Slides for Chapter 3:
Networking and Internetworking
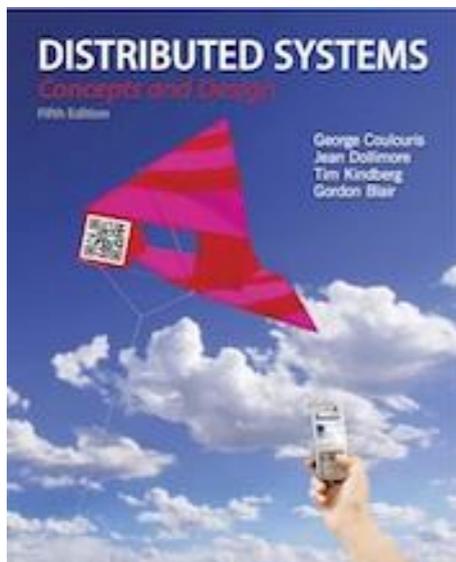
From **Coulouris, Dollimore, Kindberg and Blair**
Distributed Systems:
          Concepts and Design

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Figure 3.1
Network performance

	Example	Range	Bandwidth (Mbps)	Latency (ms)
Wired:				
LAN	Ethernet	1–2 kms	10–10,000	1–10
WAN	IP routing	worldwide	0.010–600	100–500
MAN	ATM	2–50 kms	1–600	10
Internetwork	Internet	worldwide	0.5–600	100–500
Wireless:		km		
WPAN	Bluetooth (IEEE 802.15.1)	10–30m	0.5–2	5–20
WLAN	WiFi (IEEE 802.11)	0.15–1.5 km	11–108	5–20
WMAN	WiMAX (IEEE 802.16)	5–50 km	1.5–20	5–20
WWAN	3G phone	cell: 1–-5	348–14.4	100–500

Figure 3.2
Conceptual layering of protocol software
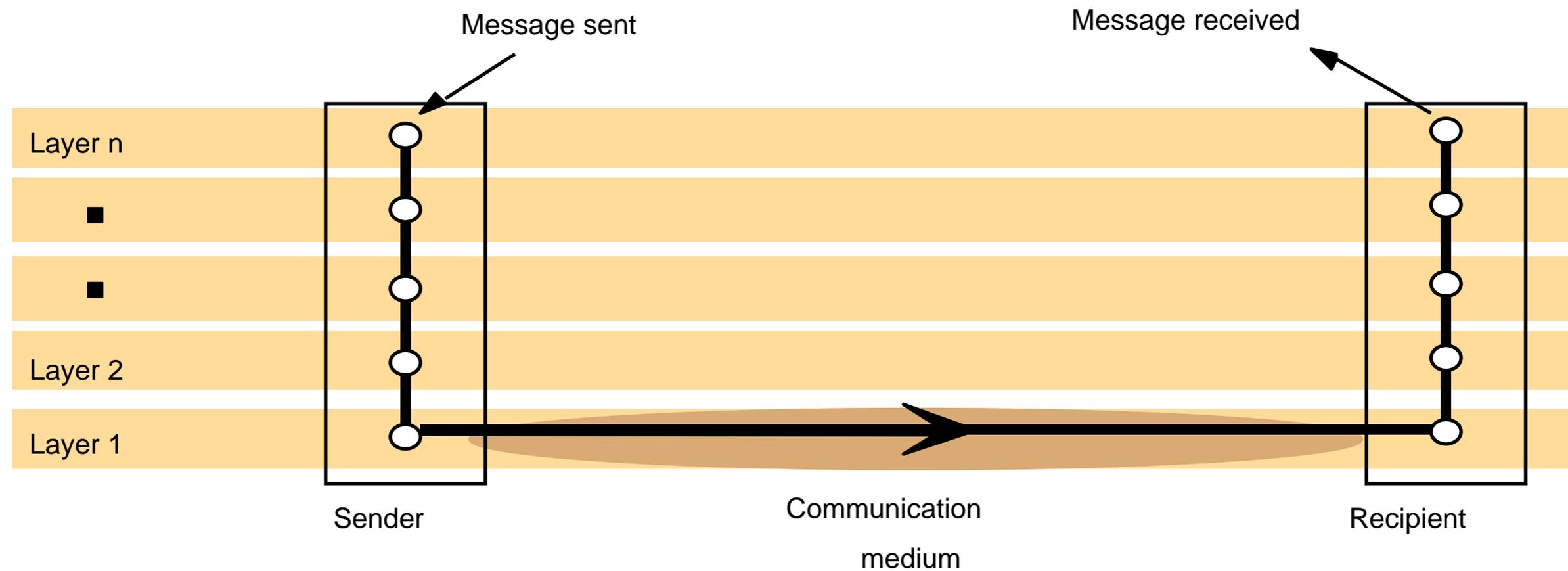
Figure 3.3
Encapsulation as it is applied in layered protocols

Application-layer message

Presentation header

Session header

Transport header

Network header
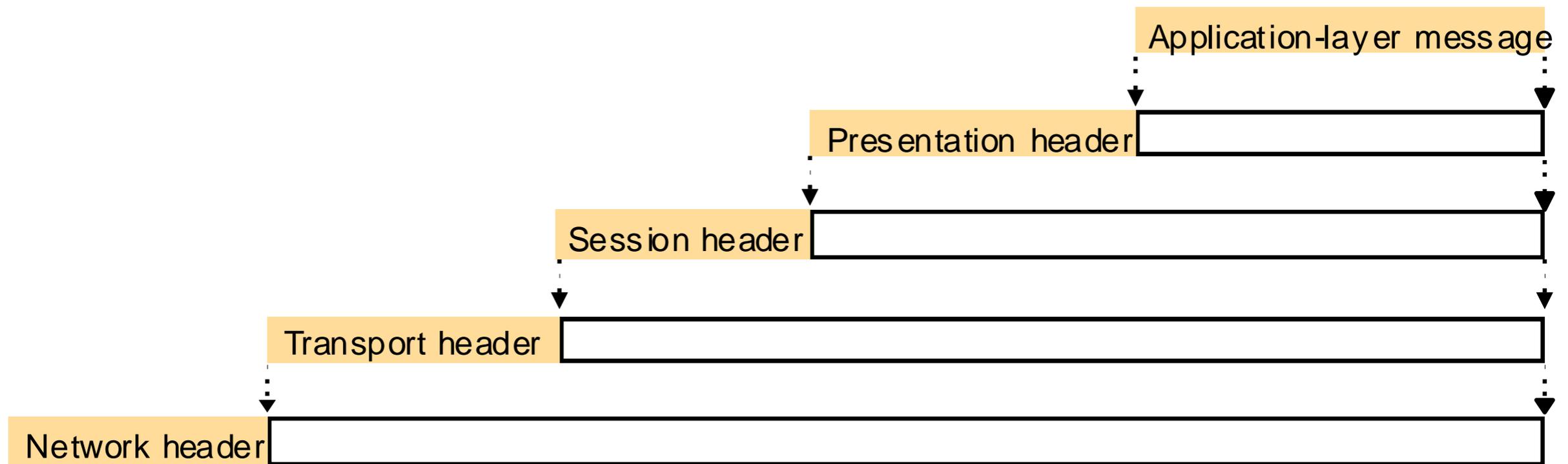
Figure 3.4
Protocol layers in the ISO Open Systems Interconnection (OSI) model
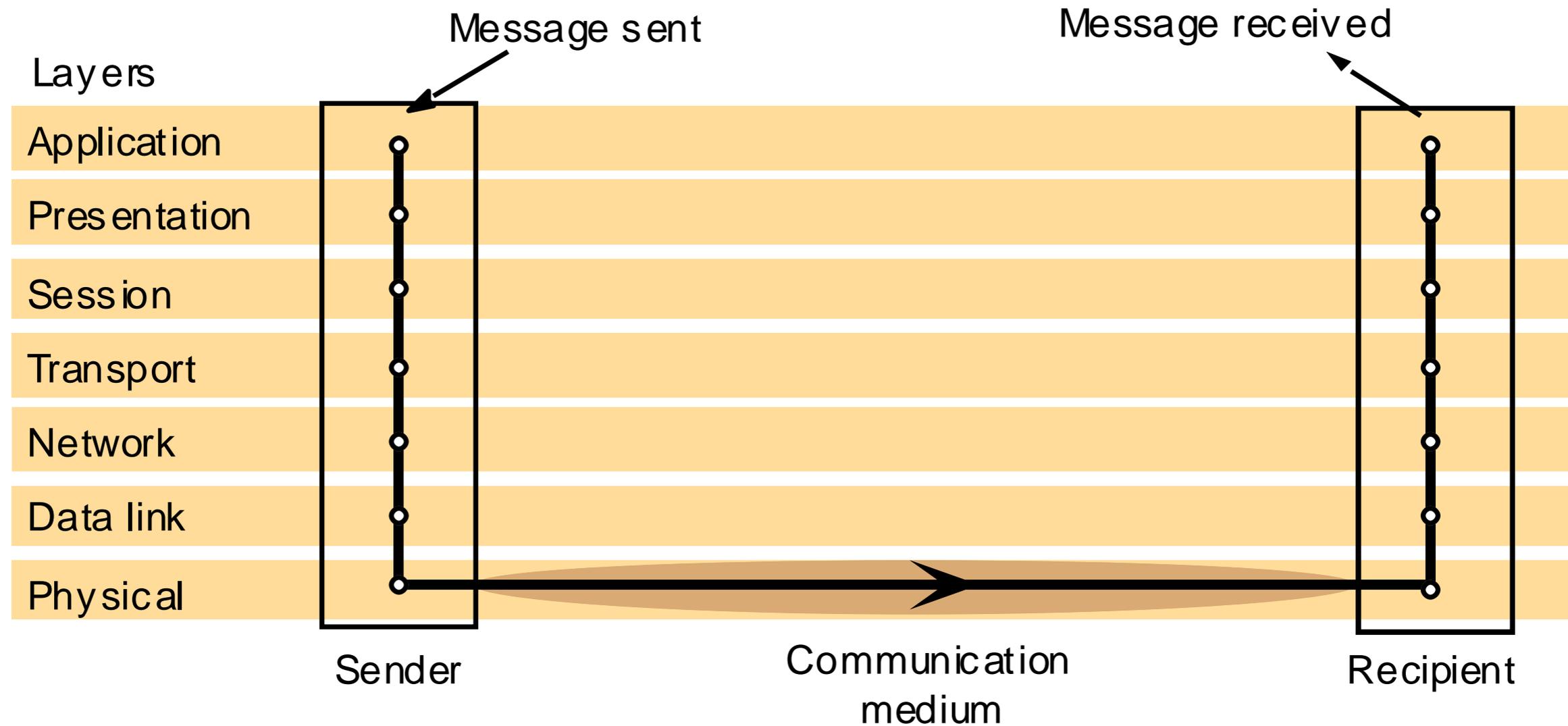
Figure 3.5
OSI protocol summary

Layer	Description	Examples
Application	Protocols that are designed to meet the communication requirements of specific applications, often defining the interface to a service.	HTTP, FTP , SMTP, CORBA IIOP
Presentation	Protocols at this level transmit data in a network representation that is independent of the representations used in individual computers, which may differ. Encryption is also performed in this layer, if required.	Secure Sockets (SSL),CORBA Data Rep.
Session	At this level reliability and adaptation are performed, such as detection of failures and automatic recovery.	
Transport	This is the lowest level at which messages (rather than packets) are handled. Messages are addressed to communication ports attached to processes, Protocols in this layer may be connection-oriented or connectionless.	TCP, UDP
Network	Transfers data packets between computers in a specific network. In a WAN or an internetwork this involves the generation of a route passing through routers. In a single LAN no routing is required.	IP, ATM virtual circuits
Data link	Responsible for transmission of packets between nodes that are directly connected by a physical link. In a WAN transmission is between pairs of routers or between routers and hosts. In a LAN it is between any pair of hosts.	Ethernet MAC, ATM cell transfer, PPP
Physical	The circuits and hardware that drive the network. It transmits sequences of binary data by analogue signalling, using amplitude or frequency modulation of electrical signals (on cable circuits), light signals (on fibre optic circuits) or other electromagnetic signals (on radio and microwave circuits).	Ethernet base- band signalling, ISDN

Figure 3.6
Internetwork layers

Message

Layers

Application

Transport

Internetwork

Internetwork packets

Network interface

Network-specific packets

Underlying network

Internetwork protocols

Underlying network protocols
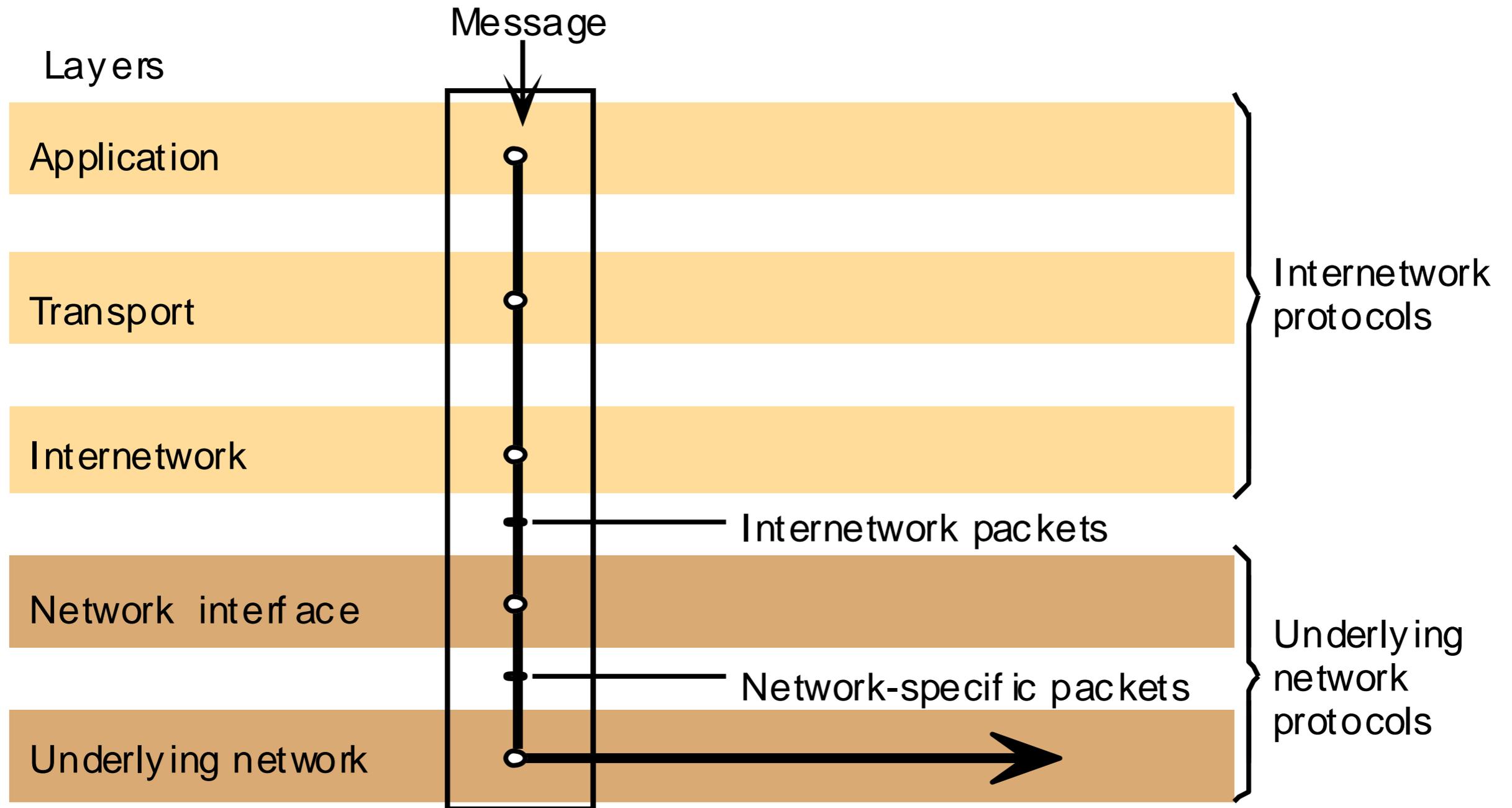
Figure 3.7
Routing in a wide area network

Hosts
or local
networks

Links

Routers
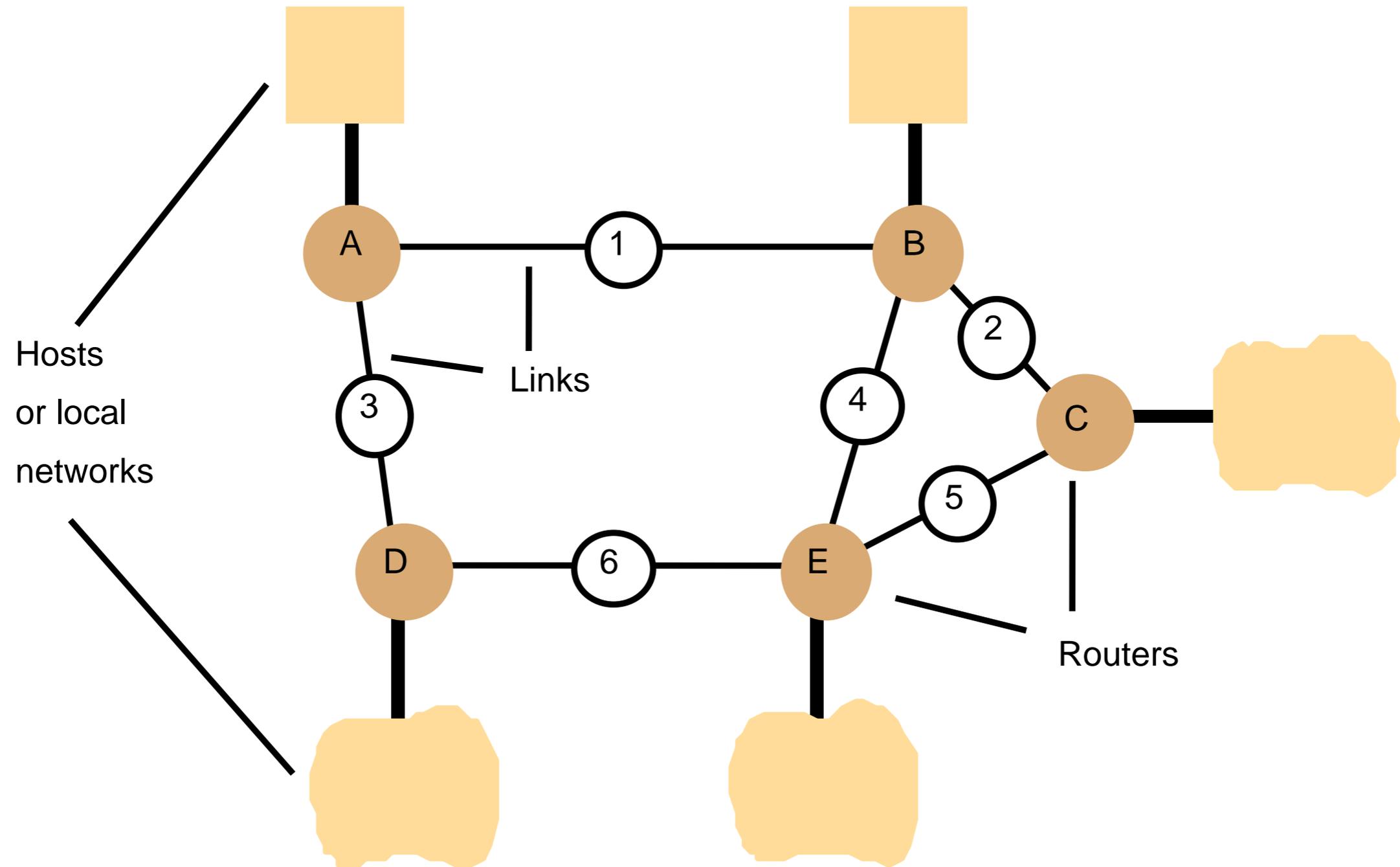
Figure 3.8
Routing tables for the network in Figure 3.7

Routings from A		
To	*Link*	*Cost*
A	local	0
B	1	1
C	1	2
D	3	1
E	1	2

Routings from B		
To	*Link*	*Cost*
A	1	1
B	local	0
C	2	1
D	1	2
E	4	1

Routings from C		
To	*Link*	*Cost*
A	2	2
B	2	1
C	local	0
D	5	2
E	5	1

Routings from D		
To	*Link*	*Cost*
A	3	1
B	3	2
C	6	2
D	local	0
E	6	1

Routings from E		
To	*Link*	*Cost*
A	4	2
B	4	1
C	5	1
D	6	1
E	local	0

Figure 3.9
Pseudo-code for RIP routing algorithm

Send: Each t seconds or when Tl changes, send Tl on each non-faulty outgoing link.
Receive: Whenever a routing table Tr is received on link n:
for all rows Rr in Tr {
if ($Rr.link \mid n$) {
$Rr.cost = Rr.cost + 1$;
$Rr.link = n$;
if ($Rr.destination$ is not in Tl) add Rr to Tl;
 // add new destination to Tl
else for all rows Rl in Tl {
if ($Rr.destination = Rl.destination$ and
        $(Rr.cost < Rl.cost$ or $Rl.link = n)) Rl = Rr$;
// Rr.cost < Rl.cost : remote node has better route
// *Rl.link = n* : remote node is more authoritative
}
}
}

Figure 3.10
## Simplified view of part of a university campus network

Campus router — 138.37.95.240/29 subnet — 138.37.95.241

router/firewall hammer

Staff subnet 138.37.88 — 138.37.88.251   138.37.94.251 — Student subnet 138.37.94

compute server bruno 138.37.88.249

Eswitch

file server/gateway custard 138.37.94.246

printers

dialup server henry 138.37.88.230

Eswitch

other servers

file server hotpoint 138.37.88.162

web server copper 138.37.88.248

hub   hub

desktop computers   138.37.88.xx

desktop computers   138.37.94.xx

Campus router — 138.37.95.248/29 subnet — 138.37.95.249

sickle router/firewall

100 Mbps Ethernet
1000 Mbps Ethernet
Eswitch: Ethernet switch

Figure 3.11
Tunnelling for IPv6 migration

IPv6 encapsulated in IPv4 packets

IPv4 network

IPv6   IPv6

A   B

Encapsulators

Figure 3.12
TCP/IP layers

Message

Layers

Application

Transport

Internet

Network interface

Underlying network

Messages (UDP) or Streams (TCP)

UDP or TCP packets

IP datagrams
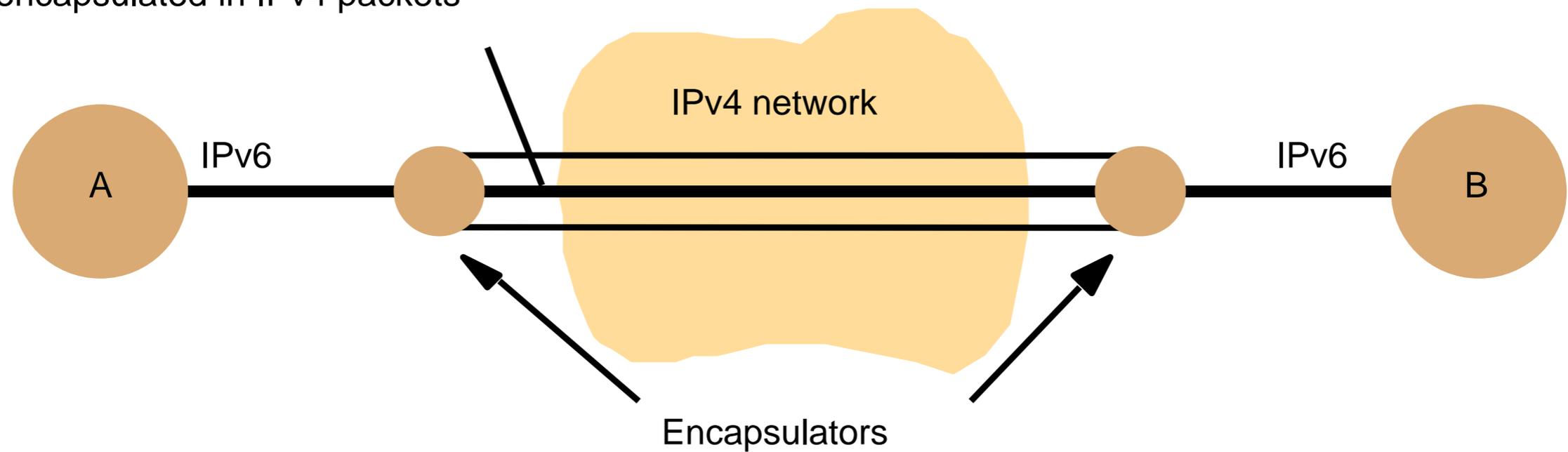
Network-specific frames
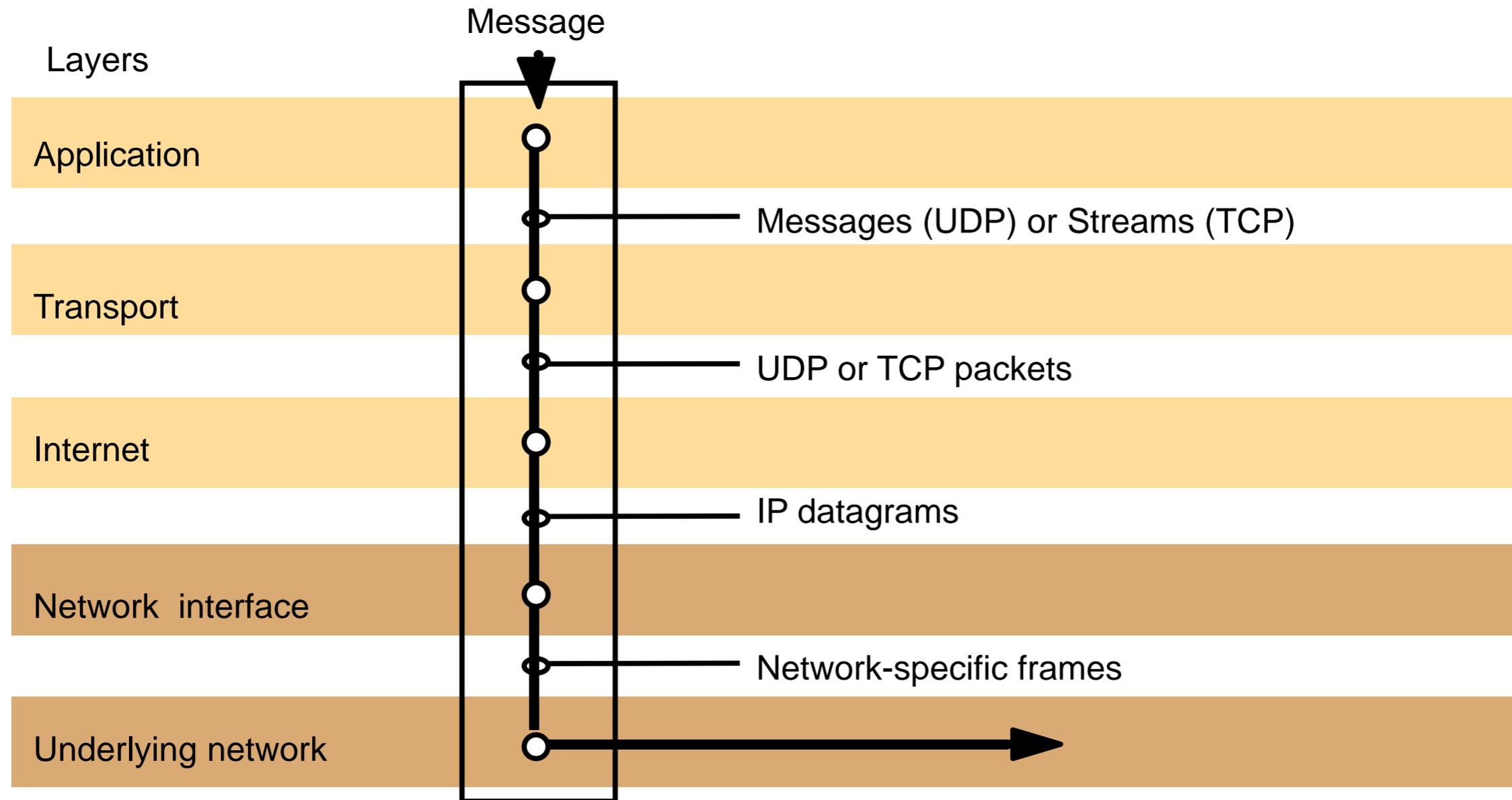
Figure 3.13
Encapsulation in a message transmitted via TCP over an Ethernet

Application message

TCP header | port

IP header | TCP

Ethernet header | IP

Ethernet frame
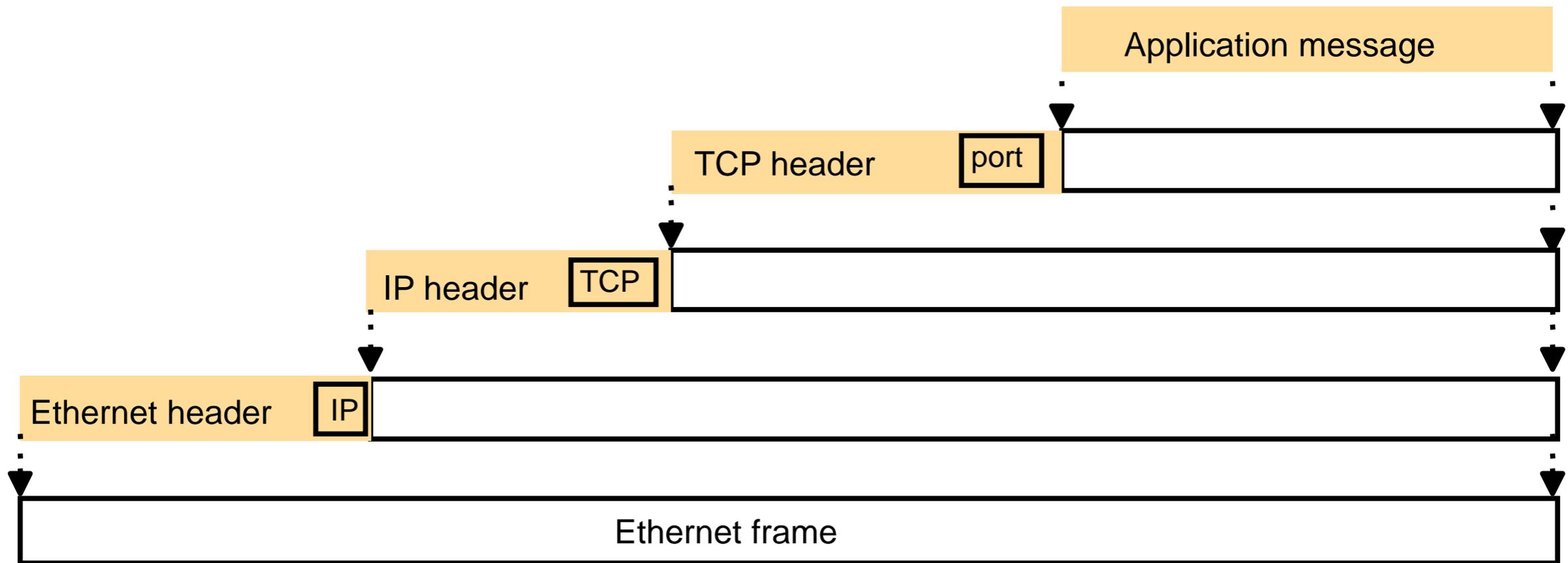
Figure 3.14
The programmer's conceptual view of a TCP/IP Internet

Application		Application
TCP		UDP
IP		
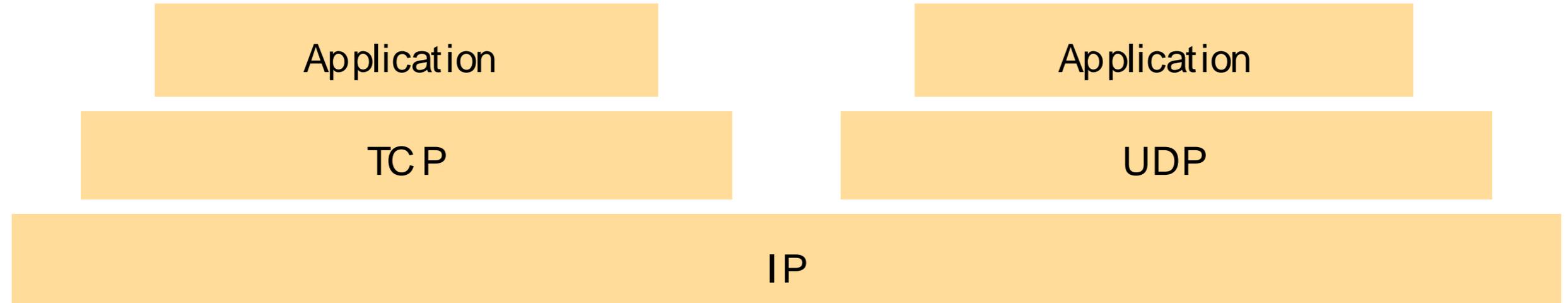
Figure 3.15
Internet address structure, showing field sizes in bits

| Class A: | 0 | Network ID (7) | Host ID (24) |

| Class B: | 1 | 0 | Network ID (14) | Host ID (16) |

| Class C: | 1 | 1 | 0 | Network ID (21) | Host ID (8) |

| Class D (multicast): | 1 | 1 | 1 | 0 | Multicast address (28) |

| Class E (reserved): | 1 | 1 | 1 | 1 | 0 | unused (27) |
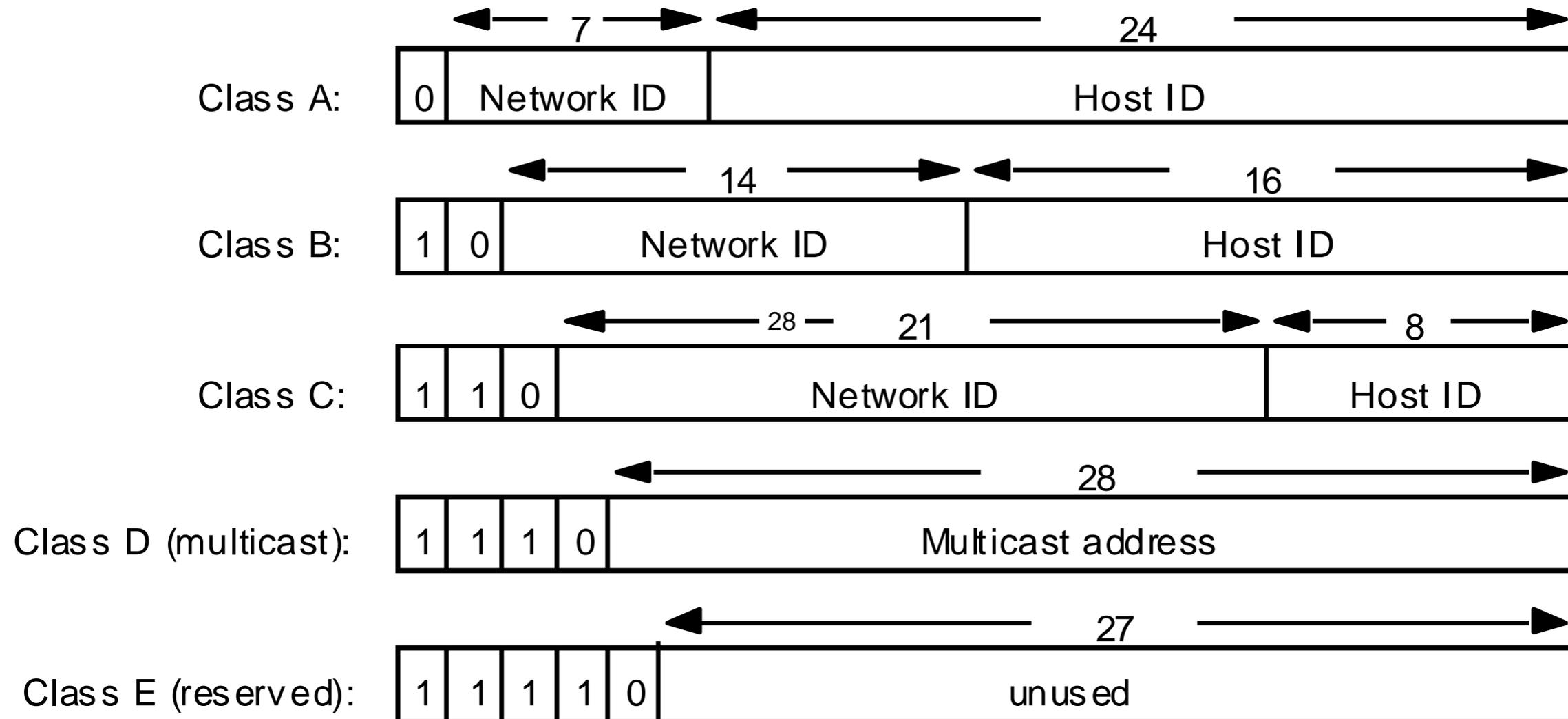
Figure 3.16
Decimal representation of Internet addresses

|	octet 1	octet 2	octet 3		Range of addresses
	Network ID		**Host ID**		
Class A:	1 to 127	0 to 255	0 to 255	0 to 255	1.0.0.0 to 127.255.255.255
		Network ID		**Host ID**	
Class B:	128 to 191	0 to 255	0 to 255	0 to 255	128.0.0.0 to 191.255.255.255
			Network ID	**Host ID**	
Class C:	192 to 223	0 to 255	0 to 255	1 to 254	192.0.0.0 to 223.255.255.255
			Multicast address		
Class D (multicast):	224 to 239	0 to 255	0 to 255	1 to 254	224.0.0.0 to 239.255.255.255
Class E (reserved):	240 to 255	0 to 255	0 to 255	1 to 254	240.0.0.0 to 255.255.255.255

Figure 3.17
IP packet layout

header						
	IP address of source	IP address of destination			data	

up to 64 kilobytes
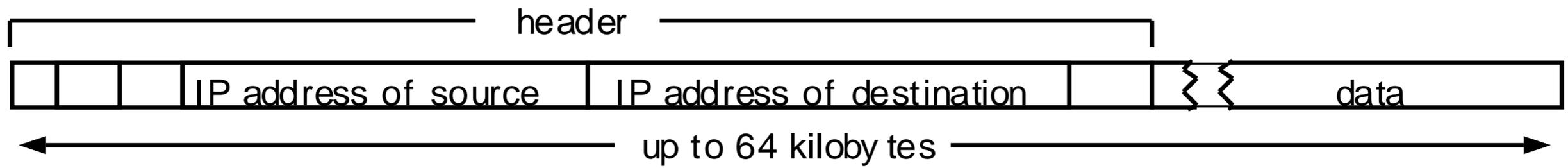
Figure 3.18
A typical NAT-based home network
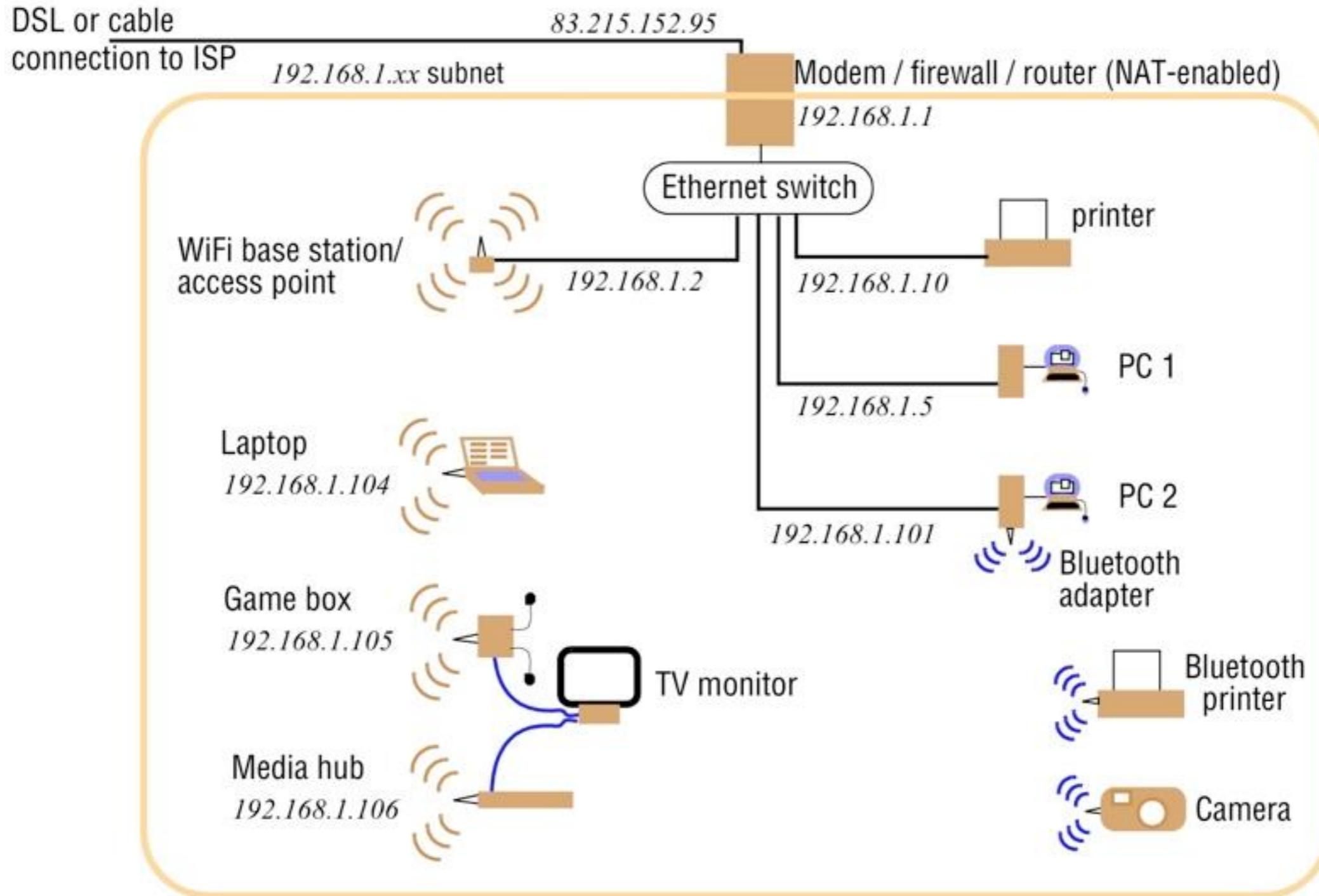
Figure 3.19
IPv6 header layout

Version (4 bits)	Traffic class (8 bits)	Flow label (20 bits)	
Payload length (16 bits)		Next header (8 bits)	Hop limit (8 bits)

Source address
(128 bits)

Destination address
(128 bits)
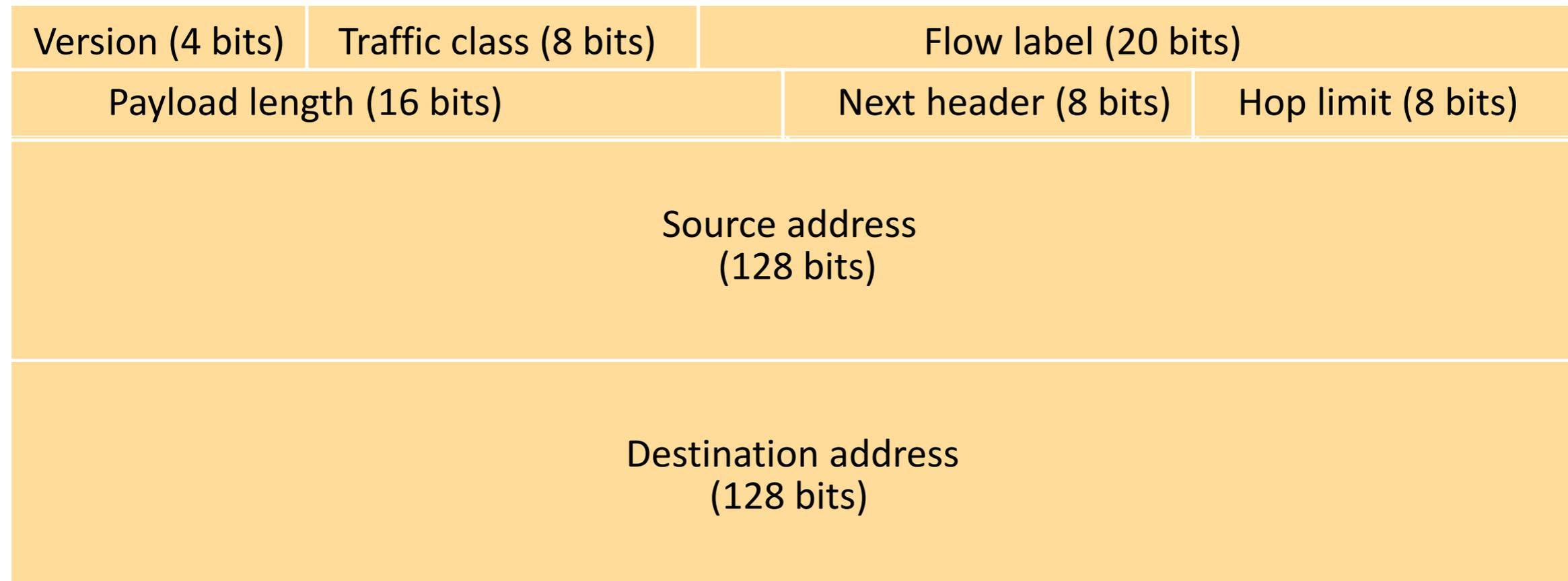
Figure 3.20
The MobileIP routing mechanism

Sender

Subsequent IP packets
tunnelled to FA

Mobile host MH

Address of FA
returned to sender

First IP packet
addressed to MH

Internet

Home
agent

First IP packet
tunnelled to FA

Foreign agent FA
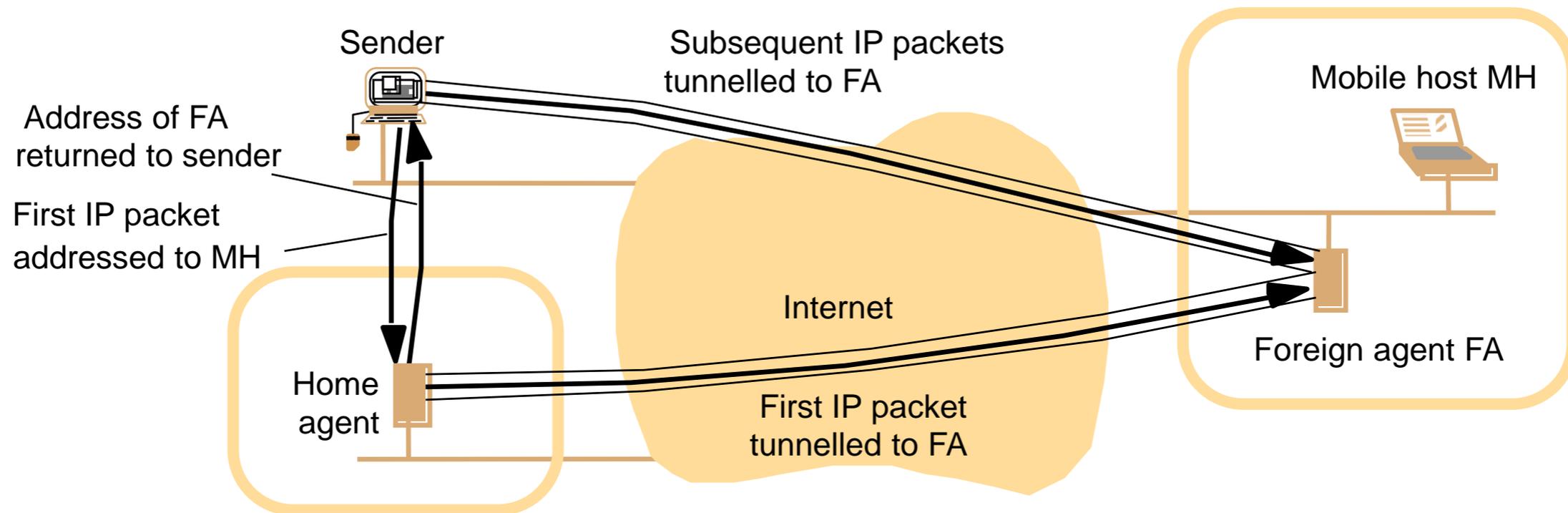
Figure 3.21
Firewall configurations

a) Filtering router

Protected intranet

Router/
filter

Internet

web/ftp
server
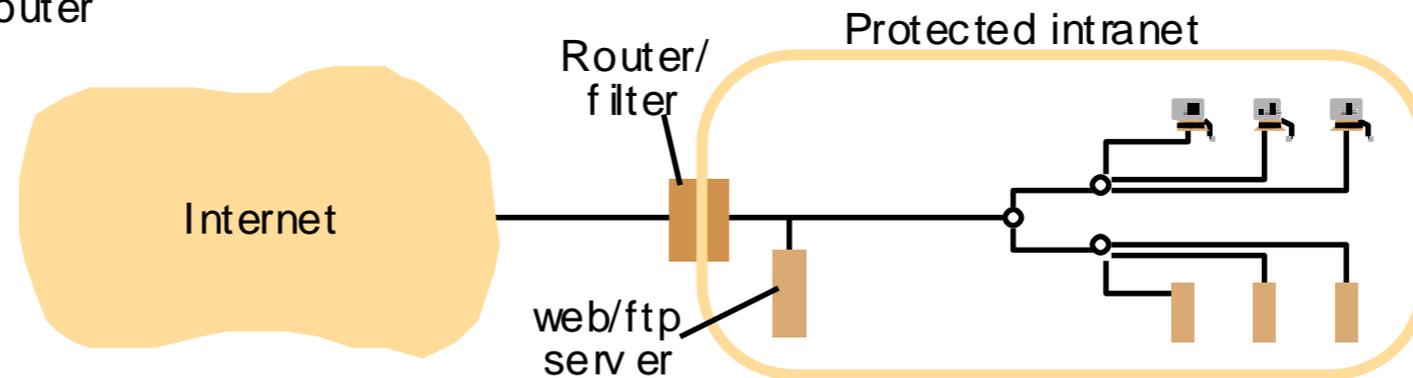
b) Filtering router and bastion

R/filter   Bastion

Internet

web/ftp
server
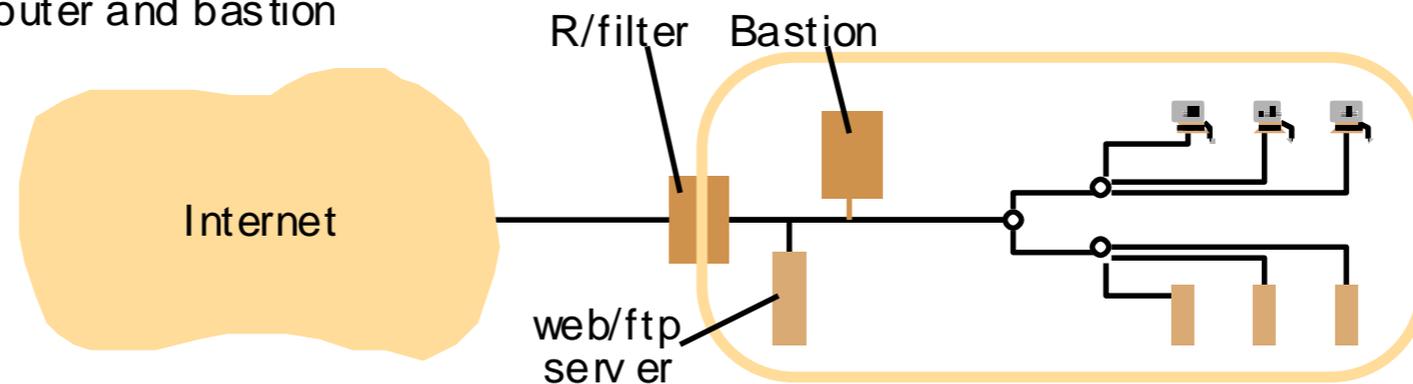
c) Screened subnet for bastion

R/filter   Bastion   R/filter

Internet

web/ftp
server
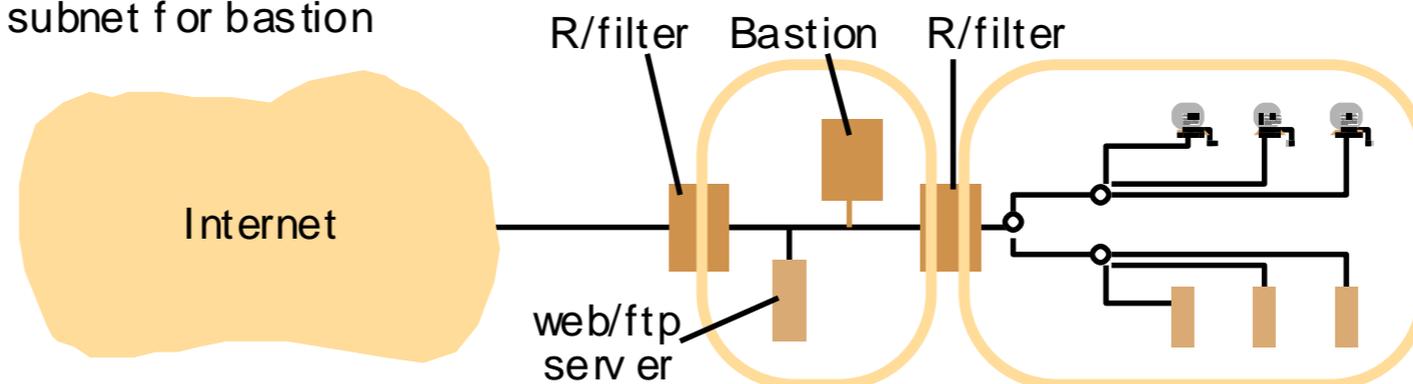
Figure 3.22
IEEE 802 network standards

IEEE No.	Name	Title	Reference
802.3	Ethernet	CSMA/CD Networks (Ethernet)	[IEEE 1985a]
802.4		Token Bus Networks	[IEEE 1985b]
802.5		Token Ring Networks	[IEEE 1985c]
802.6		Metropolitan Area Networks	[IEEE 1994]
802.11	WiFi	Wireless Local Area Networks	[IEEE 1999]
802.15.1	Bluetooth	Wireless Personal Area Networks	[IEEE 2002]
802.15.4	ZigBee	Wireless Sensor Networks	[IEEE 2003]
802.16	WiMAX	Wireless Metropolitan Area Networks	[IEEE 2004a]

Figure 3.23
Ethernet ranges and speeds

|	*10Base5*	*10BaseT*	*100BaseT*	*1000BaseT*
Data rate	10 Mbps	10 Mbps	100 Mbps	1000 Mbps
Max. segment lengths:				
Twisted wire (UTP)	100 m	100 m	100 m	25 m
Coaxial cable (STP)	500 m	500 m	500 m	25 m
Multi-mode fibre	2000 m	2000 m	500 m	500 m
Mono-mode fibre	25000 m	25000 m	20000 m	2000 m

Figure 3.24
Wireless LAN configuration

A

B

C

Laptops

radio obstruction

Wireless
LAN

Palmtop   D

E

Server

Base station/
access point

LAN
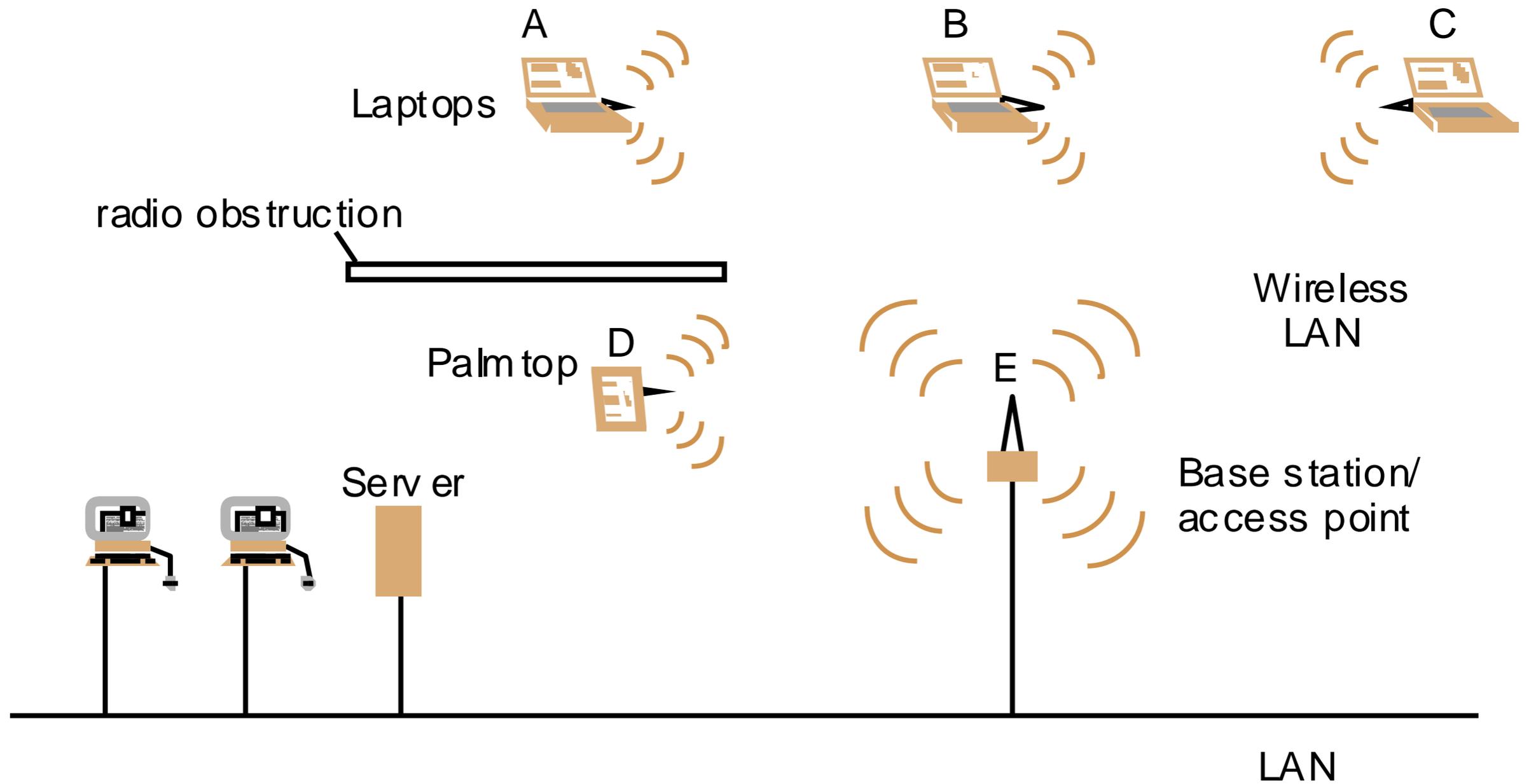
Figure 3.25
Bluetooth frame structure

bits: 72	18	18	18	0 - 2744
Access code	Header copy 1	Header copy 2	Header copy 3	Data for transmission

Header

bits: 3	1	1	1	4	8
Destination	Flow	Ack	Seq	Type	Header checksum

Address within Piconet   *= ACL, SCO, poll, null*
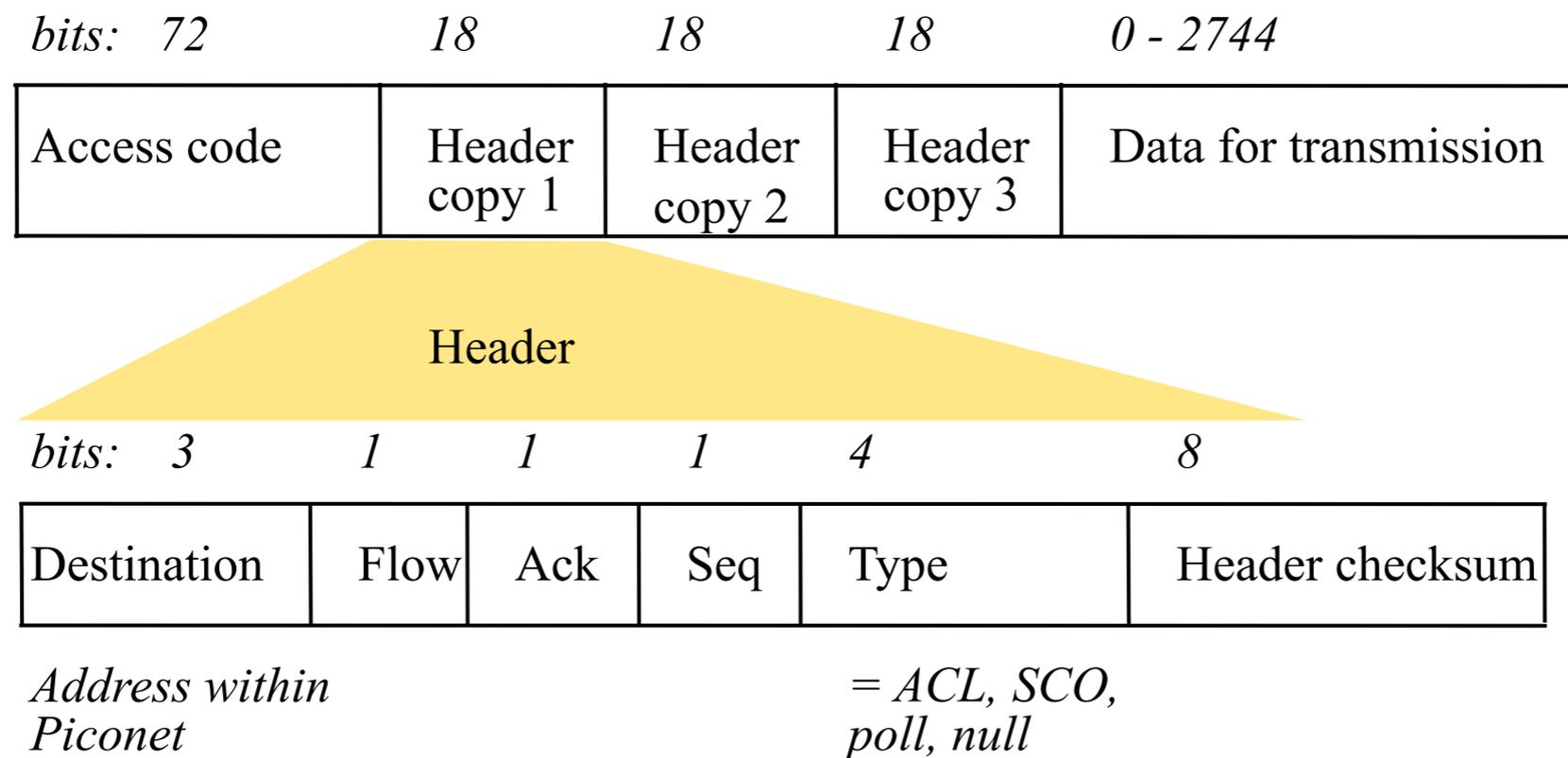
SCO packets (e.g. for voice data) have a 240-bit payload containing 80 bits of data triplicated, filling exactly one timeslot.