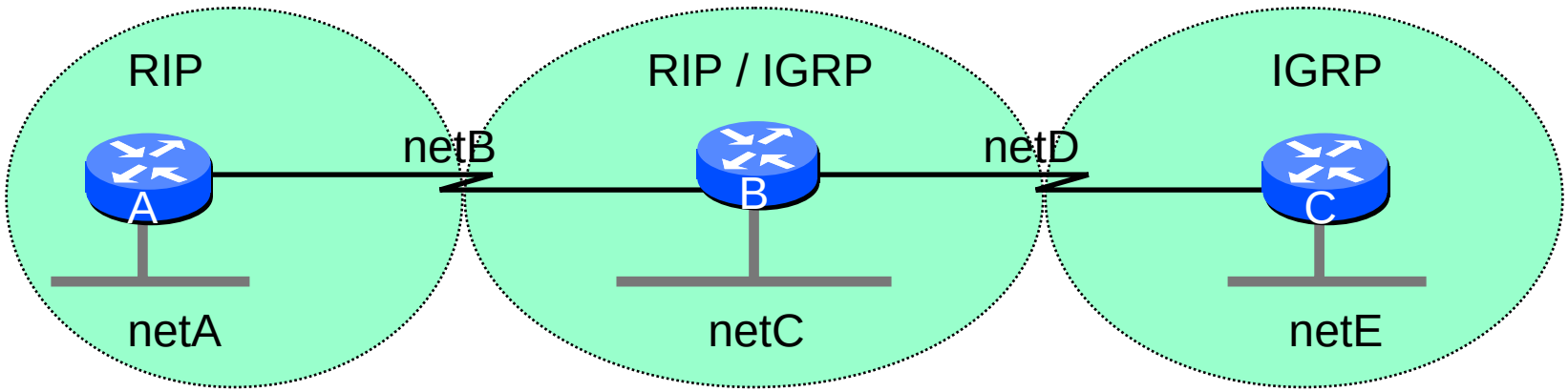
•RIP의 metric factor는 hop count

•IGRP의 metric factor는 bandwidth, delay, reliability, load, MTU

•OSPF의 metric factor는 bandwidth

IP Routing 설정 절차

- Global Configuration
  - IP routing protocol중에 하나를 선택
  - Routing Update에 참여할 자신의 Interface에 할당된 IP Network Address 선언
- Interface Configuration
  - IP Address 및 netmask 지정



IP Routing

- Static Route vs. Dynamic Route

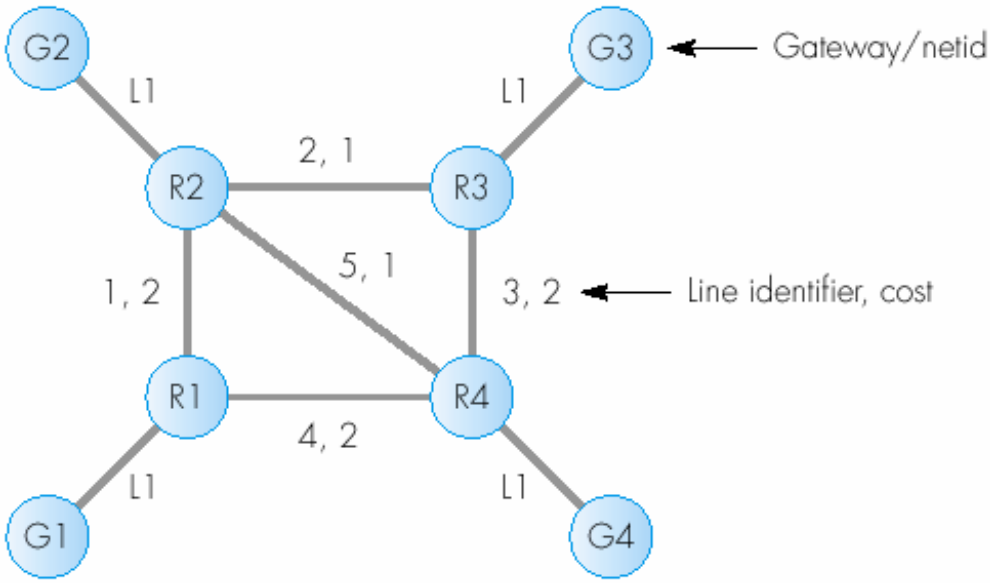
- Static Routing
  - Static Route
  - Default Route

- Dymanic Routing
  - Interior Gateway Protocll
    - RIP, IGRP(cisco), OSPF, EIGRP(cisco)
  - Exterior Gateway Protocol
    - BGP

- 라우터는 Static Route 및 Dynamic Route를 Routing Table에 관리
- 라우터는 동시에 여러개의 Routing Protocol을 운영할 수 있음

Static routing

(a)



(b)

R1:

Netid	Line
1	L1
2	1
3	1
4	4

R2:

Netid	Line
1	1
2	L1
3	2
4	5

R3:

Netid	Line
1	2
2	2
3	L1
4	3, 2

R4:

Netid	Line
1	4
2	5
3	3, 5
4	L1

Dynamic routing

- Distance vector routing
- Link-state shortest-path-first routing
  - link-state algorithm
  - Dijkstra shortest-path-first algorithm
- Hierarchical routing
- Classless inter-domain routing
- Tunneling
- broadcasting routing
  - reverse path forwarding
  - spanning tree broadcast
- Multicast routing

Route & Routing Protocol

- Dynamic Route vs Static Route

- Dynamic Routing Protocol
  - Distance Vector <-> Link State
    - 주기적 update <-> 변화시 즉시 update
  - Singleprotocol <-> Multiprotocol
    - IP, IPX를 동시에 처리 불능 <-> 동시 처리 가능
  - Interior <-> Exterior
    - 네트웍그룹내 <-> 외부네트웍그룹간
  - Singlepath <-> Multipath
    - Cost가 다른 link를 동시에 이용하지 않음 <-> 동시에 이용함
  - Hierarachical <-> Flat
    - 계층적인 정보교환 <-> 계층적이지 않음

Distance Vector Routing Protocol vs. Link State Routing Protocol

Distance Vector	Link State
인접한 라우터의 관점으로 전체 네트웍정보를 얻음	각 라우터가 전체 네트웍 상태 판단
인접한 라우터가 갖고 있는 cost와 인접한 라우터까지의 cost를 더함	자신이 직접 목적지까지의 cost를 계산함
주기적으로 정보를 update convergence time이 길다	변화즉시 정보를 update convergence time이 짧다
Routing Table을 인접한 라우터에게 전달	변화된 정보만을 다른 라우터들에게 전달

RIP (Routing Information Protocol)

- RIP은 RFC1058에 규정되어 있다.
- RIP은 BSD UNIX의 routed로 처음 발표되었었다.
- distance vector routing protocol
- interior gateway protocol
- metric factor로 hop count를 이용하며 가능한 최대값은 15
- . sing path routing protocol이다.

IGRP(Internet Gateway Routing Protocol)

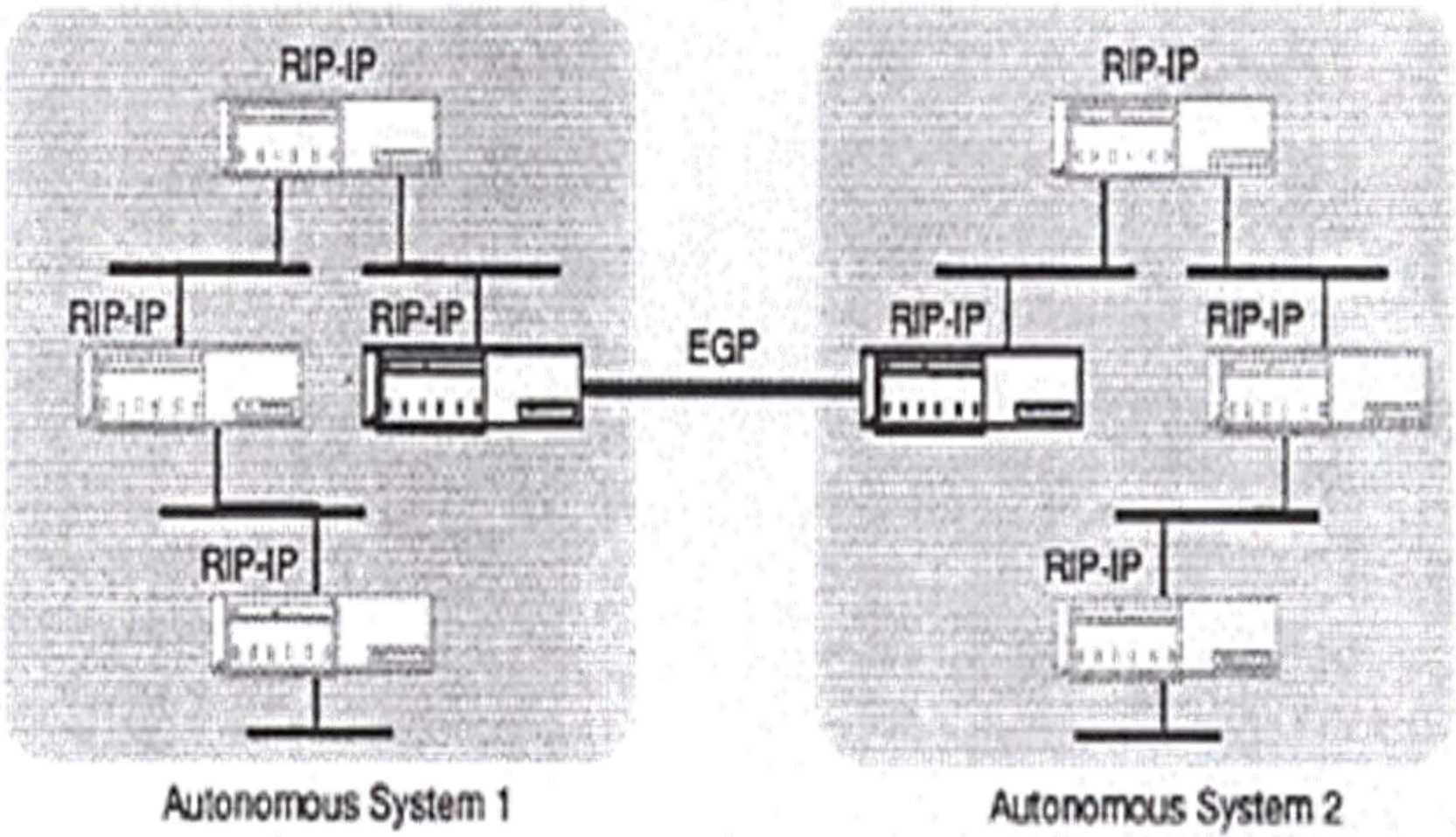
- IGRP는 cisco사에서 개발한 것임.
- distance vector routing protocol
- interior gateway protocol
- metric factor로bandwidth, delay, reliability, load, mtu를 이용한다.
- 90초마다 routing information을 전달한다. 추가적으로 네트웍의 변화를 인지했을 경우 이를 인접한 라우터에게 즉시 전달해 준다. 이런 것을 Flash Update라고 한다. 이러한 특성때문에 convergence time이 rip보다 빠르다
- multi path routing protocol이다. 그렇지만 기본적으로 single path routing으로 설정되어 있으므로 multi path routing을 할 수 있도록 설정해주어야 한다.

OSPF(Open Shortest Path First)

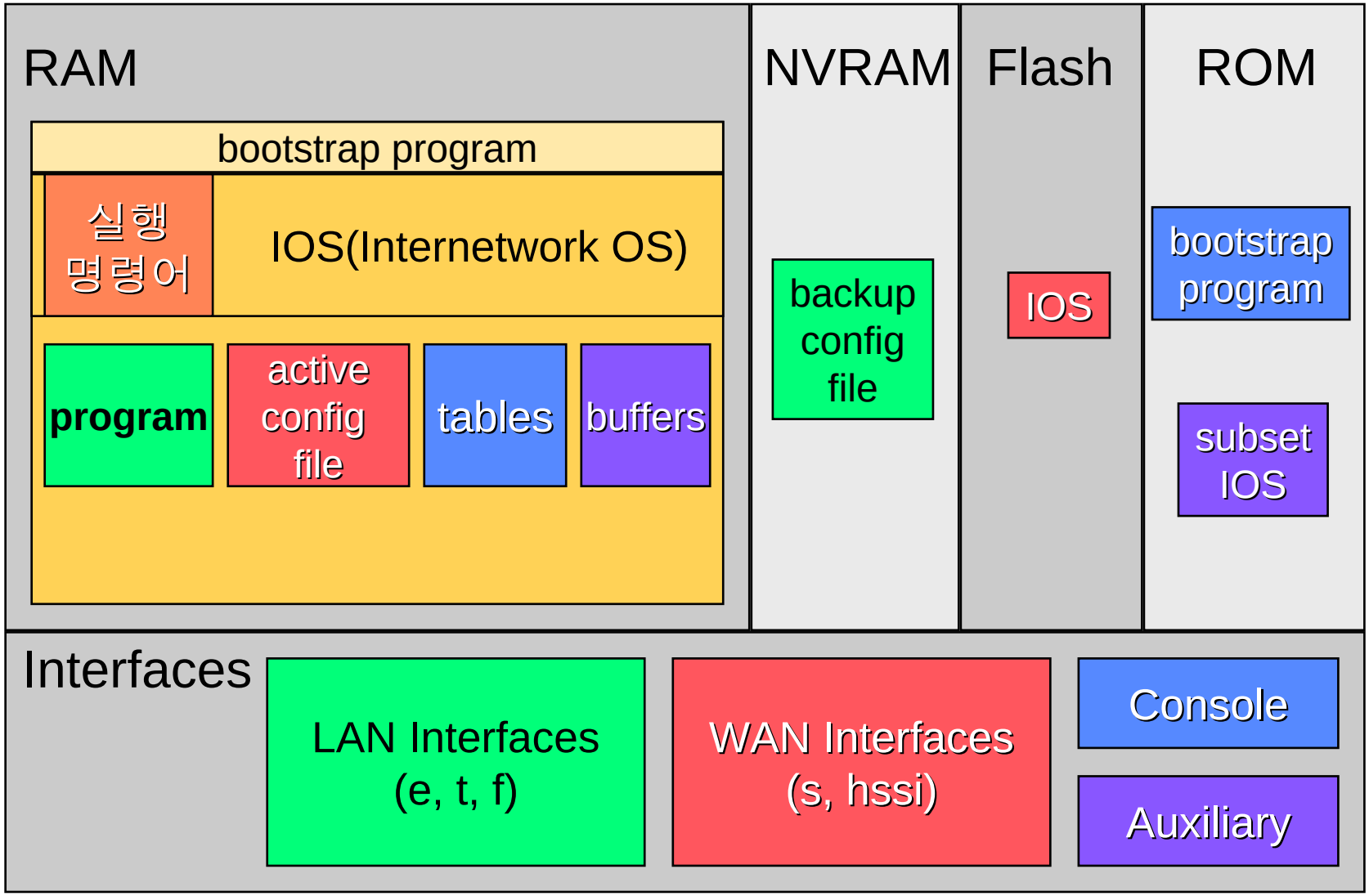
- a routing protocol developed for Internet Protocol (IP) networks by the Interior Gateway Protocol (IGP) working group of the Internet Engineering Task Force (IETF)
  - published as Request For Comments (RFC) 1247
- was formed in 1988 to design an IGP based on the Shortest Path First (SPF) algorithm for use in the Internet
- Similar to the Interior Gateway Routing Protocol (IGRP)
- was created because in the mid-1980s, the Routing Information Protocol (RIP) was increasingly incapable of serving large, heterogeneous internetworks.
- a link-state routing protocol, contrasts with RIP and IGRP

. Exterior Gateway Protocol (EGP)

- 외부 Gateway 프로토콜은 RFC-904에 문서화되어 있고, RFC-827과 RFC-888로 대표되던 초기의 문안을 개정

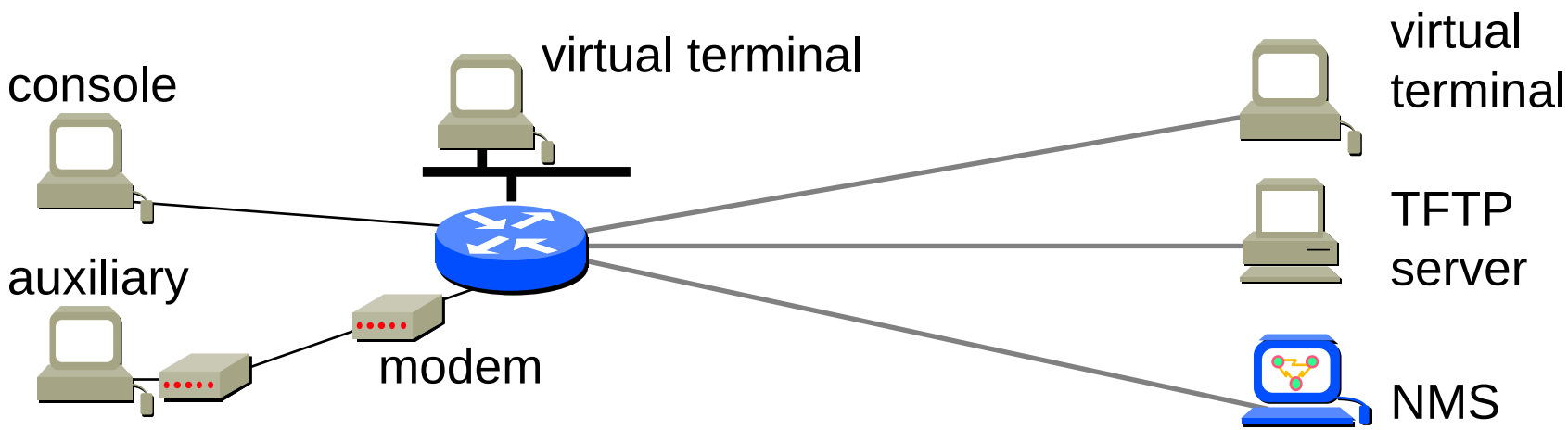


Router 구성

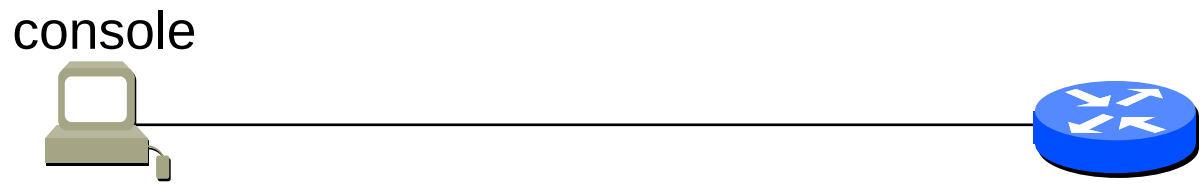

RAM
bootstrap program
실행
명령어
IOS(Internetwork OS)
program
active
config
file
tables
buffers
NVRAM
backup
config
file
Flash
IOS
ROM
bootstrap
program
subset
IOS
Interfaces
LAN Interfaces
(e, t, f)
WAN Interfaces
(s, hssi)
Console
Auxiliary

Router 환경설정 수단

- Console 이용 (async serial port)
- Auxiliary 이용 (auxiliary async serial port)
- LAN, WAN Interface를 통한 virtual terminal 이용(telnet)
- TFTP 서버를 이용
- NMS 를 이용



Console을 이용한 라우터 접근

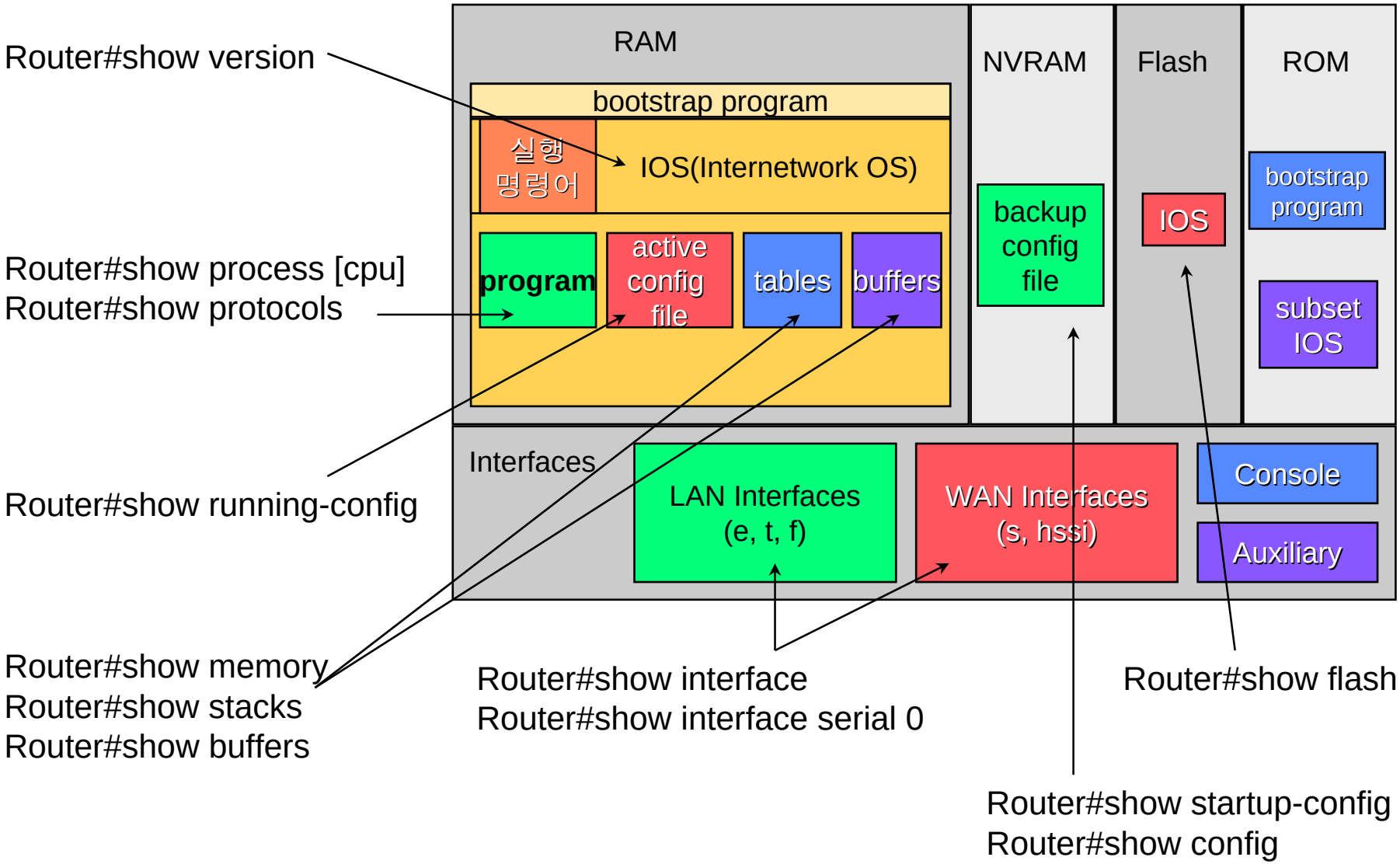



```
Router con0 is now available

Press RETURN to get started

User Access Verification
Password:
Router>
Router>enable
Password:
Router#
Router#disable
Router>
Router>quit
```

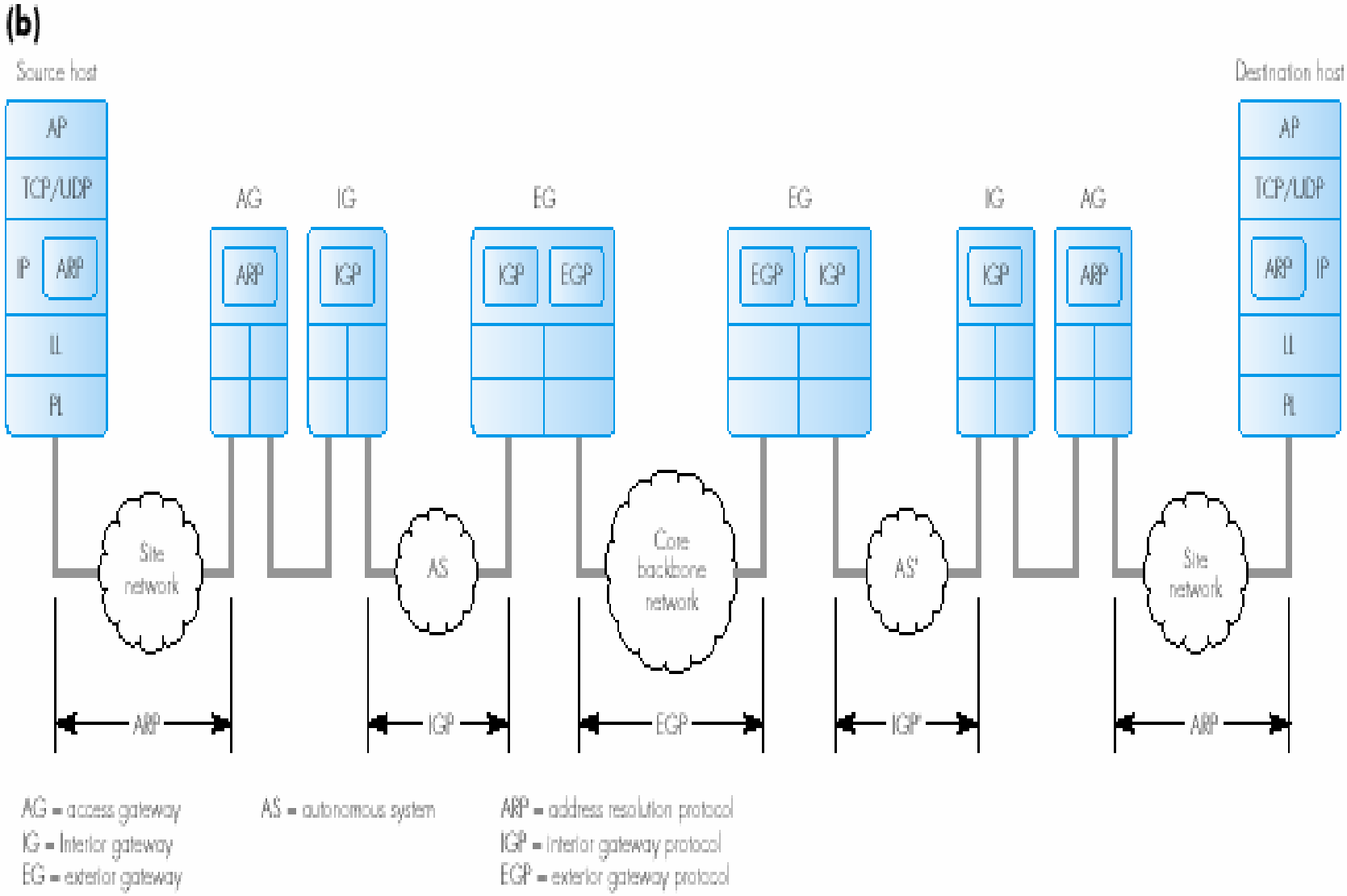
user mode prompt

previledged mode prompt

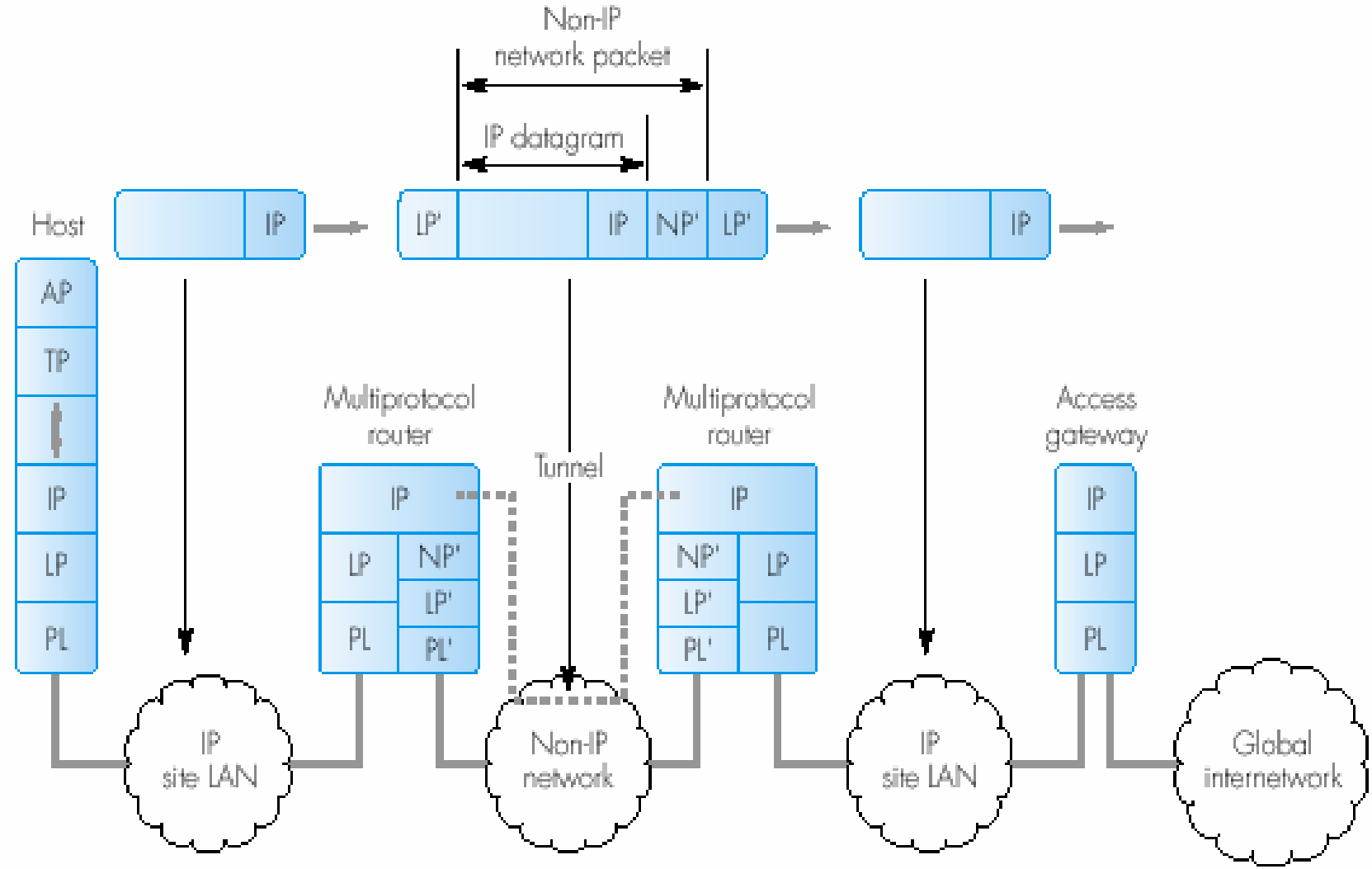
라우터 상태 조회 명령어


Router#show version
Router#show process [cpu]
Router#show protocols
Router#show running-config
Router#show memory
Router#show stacks
Router#show buffers
Router#show interface
Router#show interface serial 0
Router#show flash
Router#show startup-config
Router#show config
RAM
bootstrap program
실행 명령어
IOS(Internetwork OS)
program
active config file
tables
buffers
NVRAM
backup config file
Flash
IOS
ROM
bootstrap program
subset IOS
Interfaces
LAN Interfaces (e, t, f)
WAN Interfaces (s, hssi)
Console
Auxiliary

Hierarchical routing over the Internet



Tunneling Example



9.7 ICMP

- Internet control message protocol
  - an integral part of all IP implementation
  - Used mostly by routers to report delivery or routing problems to original source
  - Uses IP to carry control messages

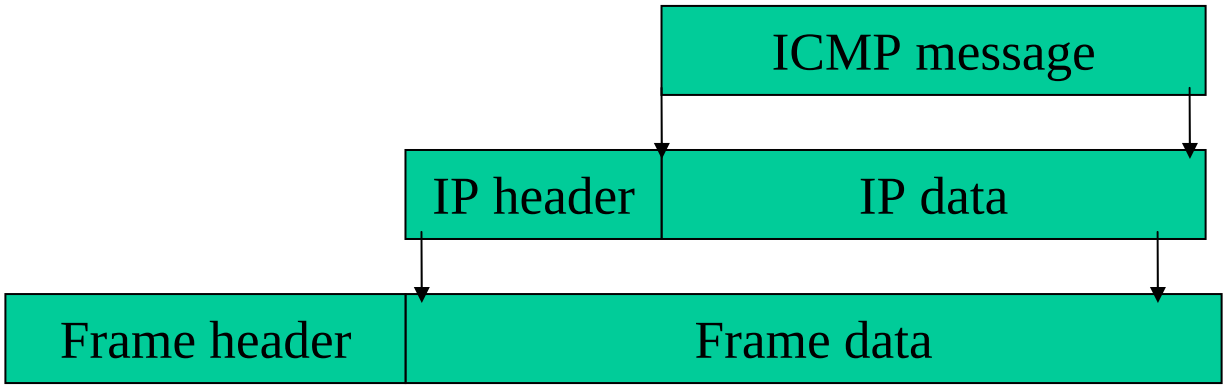
- main functions
  - error reporting
  - reachability testing
  - congestion control
  - route-change notification
  - performance measuring
  - subnet addressing

ICMP messages

- Error reporting
  - Destination Unreachable
  - Time Exceeded
  - Parameter error
- Reachability testing
  - Echo Request/Reply
- Congestion Control
  - Source Quench
- Route exchange
  - Redirect (change route)
- Performance measuring
  - Time-stamp request/reply
- Subnet addressing
  - Address Mast Request/Reply

ICMP Message Encapsulation

Type	Code	Checksum
UNUSED (Must be Zero)		
Internet header + 64 bits of data		



- ICMP message has header and data areas
- Complete ICMP message is treated as data in IP datagram
- Complete IP datagram is treated as data in physical network frame

9.8 QoS support

- To meet more varies set of QoS requirements
  - IntServ : integrated services
  - DiffServ : differentiated services

  - type of service field in IP packer header
    - be used by routers

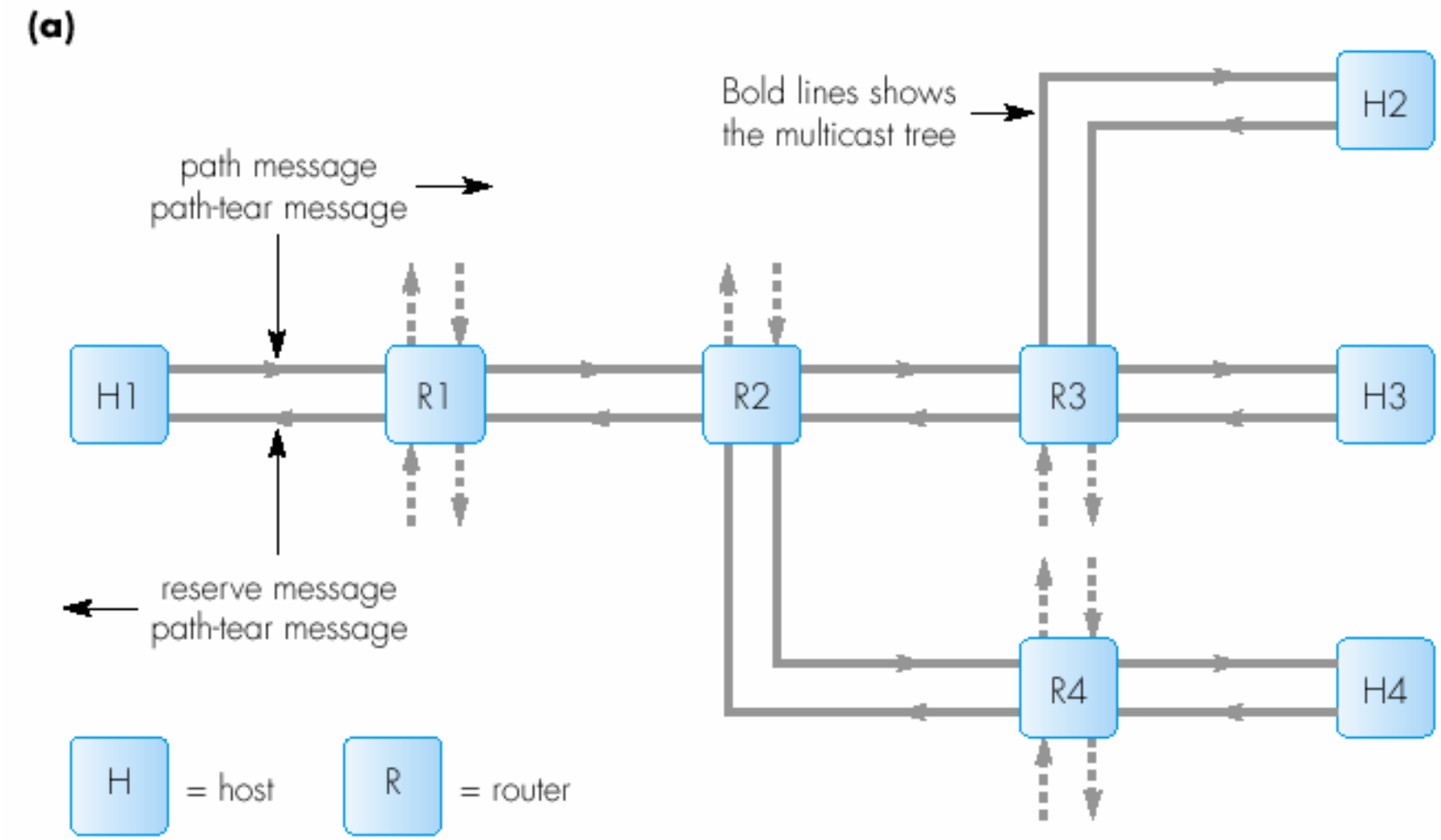
Integrated services

- Three different classes service in IntServ solution
  - guaranteed class
    - a specified Max. delay and jitter
    - an assured level of bandwidth
      - » are guaranteed
    - for application involving the playout of real-time streams
  - controlled load (as predictive) class
    - no firm guarantees are provided
    - a constant level of service equivalent to that obtained with the best-effort service at light loads
    - for application involving real-time streams that have the capability of adjusting the amount of real-time data
  - best-effort
    - for text-based applications

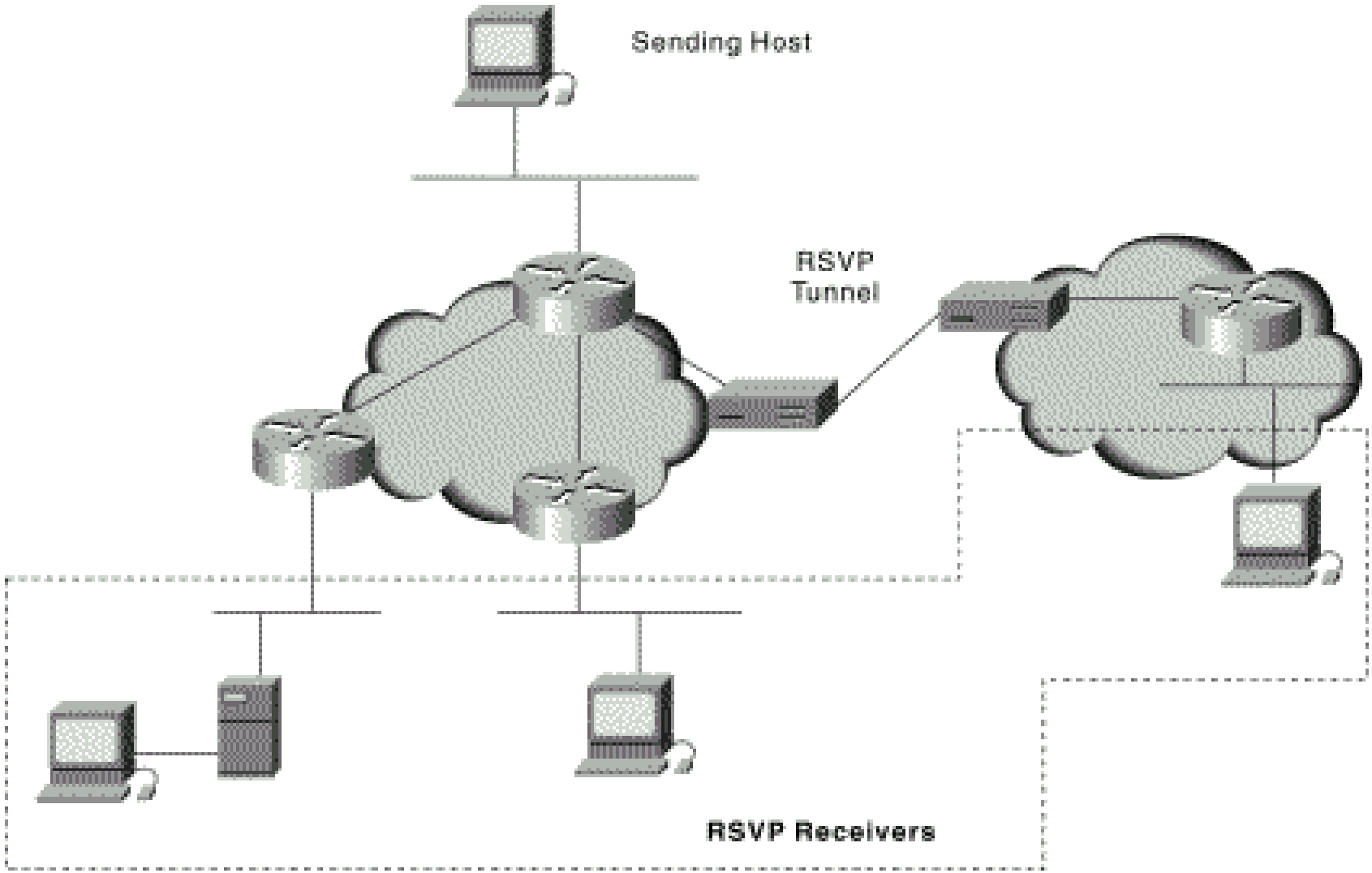
Control mechanisms for QoS

- Token bucket filter
  - an amount of buffer/queue space is reserved for each flow
    - in a container called a bucket
    - token: the quaranteed QoS requirements
- Weighted fair queuing
  - a queue management to ensure the quaranteed QoS requirements
    - compares the time-stamp of the packet
- Random early detection
  - a queue management to ensure the quaranteed QoS requirements
    - compare the queue length
- Resource reservation protocol (RSVP)

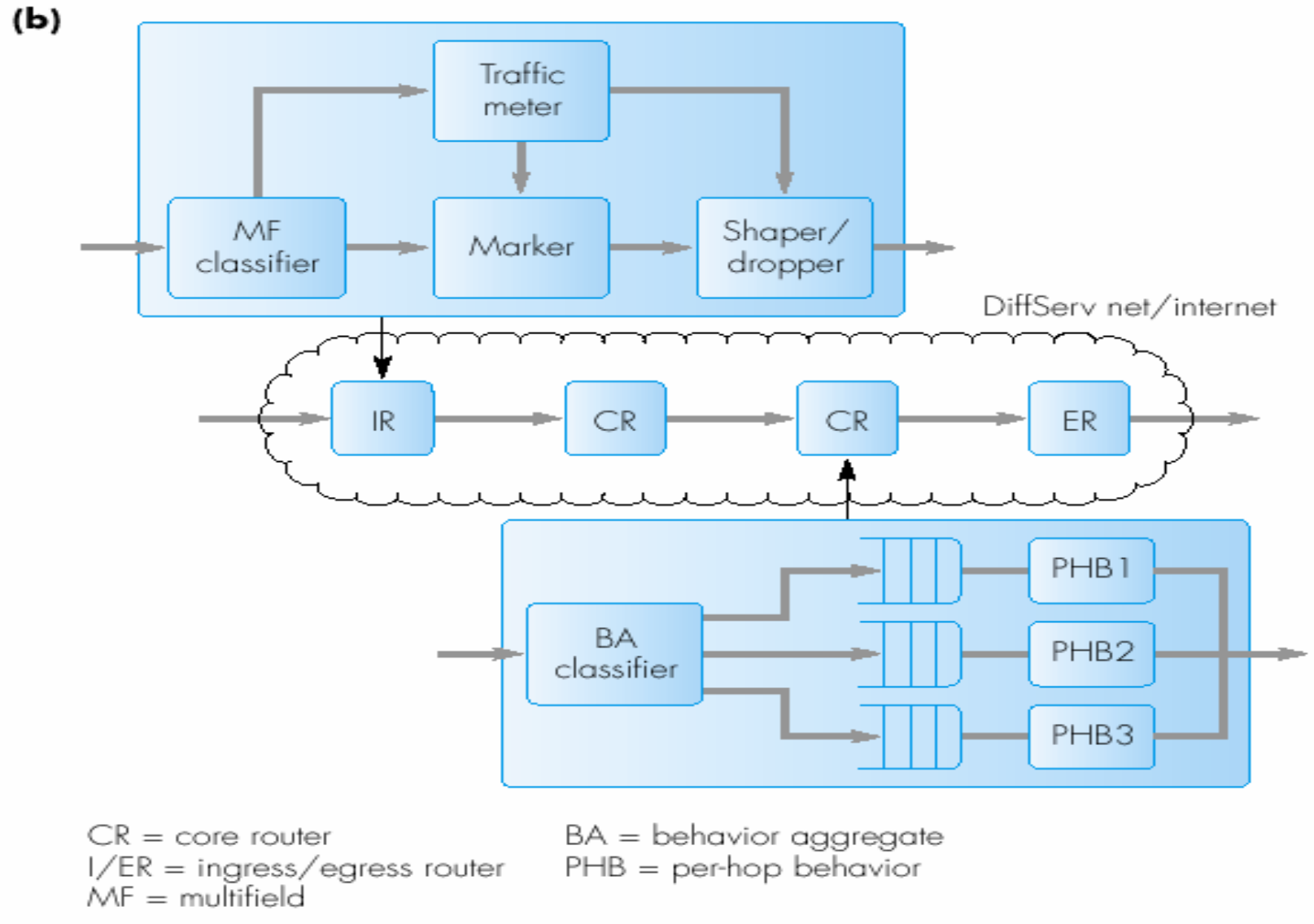
RSVP principles



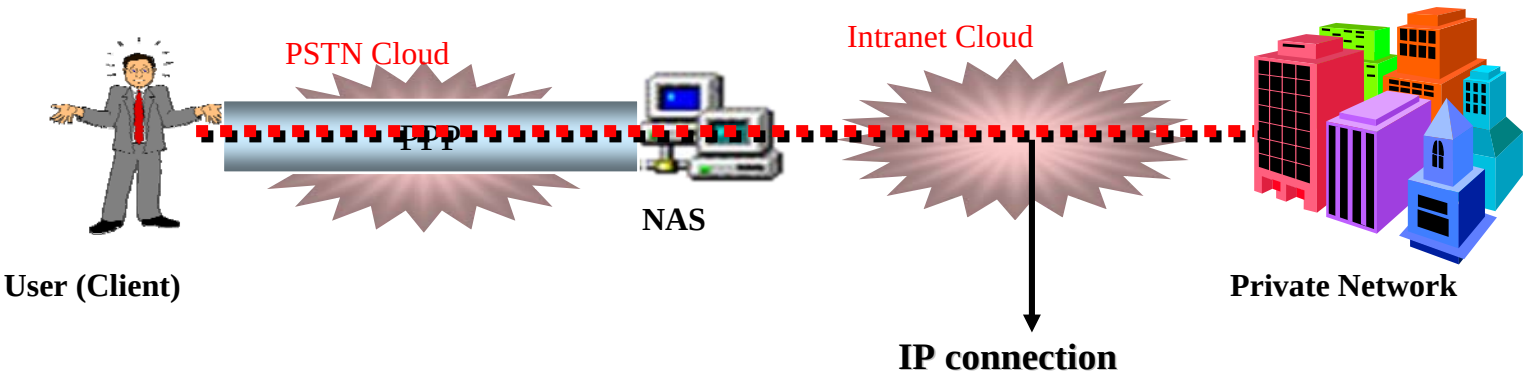
RSVP에서의 데이터 흐름



DiffServ

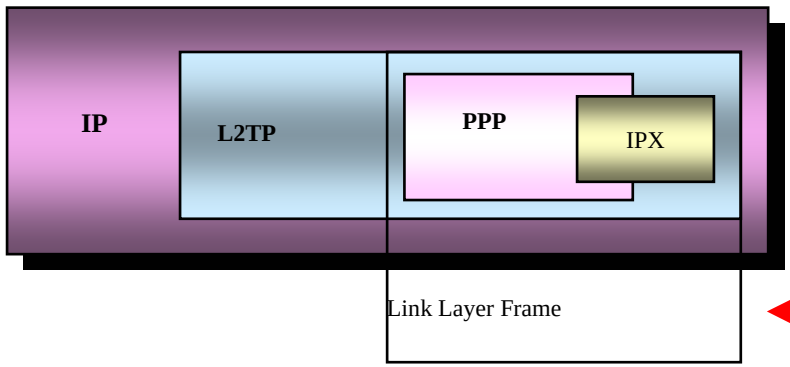

(b)
Traffic meter
MF classifier
Marker
Shaper/ dropper
DiffServ net/internet
IR
CR
CR
ER
BA classifier
PHB1
PHB2
PHB3
CR = core router
I/ER = ingress/egress router
MF = multifield
BA = behavior aggregate
PHB = per-hop behavior

9.9 PPP link layer

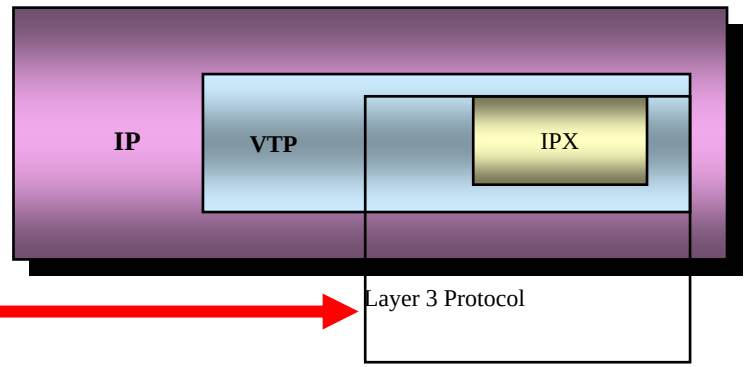


전통적인 Dial-up Service

□**Layer 2 Mode**

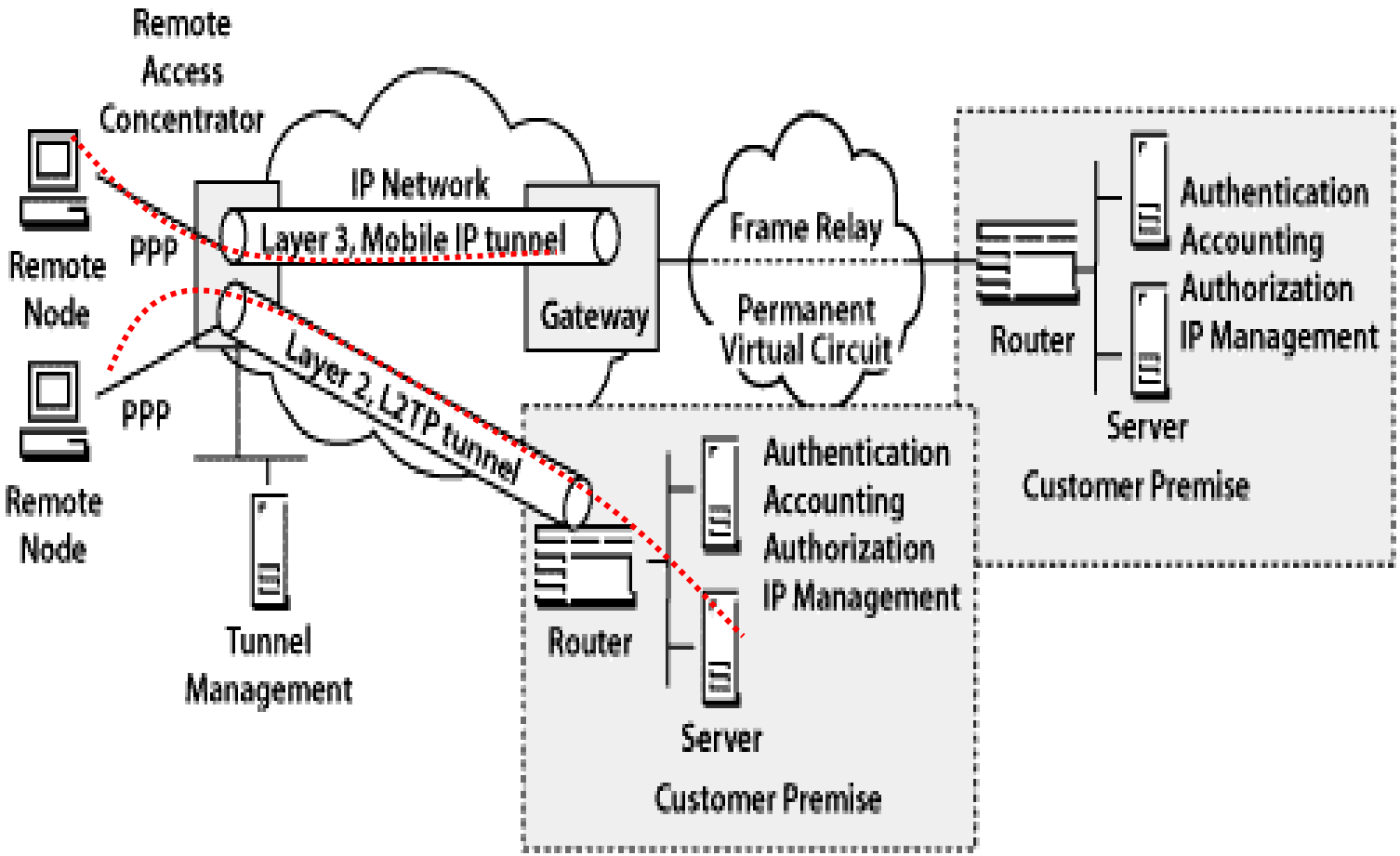


□**Layer 3 Mode**

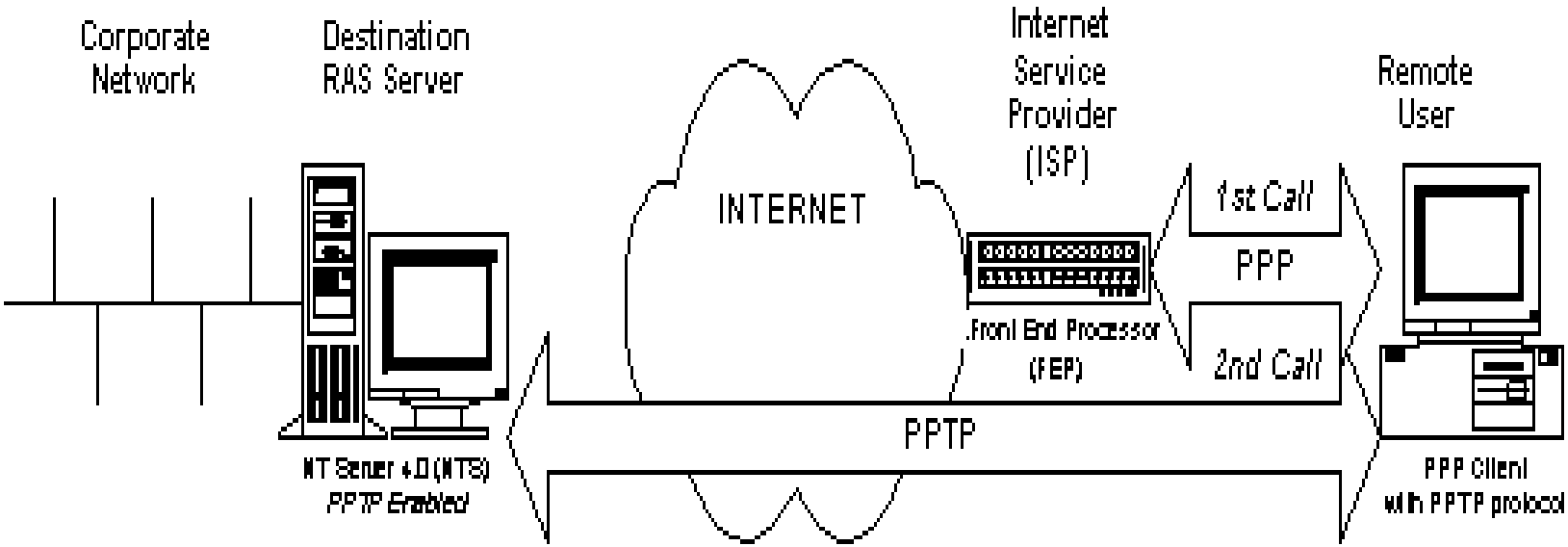


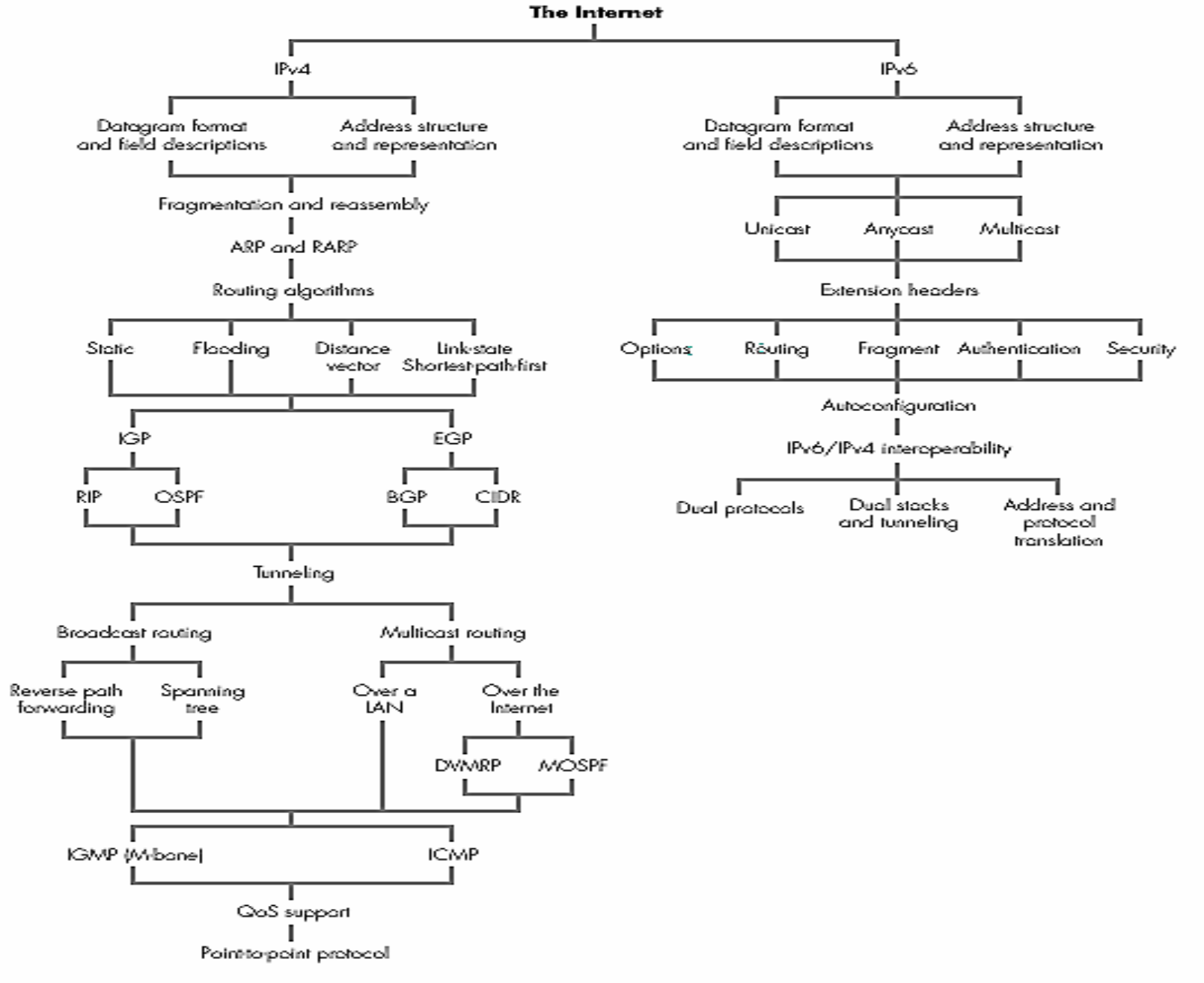
Tunneling Pakcet Format

Layer 2 Mode and Layer 3 Mode



PPTP Installation Process




The Internet
IPv4
IPv6
Datagram format and field descriptions
Address structure and representation
Fragmentation and reassembly
ARP and RARP
Routing algorithms
Static
Flooding
Distance vector
Link-state Shortest-path-first
IGP
EGP
RIP
OSPF
BGP
CIDR
Tunneling
Broadcast routing
Multicast routing
Reverse path forwarding
Spanning tree
Over a LAN
Over the Internet
DVMRP
MOSPF
IGMP (Mbone)
ICMP
QoS support
Point-to-point protocol
Datagram format and field descriptions
Address structure and representation
Unicast
Anycast
Multicast
Extension headers
Options
Routing
Fragment
Authentication
Security
Autoconfiguration
IPv6/IPv4 interoperability
Dual protocols
Dual stacks and tunneling
Address and protocol translation