C S D A 2/e

Communications, Networking, and the Internet

- Chapter Topics
  - Network communications mechanisms and signal encoding
    - Tasks, roles, and levels in the communications system
    - Communications layer models—The OSI layer model
  - Serial data communications and the RS-232 communications protocol
  - Modern buses: USB and FireWire
  - Local area networks—LANs; the Ethernet LAN
  - The Internet: TCP/IP protocols, packet routing, and IP addresses
    - Recovering wasted IP address space
      - CIDR, NAT, and DHCP

Introduction - Communications Protocols

- Modern computer communications spans the range from simple 1-1 communications to the Internet
- Whenever there is communications, there must be a *communications protocol*—an agreement or contract.
- Most communications protocols are decided by committee.

Network structures and channels

- Three kinds of mechanisms
  - Simplex. One way communications. Example: remote data logging.
  - Half-duplex. Two way communications, but only one may talk at once (Example, the Police radio)
  - Full duplex. Both may talk at once. Example: the Telephone.
- Time division multiplexing (TDM)
  - Divides the channel into “time slots.”
  - Referred to as *baseband* systems.
- Frequency division multiplexing (FDM)
  - Has several “frequency bands.” Example: The TV Cable.
  - Referred to as *broadband* systems.
- Can have combinations: Several TDM signals transmitted on each band of a FDM system.

Fig 10.1 Baseband Bit Encoding Schemes

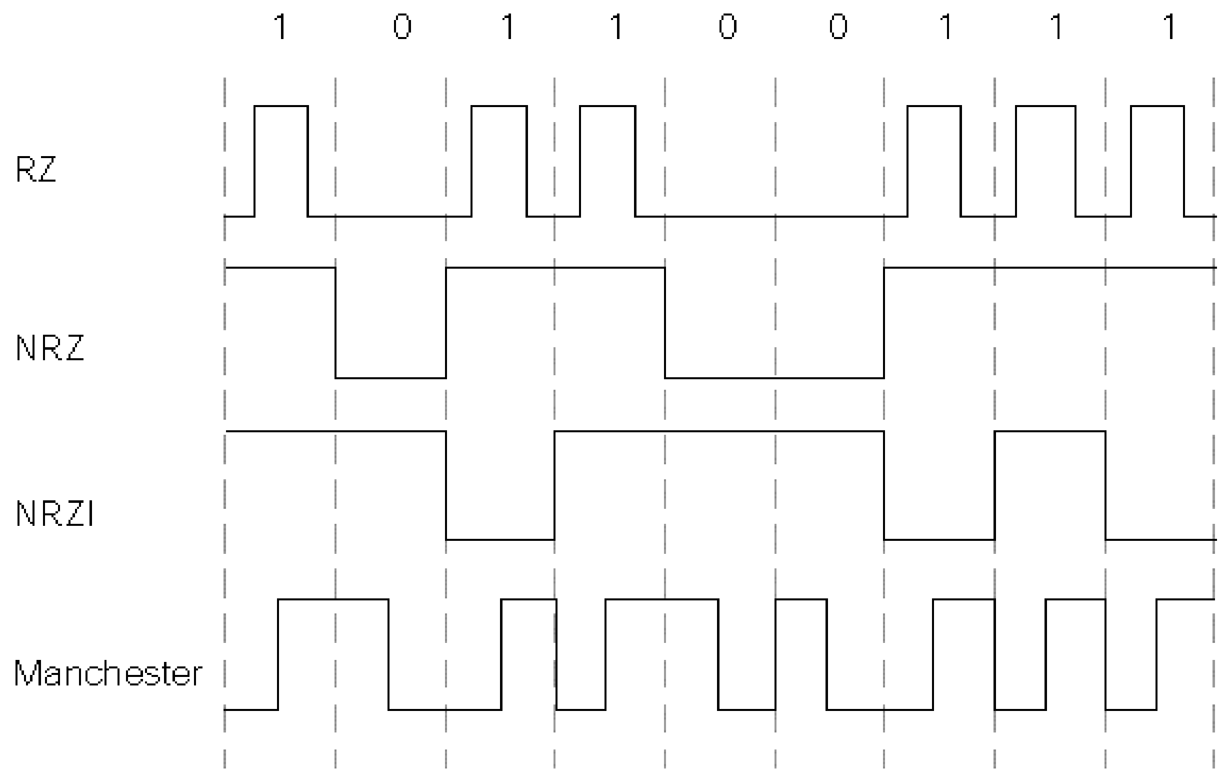
RZ:
- pulse encoding

NRZ:
- level encoding

NRZI:
- 1: transition
- 0: no transition

Manchester:
- 0: hi-lo
- 1: lo-hi

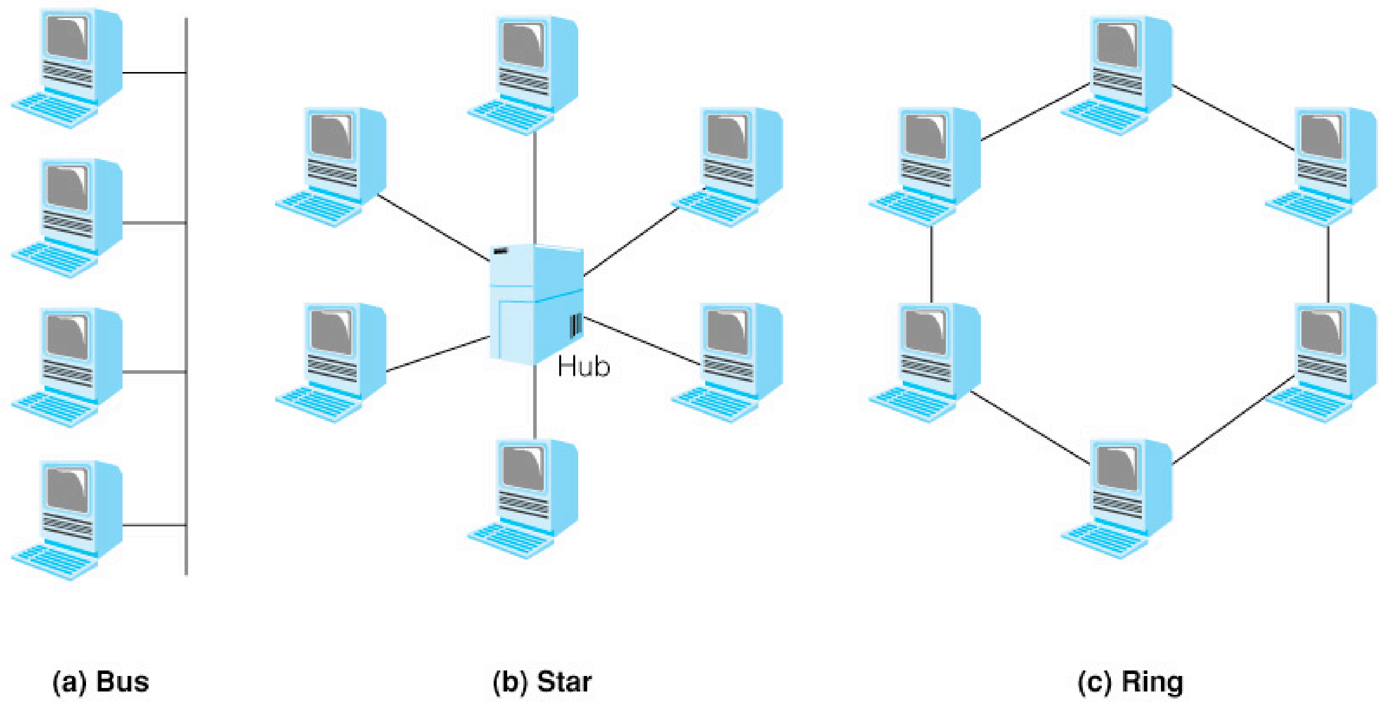
(There are many other schemes as well)



Packet vs. Circuit Switching

- Packet Switching
  - uses time slots to send a packet of information
  - Packets may be from a few bytes to many KBytes
  - Packet-switched networks route each packet independently.
  - Examples: Ethernet, Token ring, Appletalk, Novell, Internet
- Circuit Switching
  - Establishes a circuit (route) ahead of time.
  - Circuit may be a “virtual” circuit
  - Guarantees a certain bandwidth to the user.
  - Examples: the Telephone system, ATM (Asynch. Trans. Mode)

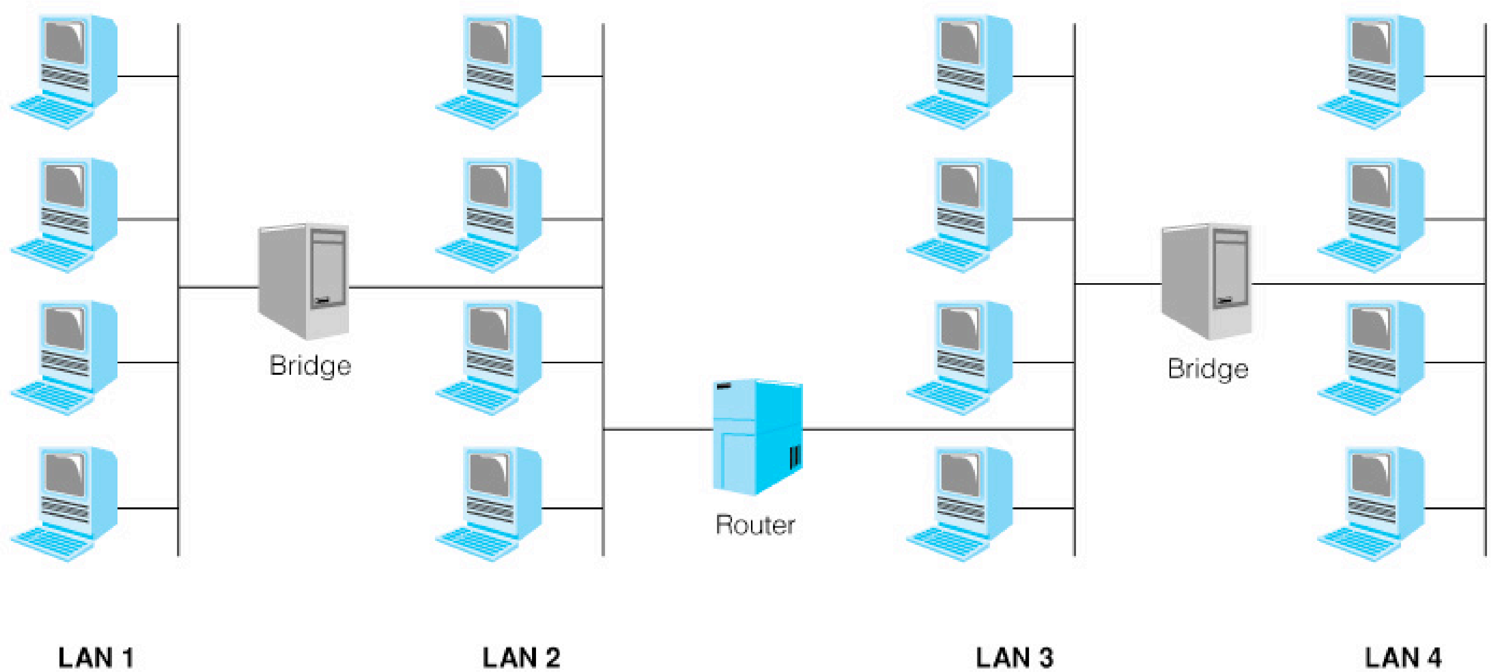
Fig 10.2 Three network topologies



Three Topologies Compared

- Bus:
  - No central controller, so continues to operate if station fails
  - Possibility of contention and collision
- Star:
  - May use hub as switch to connect any two stations (Phone system)
  - May use hub as broadcaster. (Star-Bus)
  - May use hub as *star-ring*
- Ring: Token Ring Protocol (IBM)
  - Passes a data packet, the *Token*, around the ring.
  - Receiving station removes the data, passes on an “empty” token.
  - If a station receives an empty token, it may attach data to the token, destined for another station in the ring.
  - Collision-free, but more susceptible to hardware failure if a node fails

Fig 10.3 Several LAN's Interconnected with Bridges and Routers



Bridge: passes on only non-local traffic

Router: capable of *Routing* non-local traffic

Tasks required of all Communications Systems

- Provide a high-level interface to the application
- Establish, maintain, and terminate the session gracefully
- Provide addressing and routing
- Provide synchronization and flow control
- Provide message formatting
- Assure error-free reception (error detection and error correction)
- Signal generation and detection

Fig 10.4 The OSI Layer Model

Application Layer

- Originator, final receiver of transmitted data

Presentation Layer

- encryption, format conversion (often not present)

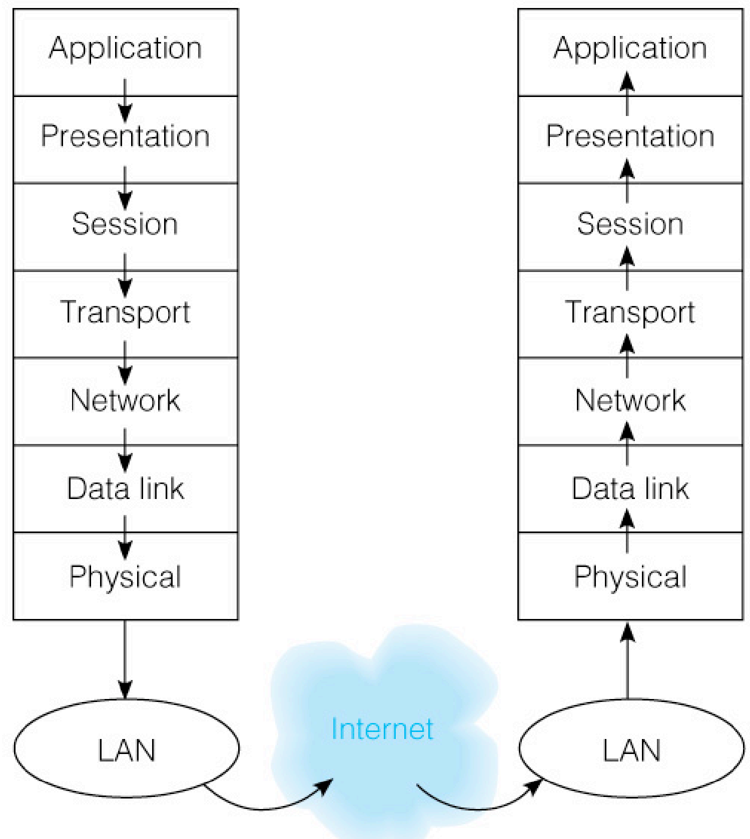
Session layer

- Establish, maintain, terminate session

Transport layer

- Packetizes data, assures all packets are received, in order of transmission.
- Requests retransmission of lost data.

- more -



The OSI Layer Model (Cont'd)

Network Layer

- formats packets for the LAN
- removes LAN info at destination

Data Link Layer

- Final preparation for transmission
- Low level synchronization and flow control

Physical Layer

- wiring, transmitting and receiving
- signaling

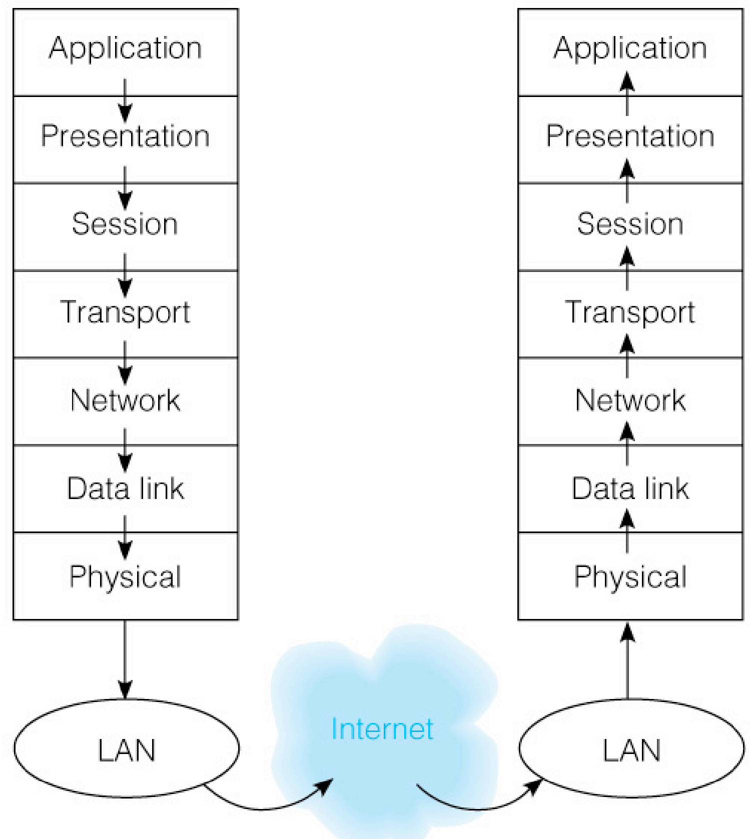


Fig 10.5 Telecommunications by modem—RS-232 Communications Protocol

- Physical layer: 25-pin, 9-pin, or mini connector
- Most use asynchronous communications
  - No common clock—clock must be inferred from arriving data

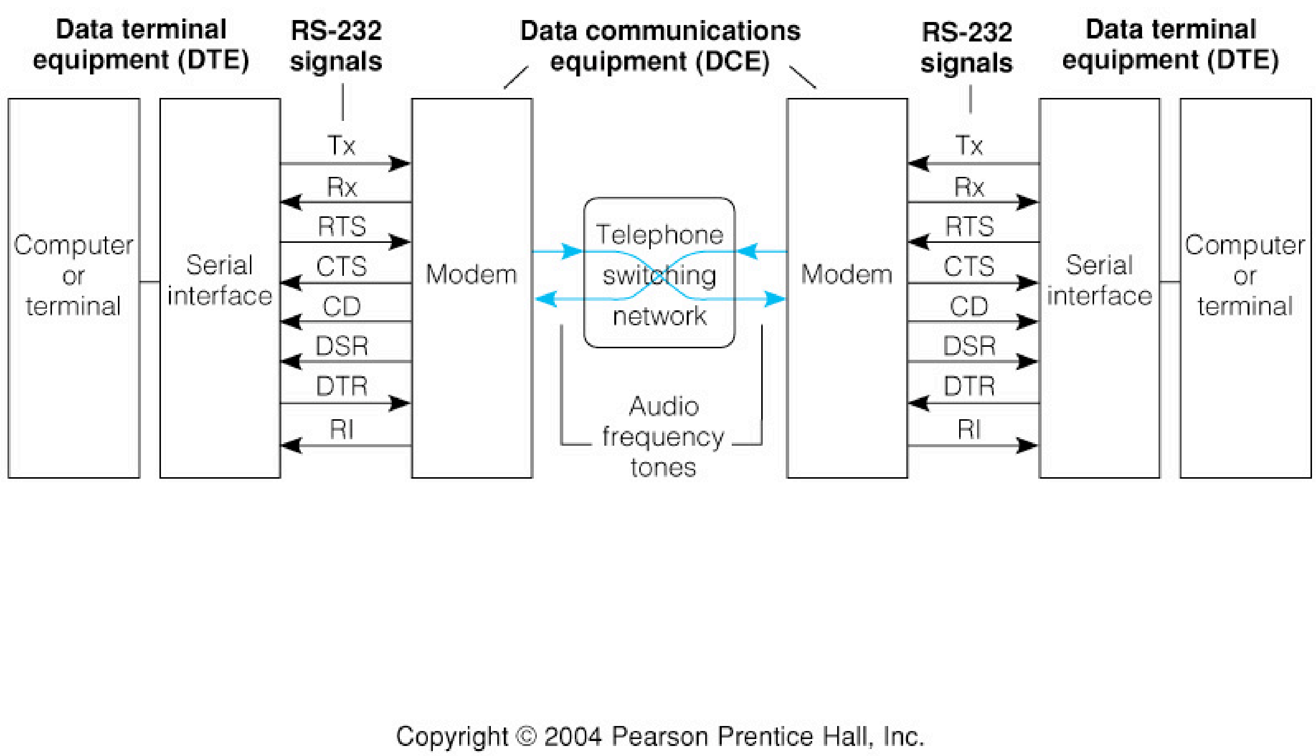
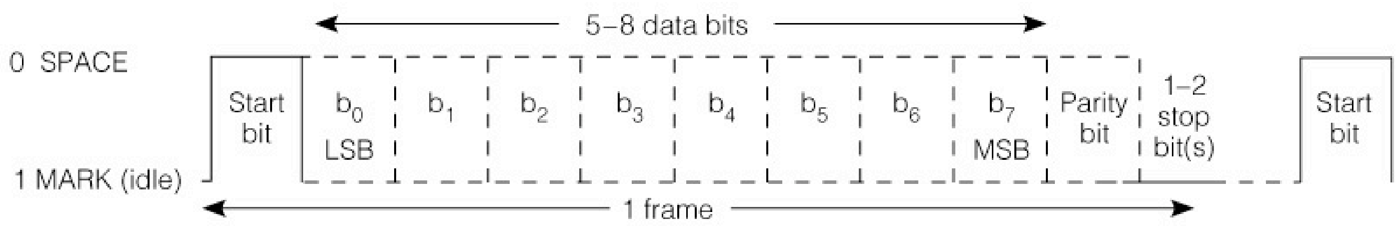


Fig 10.6 An Asynchronous Data Communications Frame—The Data Link Layer



(Physical Layer: MARK = -3 to -12 volts, SPACE = +3 to +12 VOLTS.)

RS-232 Signals and Pins

- These signals are used at the data link and session levels. Exact protocols are complex.

DB-25 Pin No.	Signal Name	Signal Identity	Signal Direction
2	Tx	Transmitted Data	To modem
3	Rx	Received Data	To computer
7	Gnd	Signal ground	Common Ref.
22	RI	Ring Indicator	To computer
8	CD	Carrier Detect	To computer
20	DTR	Data Terminal Ready	To modem
6	DSR	Data Set Ready	To computer
4	RTS	Request To Send	To modem
5	CTS	Clear To Send	To computer

EIA RS-232 signal identities and pin assignments

MODEMS (MOdulator, DEModulator)

- Convert DC signals for 0 and 1 to audio tones
  - Telephone system frequency response is ~50-3500 Hz
- Bit or bit per second (bps) rate is # bits sent per second
- Baud (after J-M-E Baudot) rate is # of signal changes per second.
  - Maximum Baud rate for the phone system is 2400.
- It is possible to send multiple bits per baud, by signaling at different frequencies.
  - Example: send one of 4 different signals, 2400 times per second:
  - The four signals represent 00, 01, 01, or 11, so can send two bits per baud.
  - bps rate = baud rate x $\log_2(n)$

"Smart" Modems

- Sometimes called "Hayes-compatible"
- Computer controlled:
  - dialing
  - set bit rate
  - program answering, redialing, etc.
  - capable of data compression
- Modems are still 2400 baud maximum
- Highest bit rate available today, 56,000 bps, near the theoretical maximum rate

The ASCII Code

Notice tricks with x, X, and ^X, and with “1” and 1

lsbs,		Most	significant	bits,	654			
3210	000	001	010	011	100	101	110	111
0000	NUL, ^@	DLE, ^P	SPACE	0	@	P	`	p
0001	SOH, ^A	DC1, ^Q	!	1	A	Q	a	q
0010	STX, ^B	DC2, ^R	"	2	B	R	b	r
0011	ETX, ^C	DC3, ^S	#	3	C	S	c	s
0100	EOT, ^D	DC4, ^T	$	4	D	T	d	t
0101	ENQ, ^E	NAK, ^U	%	5	E	U	e	u
0110	ACK, ^F	SYN, ^V	&	6	F	V	f	v
0111	BEL, ^G	ETB, ^W	'	7	G	W	g	w
1000	BS, ^H	CAN, ^X	(	8	H	X	h	x
1001	HT, ^I	EM, ^Y	)	9	I	Y	i	y
1010	LF, ^J	SUB, ^Z	*	:	J	Z	j	z
1011	VT, ^K	ESC, ^[	+	;	K	[	k	{
1100	FF, ^L	FS, ^\	,	<	L	\	l	|
1101	CR, ^M	GS, ^]	-	=	M	]	m	}
1110	SO, ^N	RS, ^^	.	>	N	^	n	~
1111	SI, ^O	US, ^_	/	?	O	_	o	DEL

The ASCII Control Characters

NUL	Null, idle	SI	Shift in
SOH	Start of heading	DLE	Data link escape
STX	Start of text	DC1-4	Device control
ETX	End of text	NAK	Negative acknowledgment
EOT	End of transmission	SYN	Synch character
ENQ	Enquiry	ETB	End of transmitted block
ACK	Acknowledge	CAN	Cancel preceding message or block
BEL	Audible bell	EM	End of medium (paper or tape)
BS	Backspace	SUB	Substitute for invalid character
HT	Horizontal tab	ESC	Escape (give alternate meaning to following)
LF	Line feed	FS	File separator
VT	Vertical tab	GS	Group separator
FF	Form feed	RS	Record separator
CR	Carriage return	US	Unit separator
SO	Shift out	DEL	Delete

The ASCII Code "tricks"

^X:	001 1000
"X":	101 1000
"x":	111 1000
"1":	011 0001
1:	000 0001

Local Area Networks

- Not precisely defined, but generally taken to be:

  "a network wholly contained within a building or campus."

- Defined more by intended use: sharing resources within an organization.
- Span the range from 230Kbps Apple Localtalk to Gigabit Ethernet.
- Most LAN protocols are defined only at the data link and physical layers.

The Ethernet LAN

- Developed at Xerox in 1970s, now the most popular LAN.
- Physical layer can be coaxial cable, twisted pair (telephone cable), optical fiber
- Data rates of 10, 100, 1000 Mbps possible
- Data link layer: packets from 64 to 1518 bytes long.
- Connectionless protocol
- Broadcast medium: every controller receives and examines every packet. Collisions possible
- Addresses are 48 bits long, organized as 6, 8-bit “octets”
- Addresses guaranteed globally unique, formerly assigned by Xerox, now by IEEE

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Ethernet Cabling

Cable	IEEE Standard	Maximum segment length, m	Maximum Total length, m.	Topology
RG-8U (thicknet)	10BASE-5	500	2500	bus
RG-58U (thinnet)	10BASE-2	185	1000	bus
Unshielded Tw. Pair (Phone wire)	10BASE-T	100	2500 w. thick backbone	star-bus

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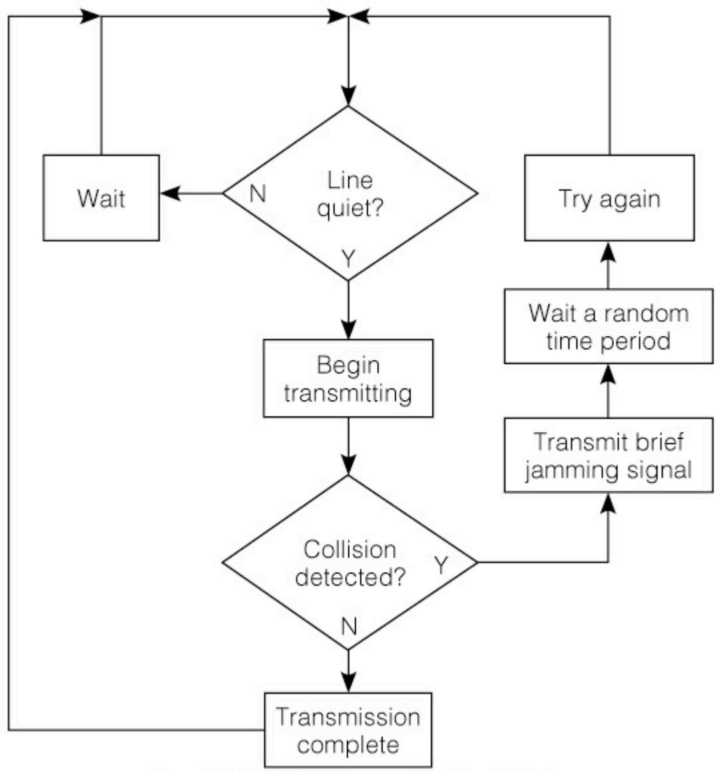
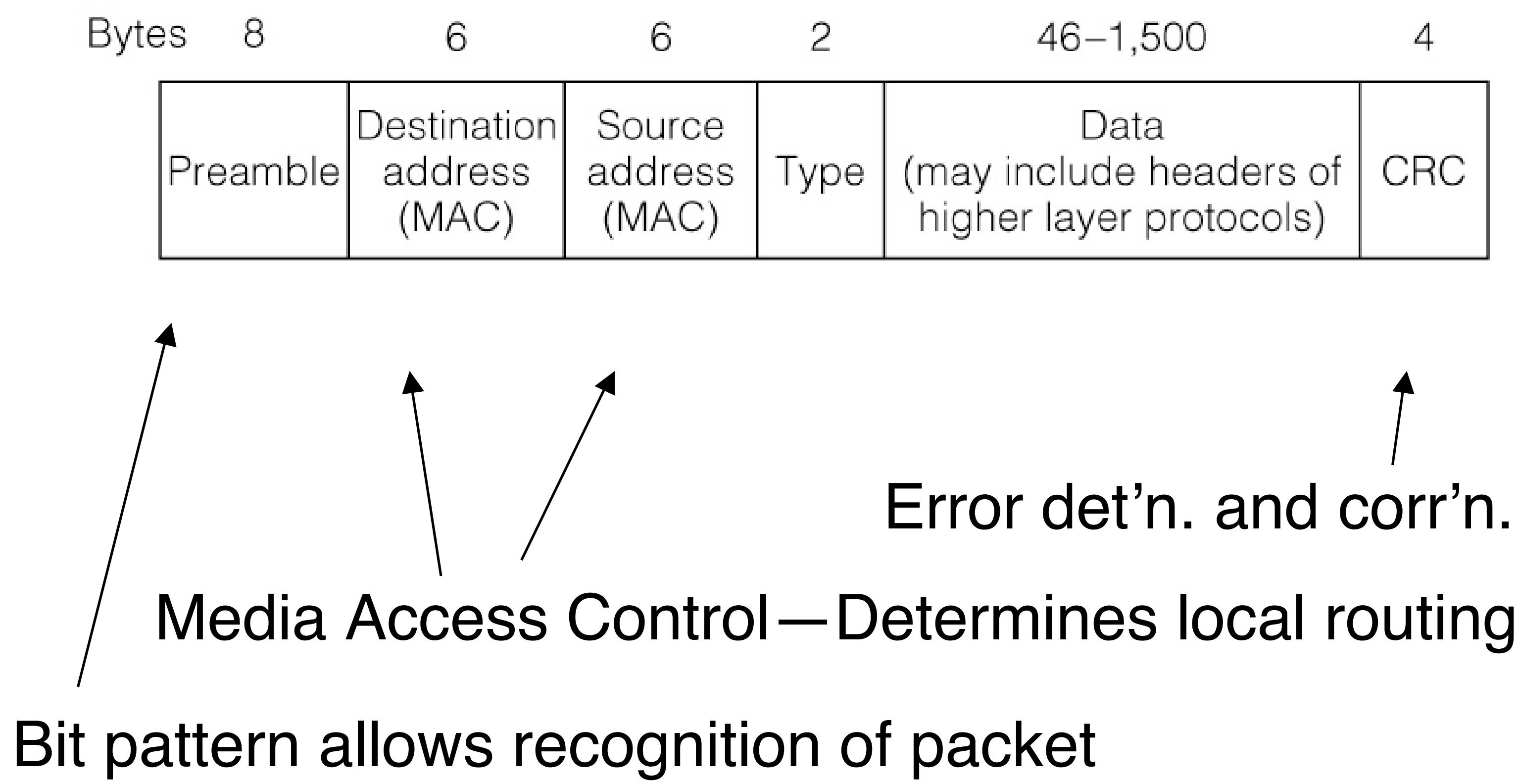
Fig 10.7 The Ethernet CSMA/CD† Medium Access Control Mechanism



† Carrier sense multiple access/collision detect

Fig 10.8 Ethernet Packet Structure



USB and FireWire†–Similarities

- These two serial modern buses have several characteristics in common that set them apart from earlier bus protocols:
  - Bus Power: each bus can supply a certain amount of power to attached devices, so some low-power devices do not need a power source.
  - Hot Plugability: Unlike earlier buses, devices can be plugged and unplugged while the computer is running.
  - Layer models similar to the ISO layer model, that simplify device programming and abstract details of the interface.
  - Asynchronous and isochronous (guaranteed bandwidth) communications possible.

†Also known as Sony iLink, and by the IEEE standards 1394 and 1394b.

USB and FireWire–Differences

- USB requires a host computer as the controller, topology is a tree.
- USB was designed primarily as a relatively inexpensive, relatively slow interface for computer peripherals such as mouse, keyboard, slow-speed disk drive.
- FireWire does not require a host; topology is an acyclic graph that is reconfigured each time a device is plugged or unplugged.
  - Example: A FireWire camcorder can be plugged into a VCR with a FireWire interface and the data loaded into the VCR from the camera.
- FireWire was designed as a more expensive, higher-speed bus for interconnecting video and high-speed data.

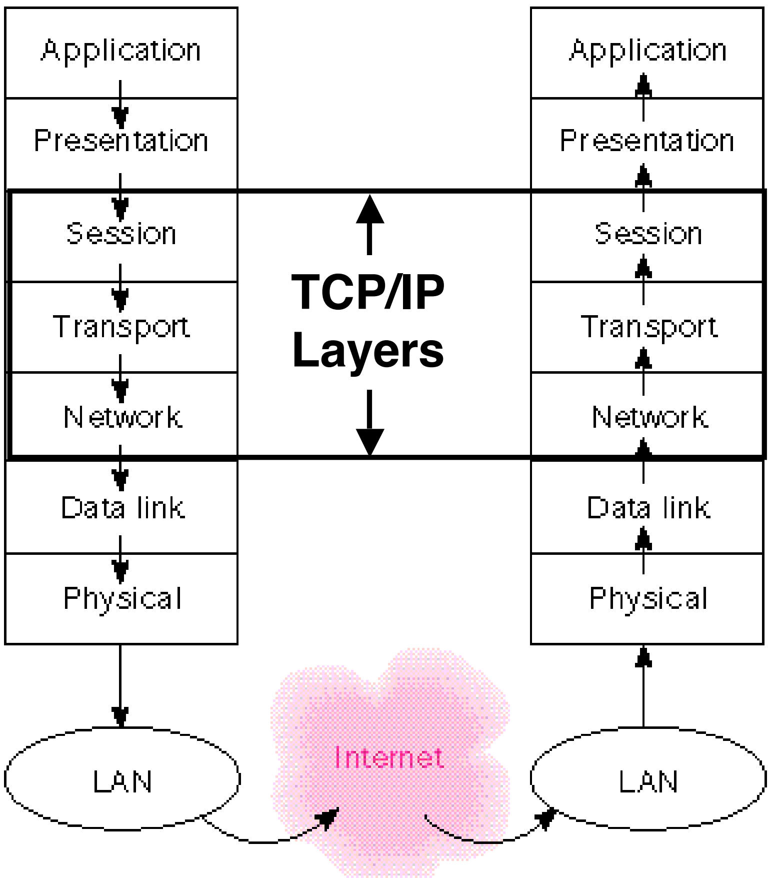
Table 10.4 USB and FireWire Characteristics

Characteristic	USB (USB2)	IEEE1394 (IEE1394B)
Powered Bus	Yes	Yes
Hot-pluggable, plug-and-play	Yes	Yes
Data rates	1.5, 12 Mbps (480 Mbps)	100, 200, 400 Mbps (800, 1600, 3200 Mbps)
Topology	Star-hub	Arbitrary acyclic graph.
Root node (host controller, bus manager) configuration	At system design time.	Negotiated by devices whenever a new device is connected
Maximum cable length	5m (5m)	5m (100m)
No. of wires in cable	4: 4.5 V, Ground, +Data, –Data	6: 8 - 40 V, Ground, 2 Twisted Pairs; Optional 4-pin mini-cable without power.
Bus cycle time (time per frame)	1ms.	125 μs
Asynchronous max payload size per packet.	64 bytes at 12 Mbps bus speed	2048 bytes at 400 Mbps bus speed.
Isochronous max payload size per packet.	1024 bytes at 12 Mbps bus speed	4096 bytes at 400 Mbps bus speed.
Percent total bus cycle time guaranteed to isochronous data transfers	90	80

The Internet

- Developed by ARPA, Advanced Research Projects Agency, a DOD agency.
- First Experiments in 1969-74
- Over 150 Million host computers on the net in 2003.
- For public computer net communications, it is the “only game in town.”
- Distributed, connectionless protocol.
- Independent routers pass packets from source to destination.

The Internet



- Does not include the Application or Presentation layers, the data link layer, or the physical layer.
- Relies on other LAN protocols to transport its packets.
- Can use Ethernet, Token Ring, Appletalk, dialup phone lines, or any other comm protocol.
- Uses the TCP/IP (Transport Control Protocol/Internet Protocol)
- Distributed protocol

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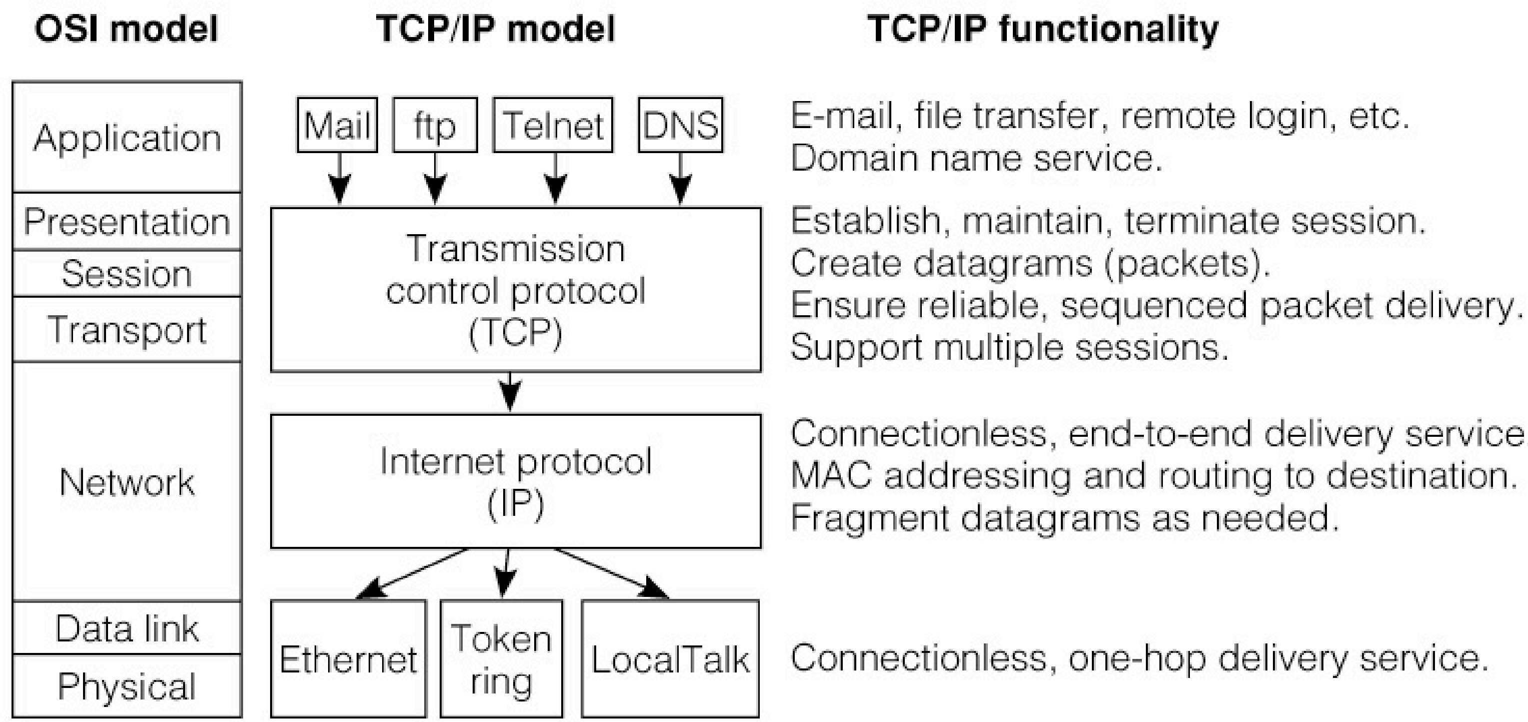
Fig 10.9 The TCP/IP Model related to the OSI Model



Internet Names and Addresses

For Humans → DOMAIN NAME

For Machines → IP Address

DOMAIN NAME		IP Address
riker.cs.colorado.edu	↔	128.138.244.9
ucsu.colorado.edu	↔	128.138.129.83

Network # . Host ID

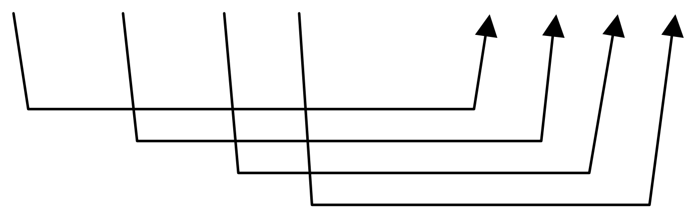
Network #: Assigned by one of several designated organizations

Host ID: Assigned by CU

Originating machine requests lookup of IP address from a Domain Name Server, using Domain Name Service

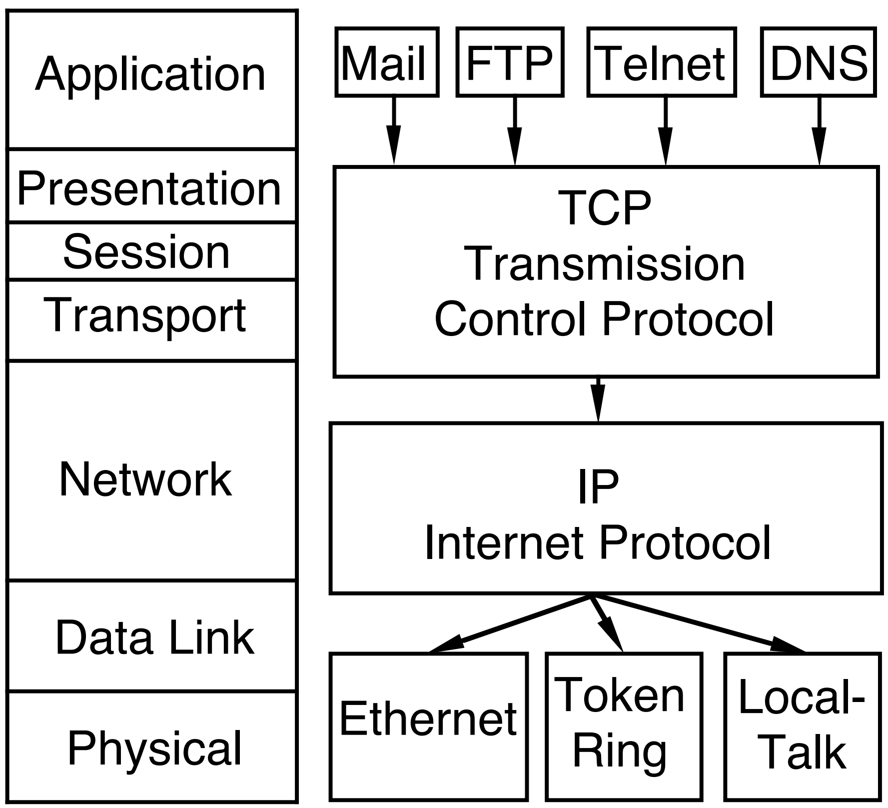
Internet Names and Addresses Cont'd.

- 128.138.244.9 : "dotted decimal notation"
- In the machine the IP address is a 32bit integer.
- Each "dot" separates a byte:
- 128.138.244.9 ↔ 808AF409



The TCP/IP Protocol Revisited

OSI Model | **TCP/IP Model** | **TCP/IP Functionality**



E-mail, file transfer, remote login, etc.
Domain name service

Establish, maintain, terminate session
Create datagrams (packets)
Ensure reliable, sequenced packet delivery
Support multiple sessions

Connectionless end-to-end delivery service
MAC addressing and routing to destination
Fragment datagrams as needed

Connectionless one-hop delivery service

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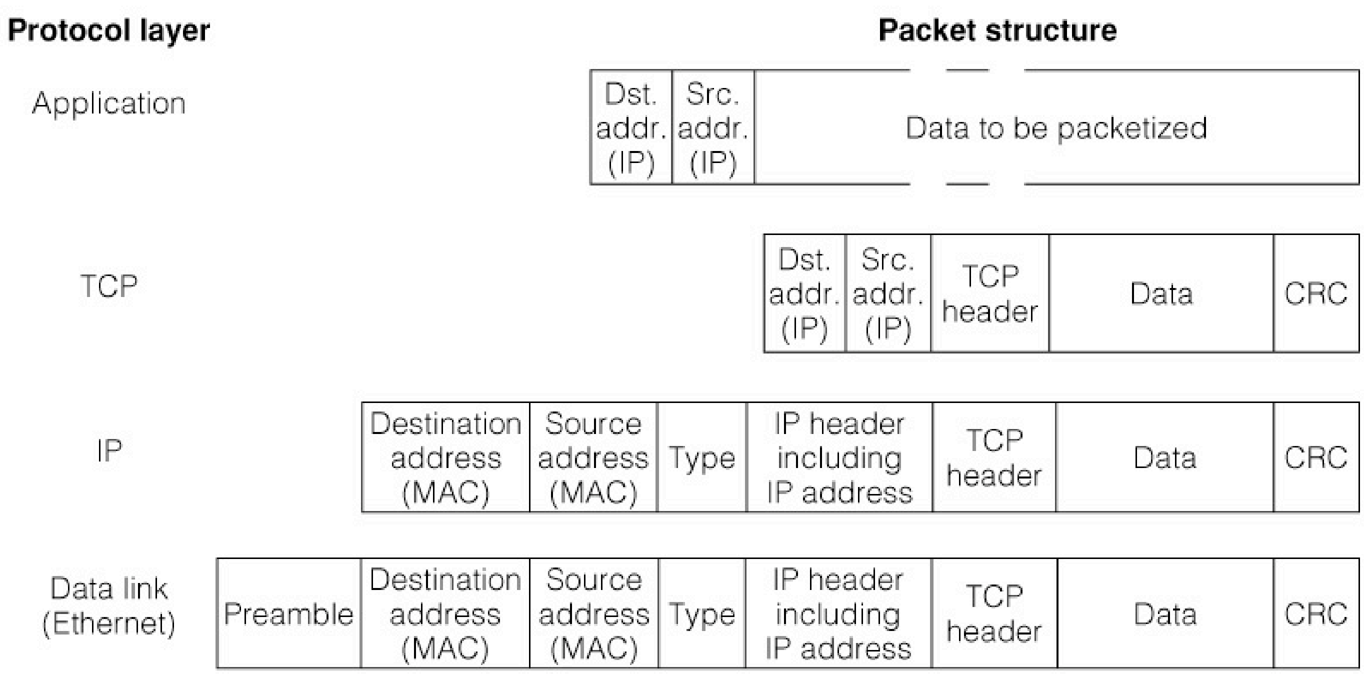
Fig 10.10 Data flow through the TCP/IP Protocol Stack



Each Layer adds/subtracts its own information:
Separation of Concerns/Principle of Abstraction

Fig 10.11 The Internet Routing Process (simplified)

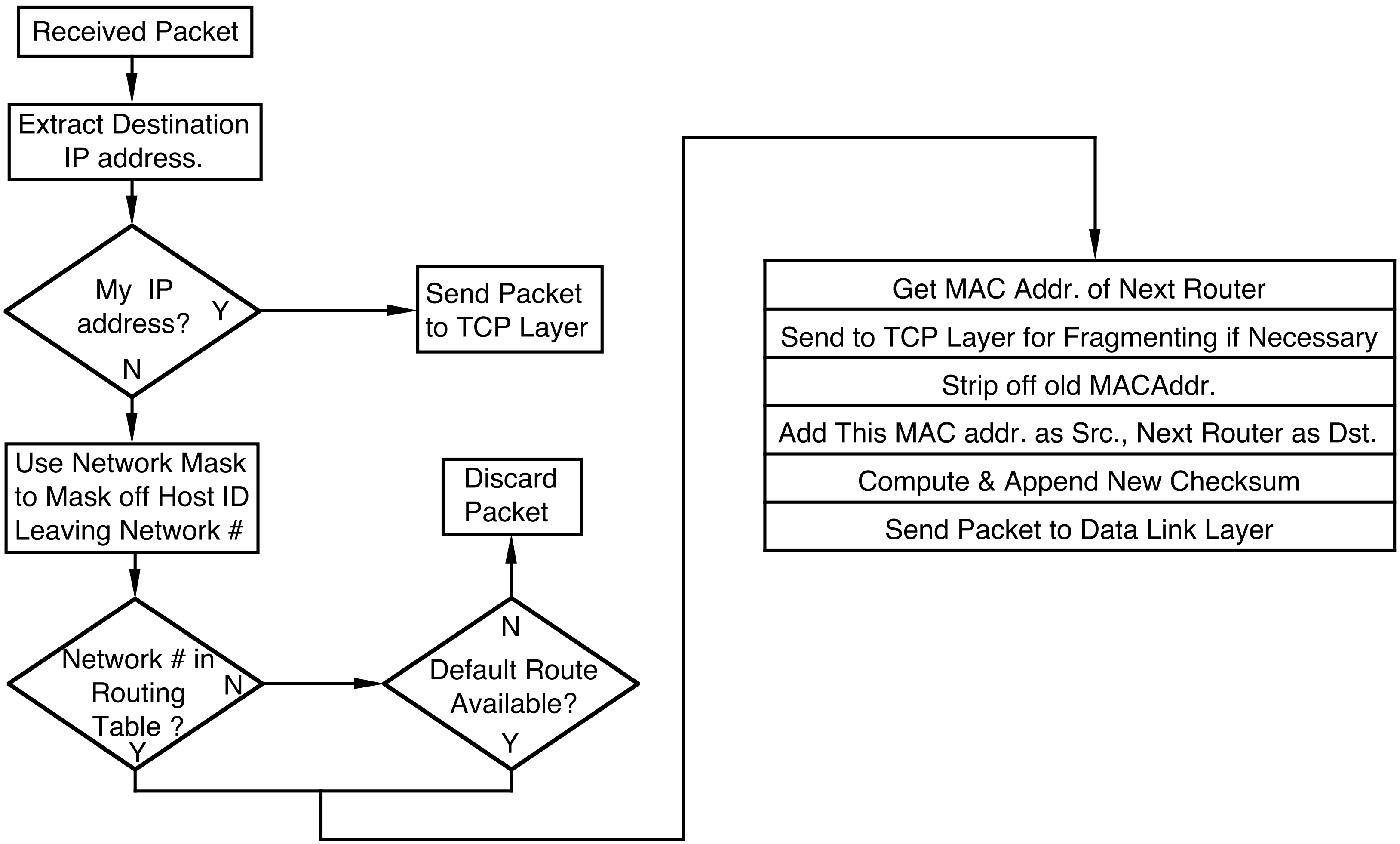


Table 10.4 Class A, B, and C Internet addresses

IP Address Class	Network#/Host# split	Network#
A (MSB = 0)	N.H.H.H	N.0.0.0
B (MSBs = 10)	N.N.H.H	N.N.0.0
C (MSBs = 110)	N.N.N.H	N.N.N.0

Fig 10.12 Class A, B, and C Internet Addresses

Network Addr. Range

IP Addr. Range

Class A

1.0.0.0 to 126.0.0.0

1.0.0.1 to 126.255.255.254

Class B

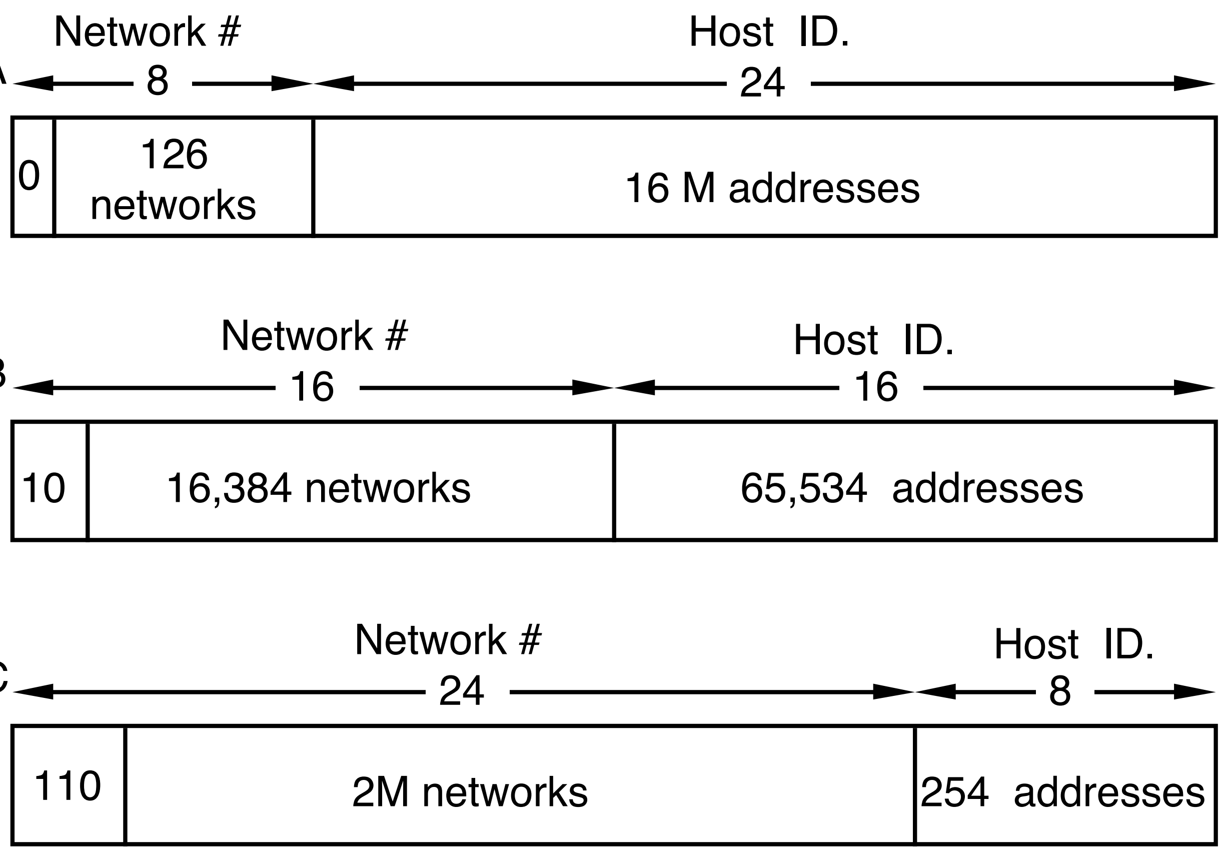
128.0.0.0 to 191.255.0.0

128.0.0.1 to 191.255.255.254

Class C

192.0.0.0 to 223.255.255.0

192.0.0.1 to 223.255.255.254



Subnets and subnetting

- The Internet routers outside colorado.edu care only about the network number, and do not care about the host ID. (It is masked off before routing)
- The routers inside colorado.edu are free to interpret the “host ID” number in any way they wish.
- CU might wish to have many LANs within its domain to cut down on traffic inside the domain.
- CU is free to program its routers to interpret part of the Host ID as a network number.

Fig 10.13 Example of a Class B Network with a 6-bit Subnet

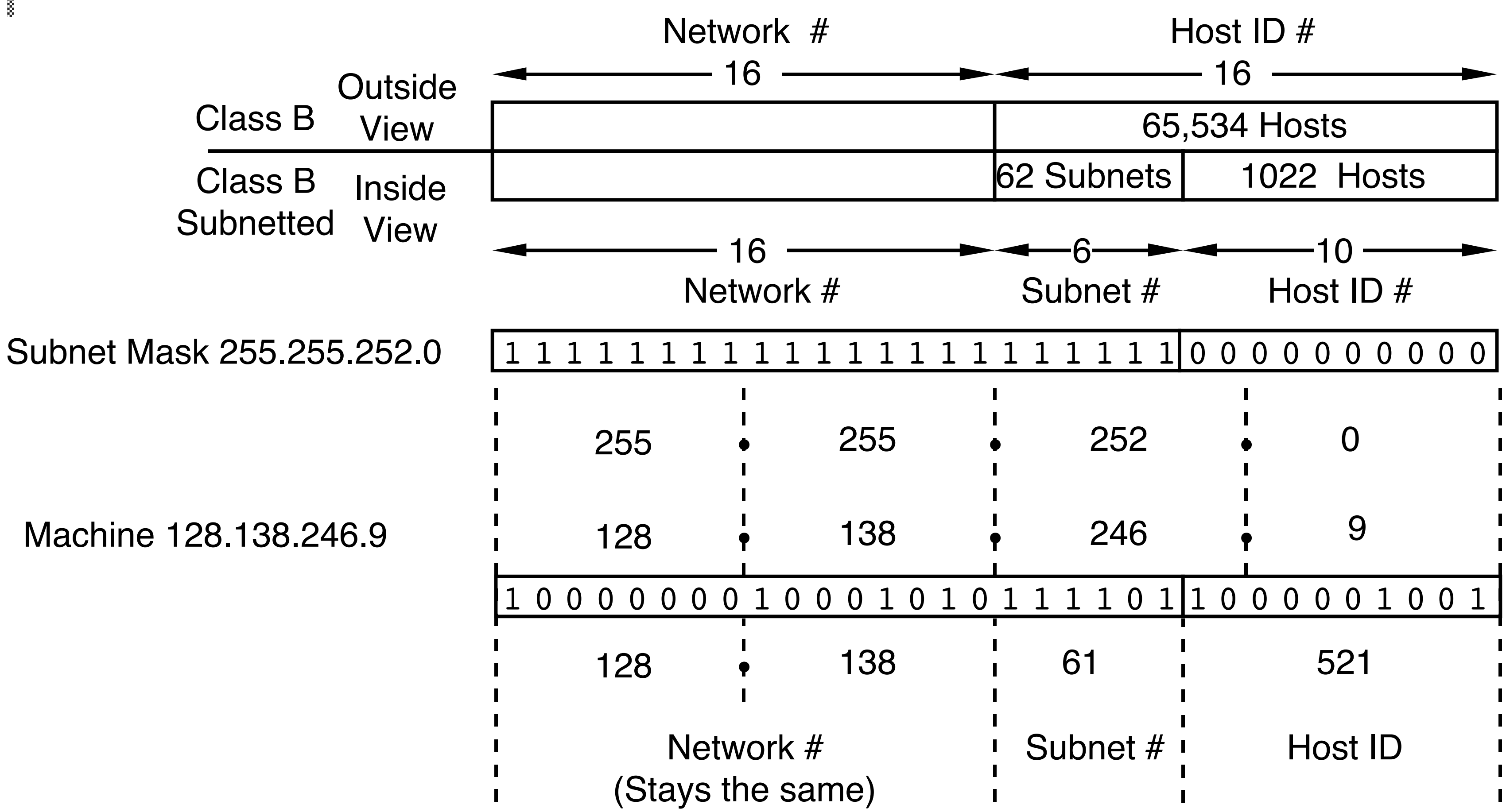
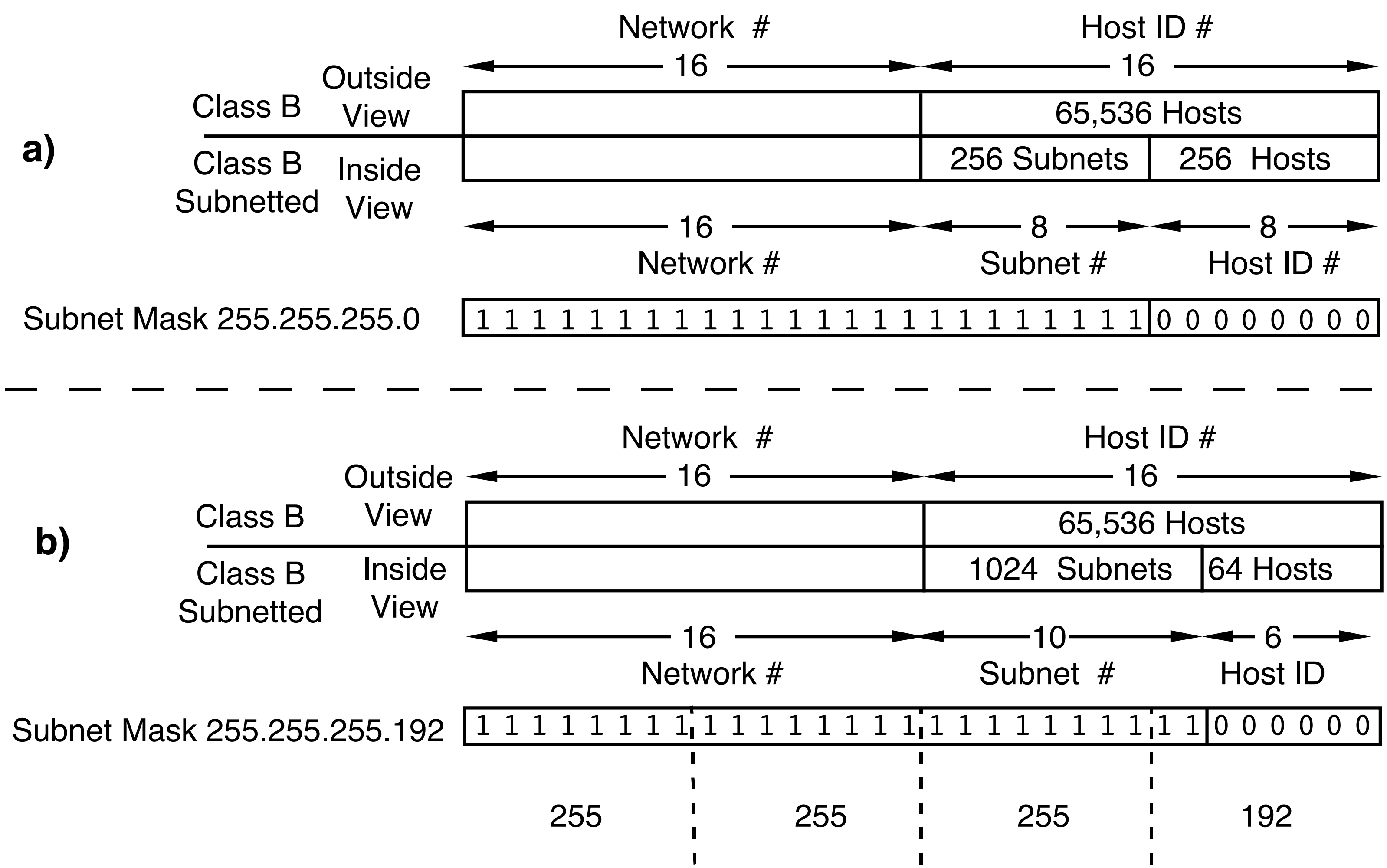


Fig 10.14 Subnetting a class B network
a) an 8-bit subnet address
b) a 10-bit subnet address



IP Address Space is Wasted by the Class A, B, C Scheme, and by Static IP Addresses

- Class A, B, and C addressing wastes space:
  - Each of the 126 class A networks consumes 16 million IP addresses, yet no single entity can use this many addresses.
  - Each class B network consumes 65,534 IP addresses, yet most class B networks do not nead nearly that many.
  - Likewise each class C network consumes 254 IP addresses.
- Static IP addresses waste space:
  - When a permanent, or *Static* IP address is assigned to a machine, that address is unavailable to others even if the given machine is off-line, retired from service, etc.

C S D A 2/e

One Way of Regaining Lost IP Address Space: CIDR

- CIDR, Classless Internet Domain Routing, does away with the class A, B, C system, replacing it with a system that uses the first n bits as the network number, where n can be between 13 and 27:

CIDR Block Prefix#	**Equivalent Class C**	**# of Host Addresses**
/27	1/8th of a Class C	32 hosts
/26	1/4th of a Class C	64 hosts
/25	1/2 of a Class C	128 hosts
/24	1 Class C	256 hosts
/23	2 Class C	512 hosts
/22	4 Class C	1,024 hosts
. . .		
/16	256 Class C	65,536 hosts(= 1 Class B)
/15	512 Class C	131,072 hosts
/14	1,024 Class C	262,144 hosts
/13	2,048 Class C	524,288 hosts

For example, in the CIDR address 206.13.01.48/25, the "/25" indicates the first 25 bits are used to identify the unique network leaving the remaining bits to identify the specific host.

Two Ways of Making IP Addresses Go Further

- NAT, Network Address Translation, uses a router to generate "fictitious" IP addresses within a domain, and translates one external IP address to one of the fictitious addresses internally, assigning each internal machine one of these unique addresses.
  - The address ranges 10.0.0.0/8, 172.16.0.0/12, and 192.168.0.0/16 are permanently unassigned and are available for use in NAT applications.
- DHCP, Dynamic Host Configuration Protocol, assigns a temporary IP address to a machine when it first comes on line. When the computer goes off line that address is reclaimed and can be assigned to another machine.
- Both can be used in concert. For example, a household computing system with a high-speed DSL or Cable Modem connection may have only one external IP address, but the DSL router or cable modem translates that address to an internally unique address in one of the ranges above, and assigns it as needed using DHCP.

CSDA 2/e

Internet Futures

- CIDR, NAT, and DHCP only postpone the inevitable. The current 32-bit IP address is inadequate to handle future needs.
- There are several proposals to expand IP address space, the most likely to be widely adopted is "IPv6," Internet Protocol version 6.
- IPv6 extends the address from 32-bits to 128-bits. Not only does this provide more than enough address space for the forseeable future, it also provides several additional features
  - Removes the need for NAT and DHCP, so each device may have its own externally-visible address.
  - Increased security
  - Routing information included in header
  - Header can contain information about quality of service
- Perhaps in the future wall plugs and wrist watches will have IP addresses!

