INTERNETWORKING TUTORIAL

Juan-Pablo Cáceres

Network Musical Performance Workshop

Technical and Artistic Strategies to Perform Around the Globe

Center for Computer Research in Music and Acoustics (CCRMA)
Stanford University

What is a NETWORK?

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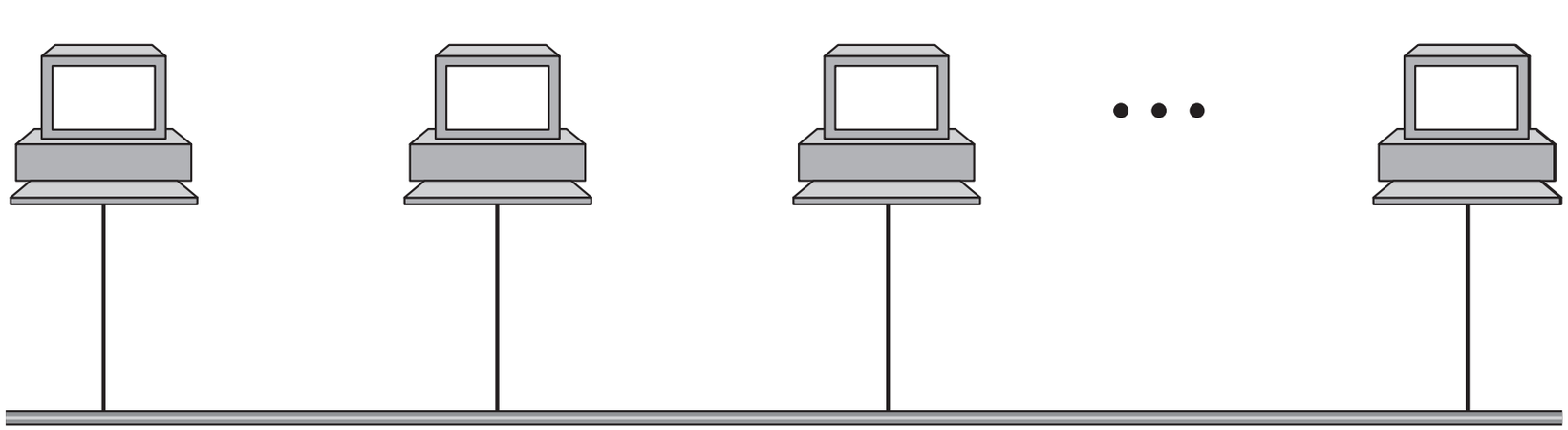
Direct Links

point-to-point



multiple-access

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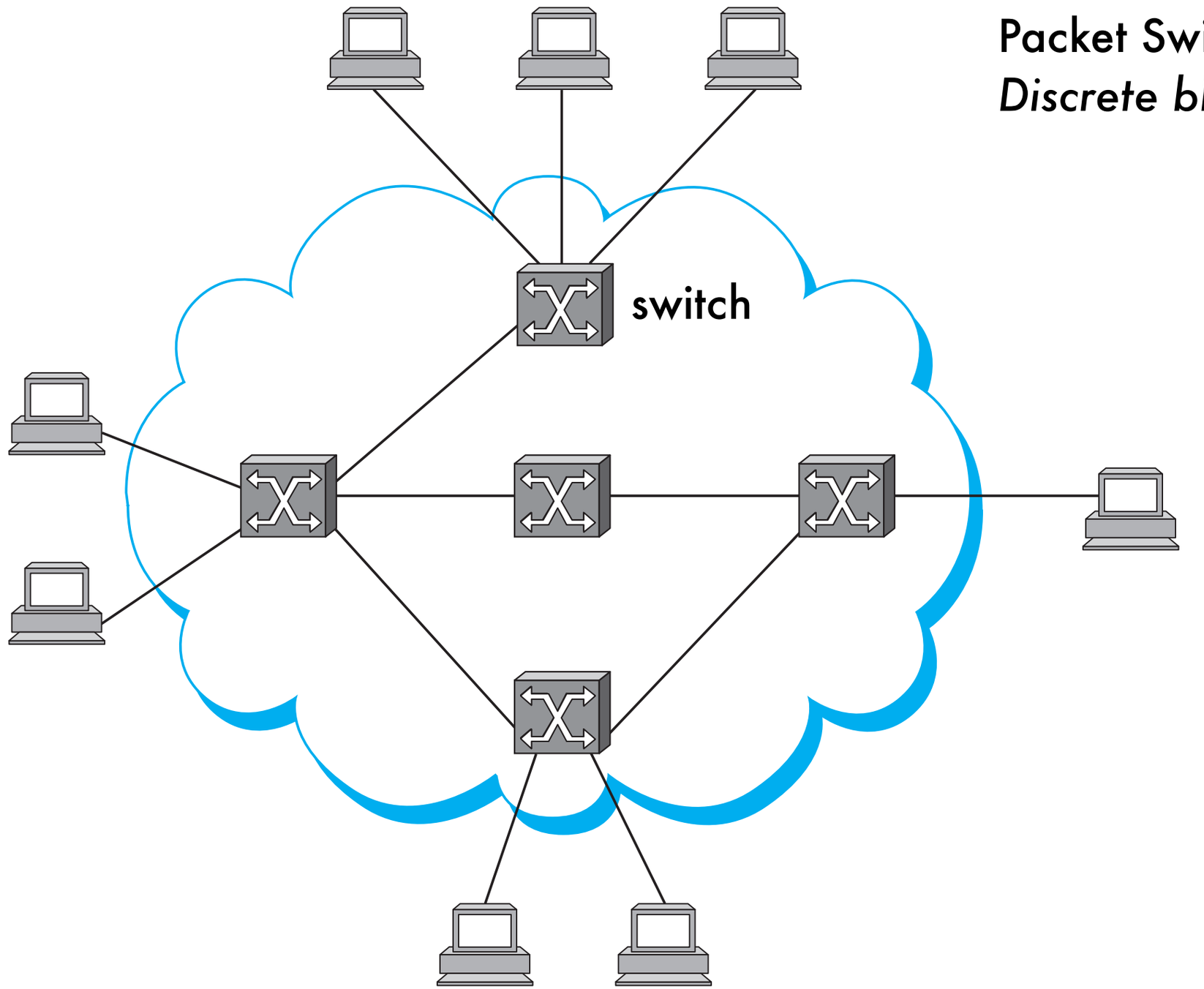
Switched Network



Packet Switched

Discrete blocks of data

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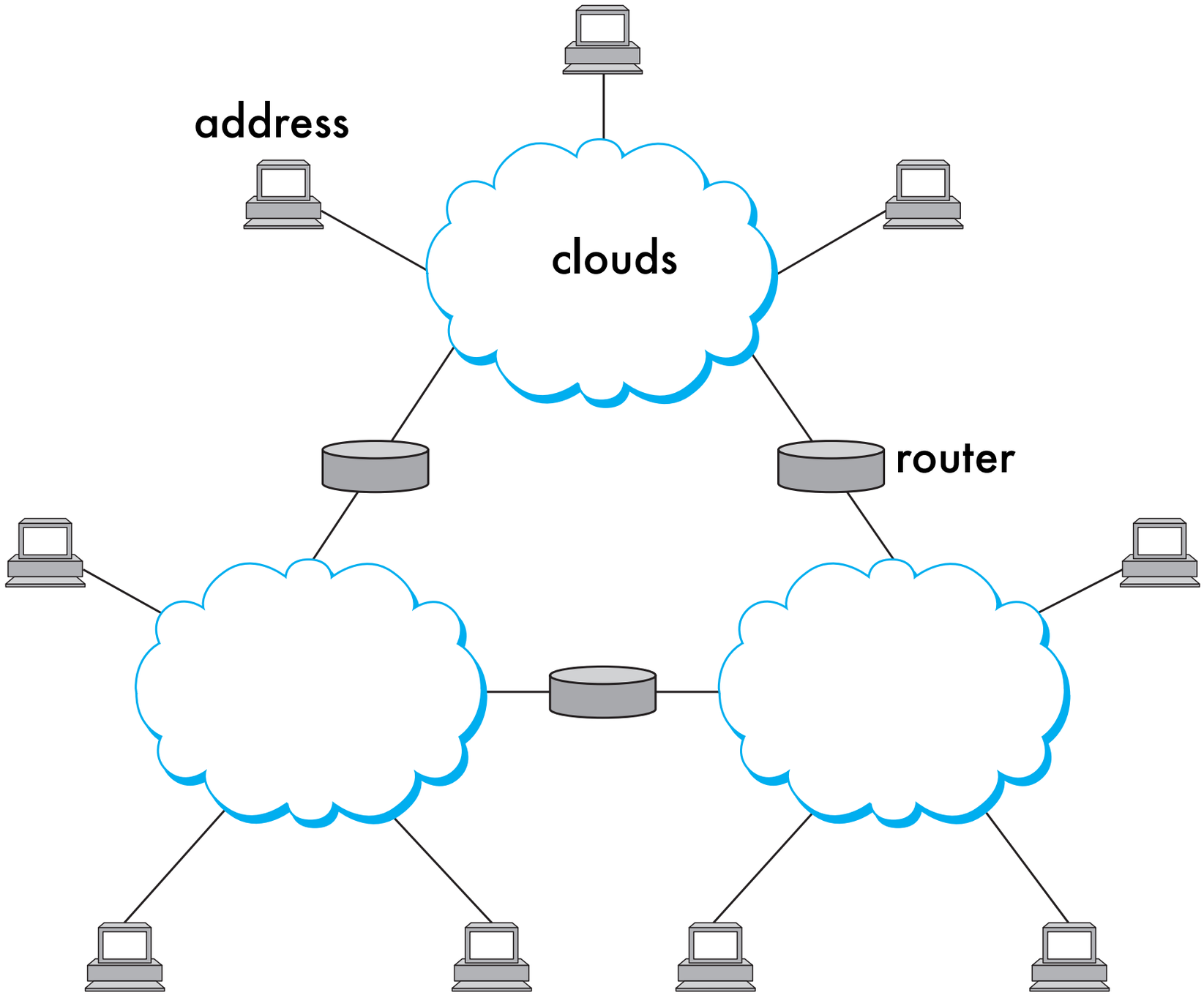
Internetwork



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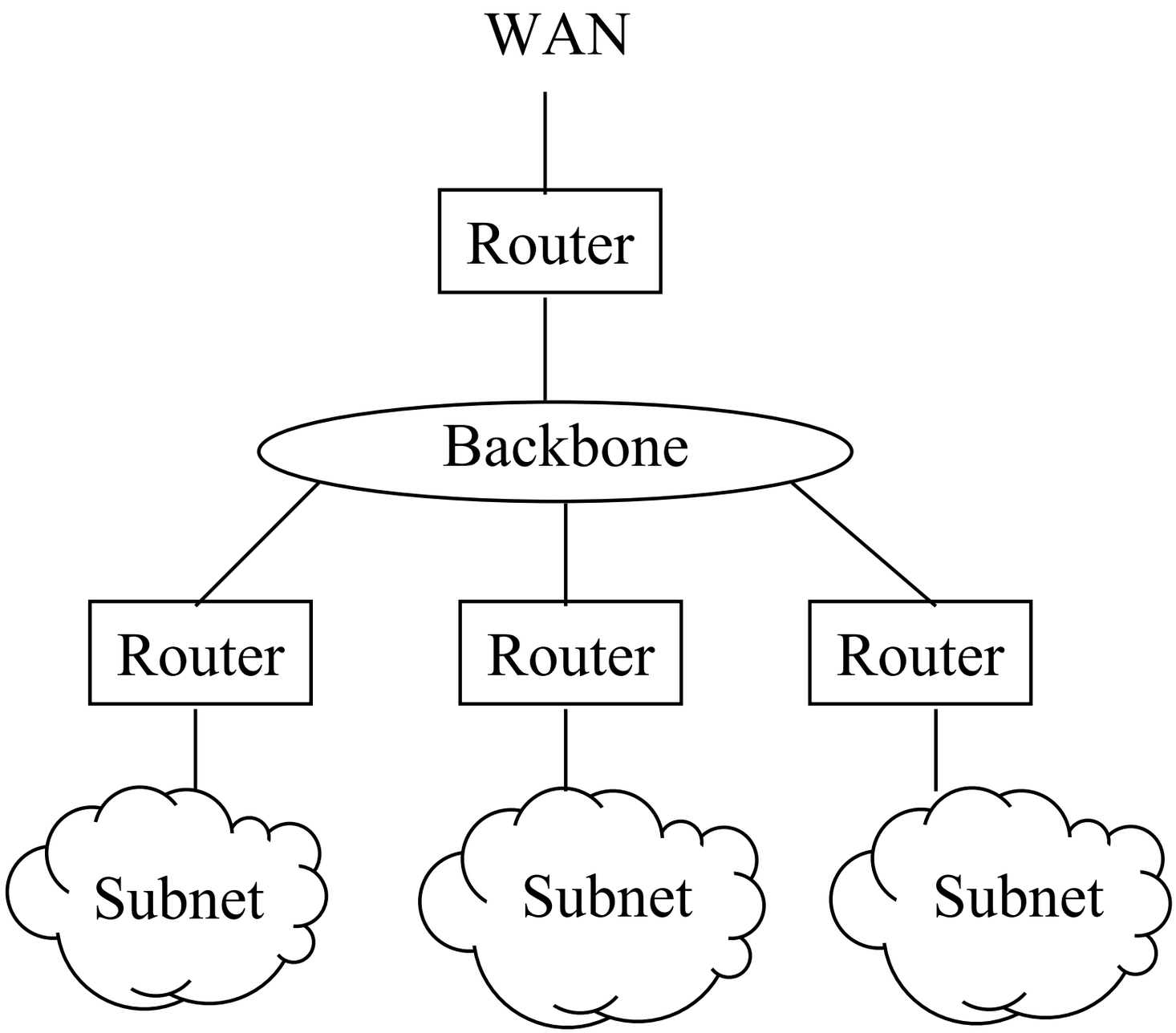
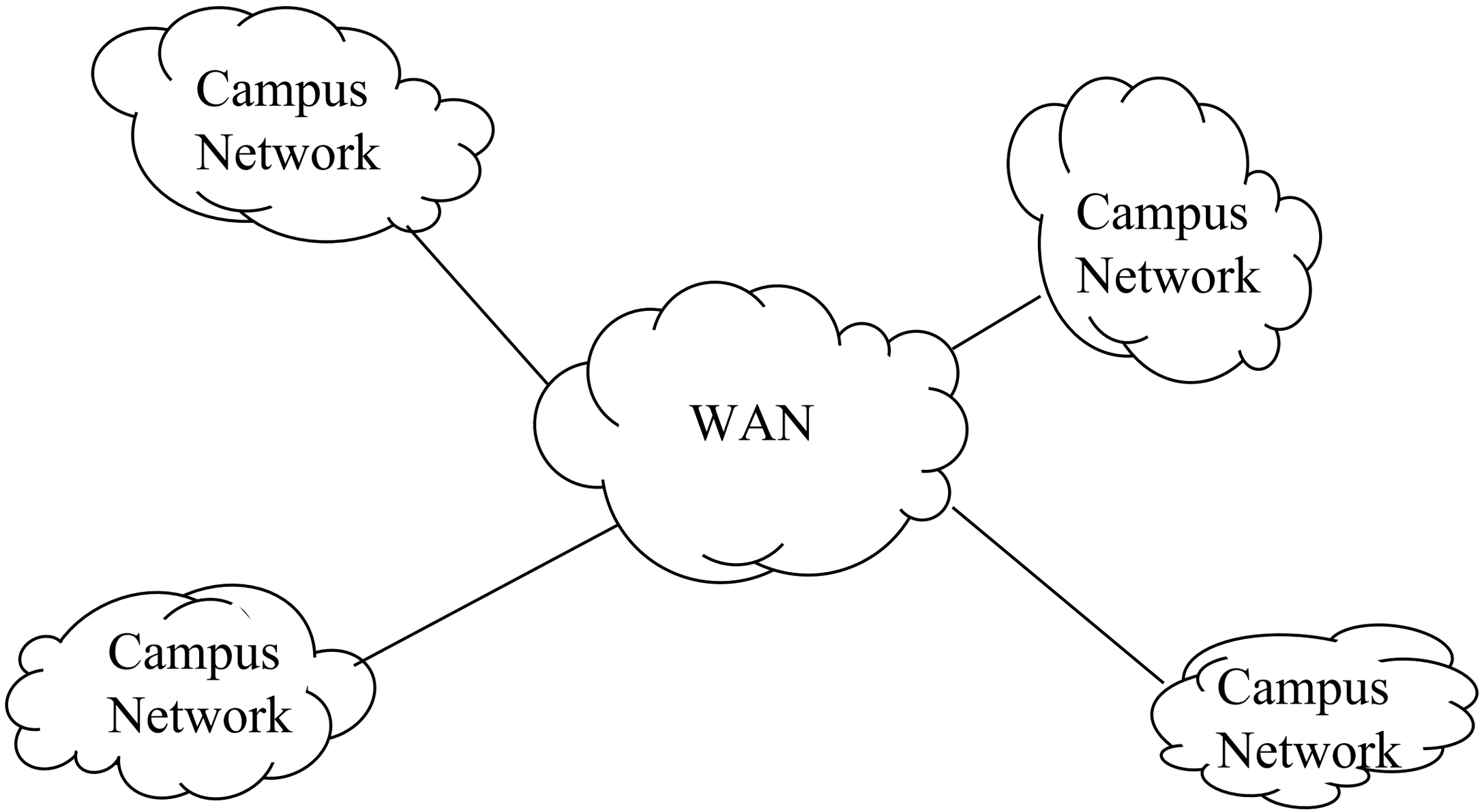
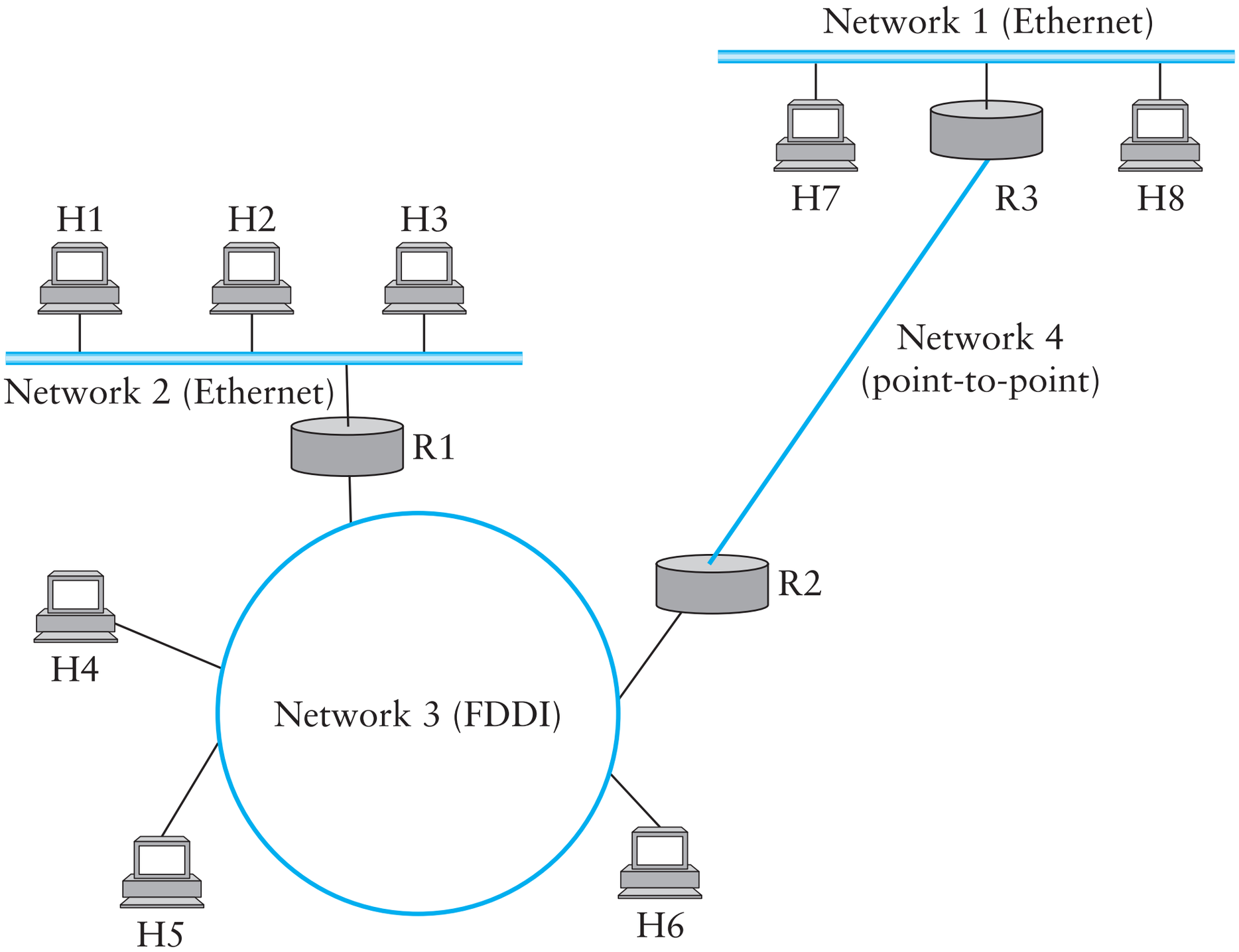
Typical Campus Network Infrastructure



Global Network Infrastructure



Simple Internetworking



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Demo: *traceroute*

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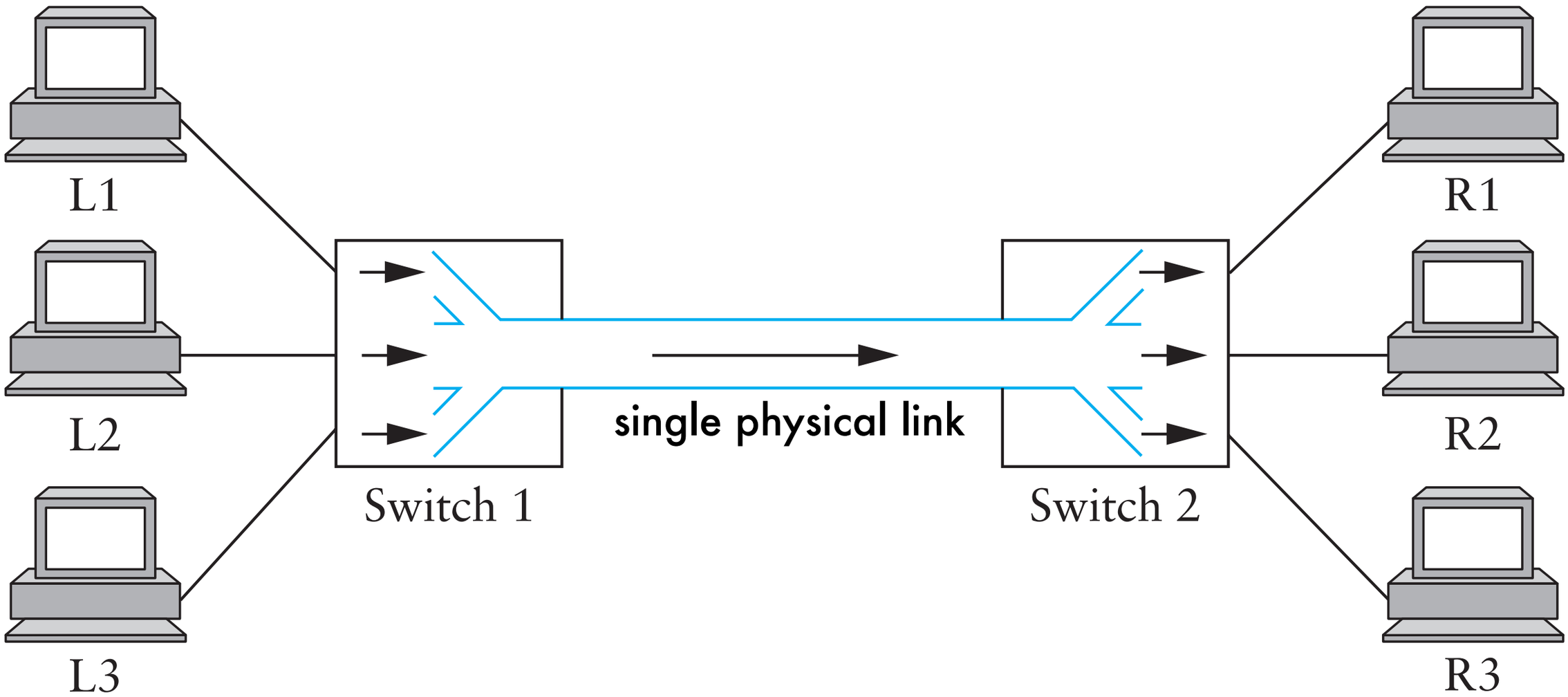
Multiplexing



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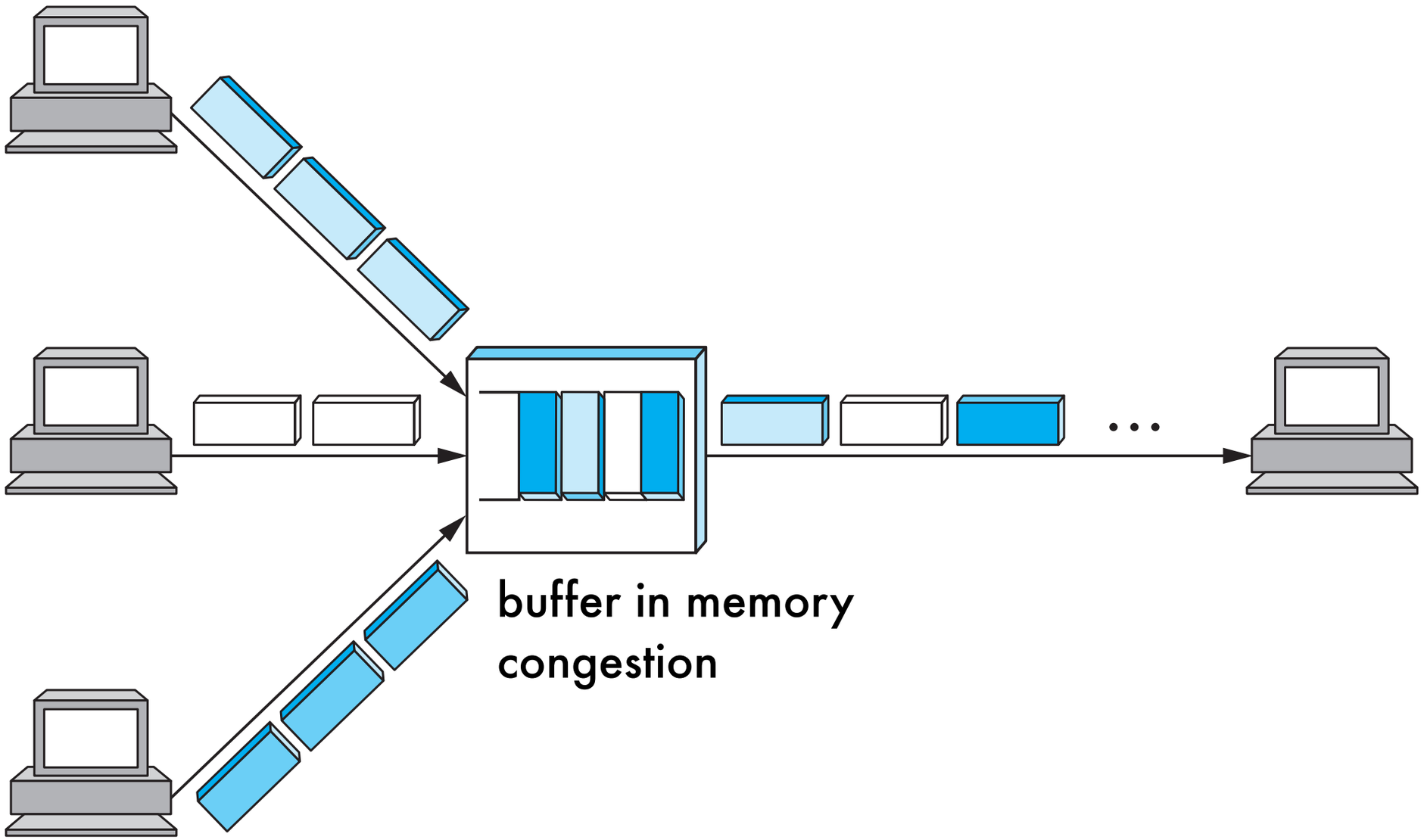
Switch Multiplexing Packets



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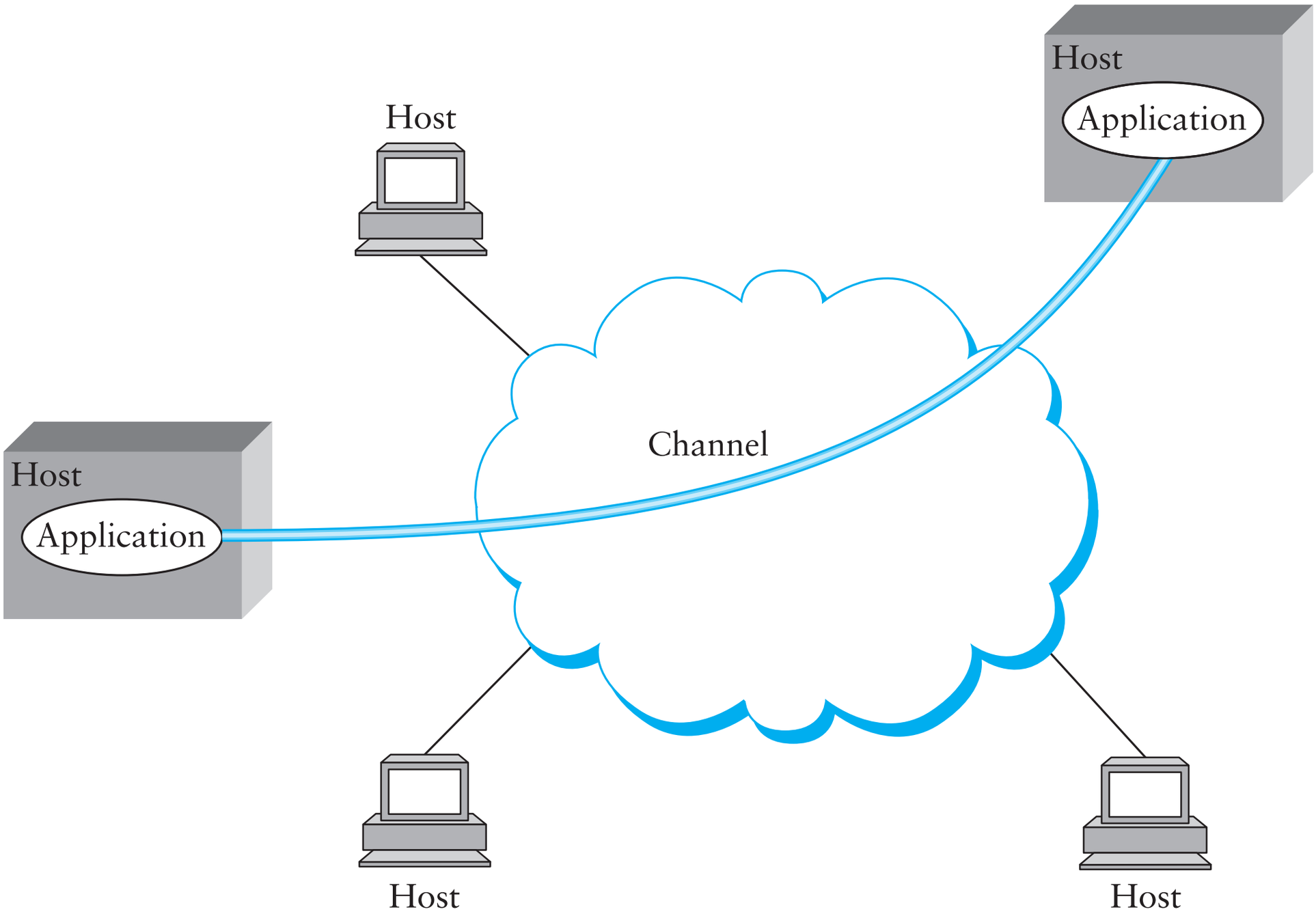
Process Communication



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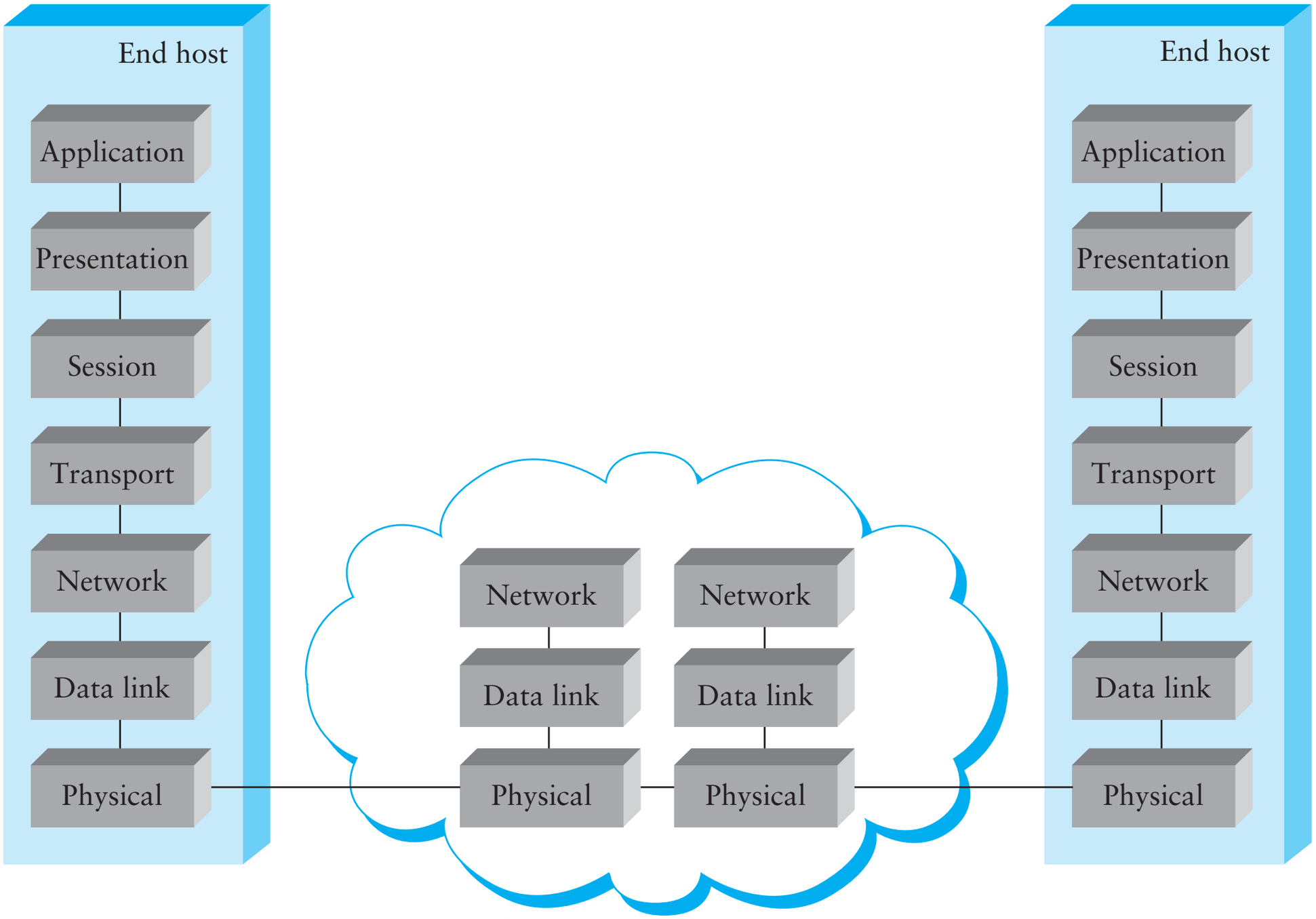
Open Systems Interconnection (OSI) Architecture



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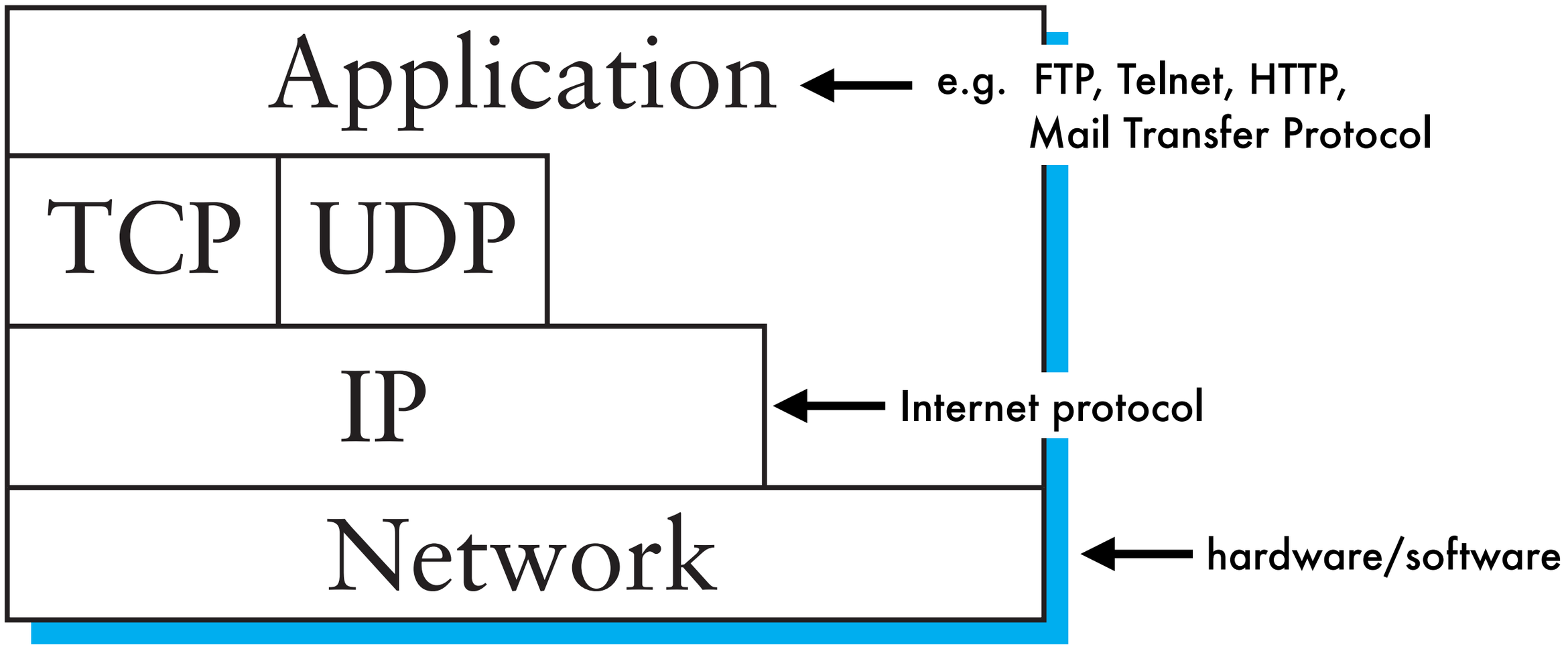
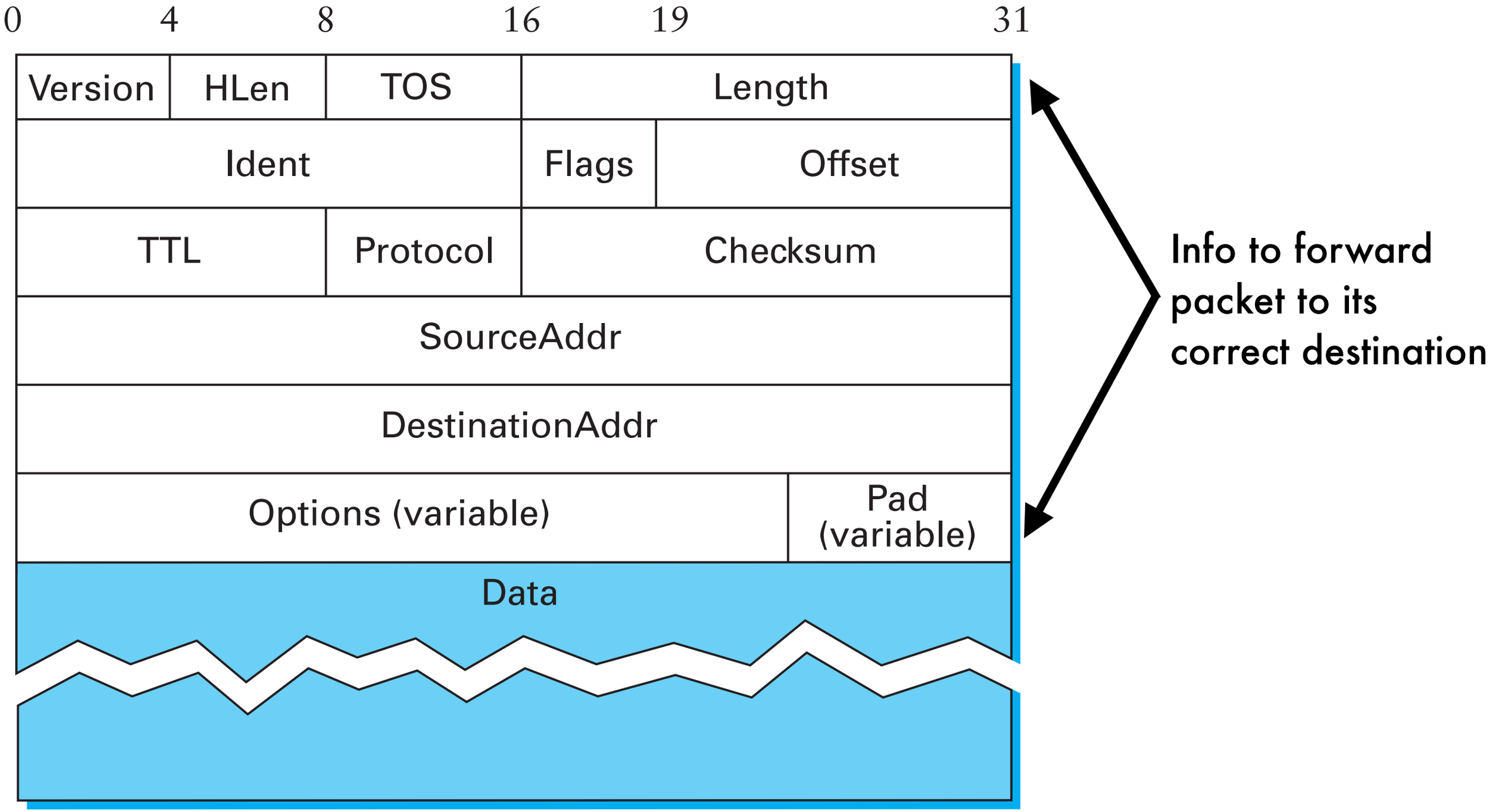
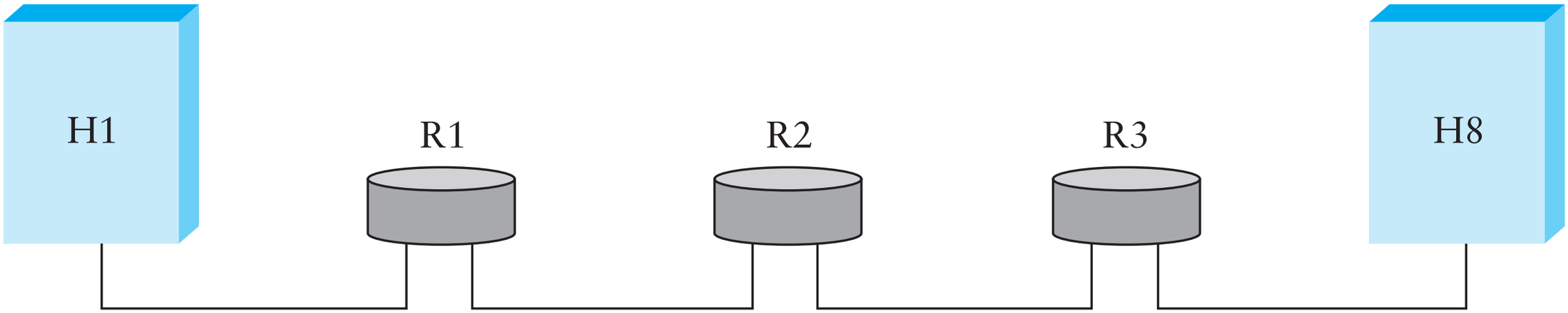
Internet: TCP/IP Architecture



Datagram Delivery and Packer Format (IPv4)



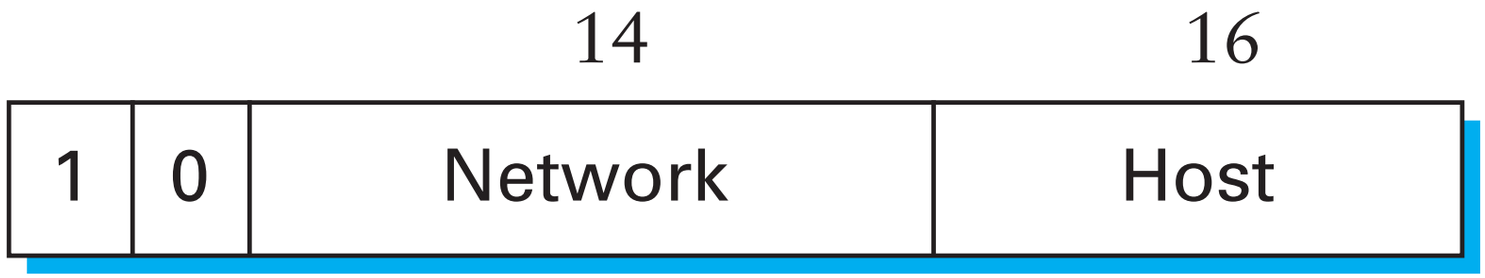
Fragmentation



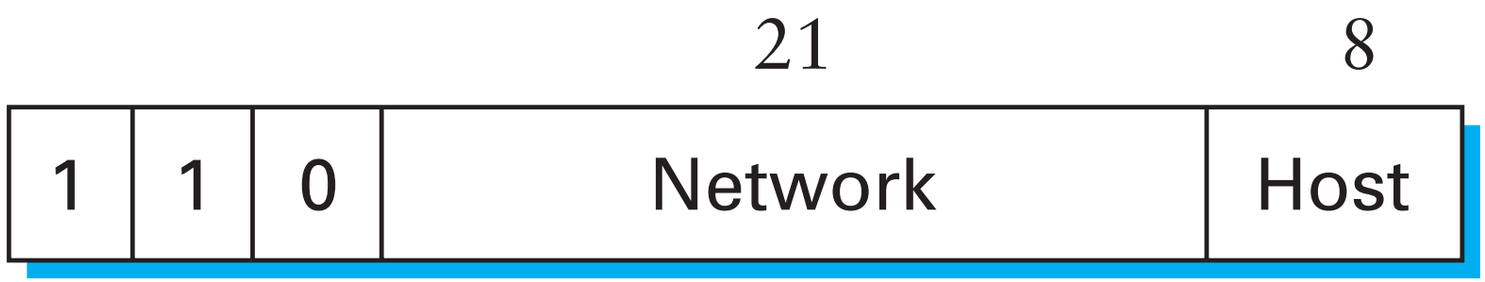
IP Global Addresses (32 bits)

Classes | Network Sizes

← class a



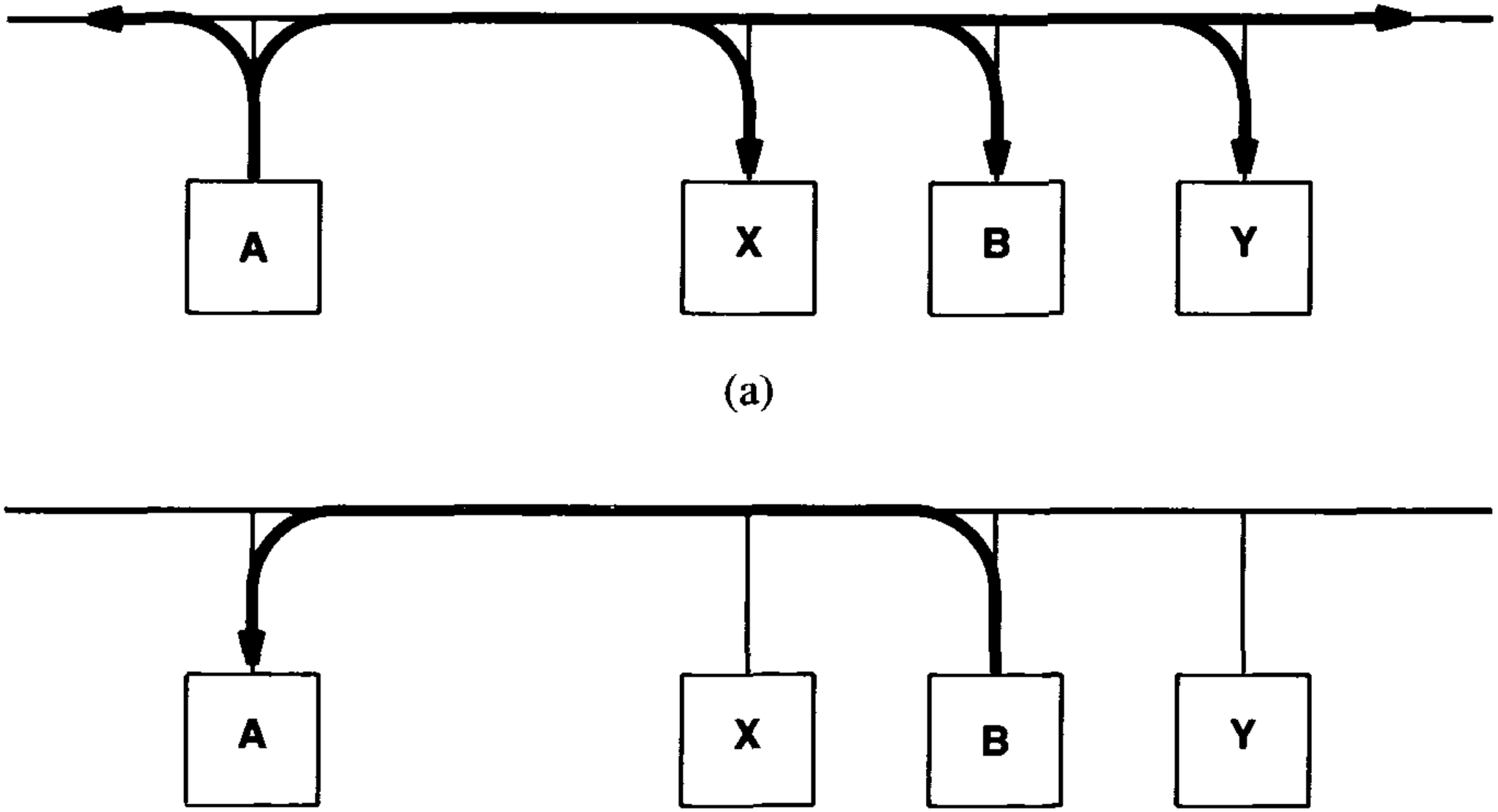
← class b



← class c

ARP: IP to Physical Address

Address Resolution Protocol



Localhost (loopback)

127.0.0.1

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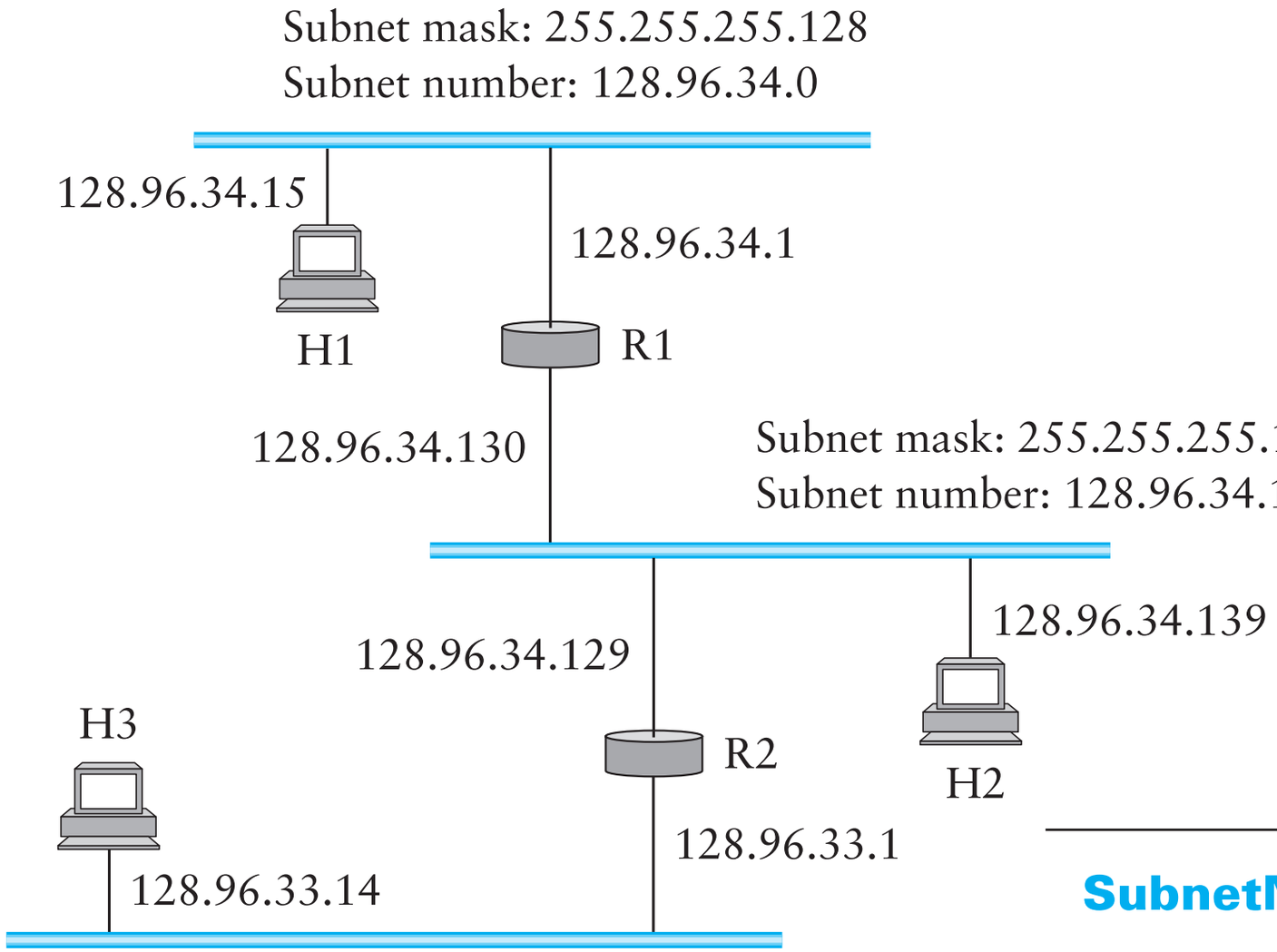
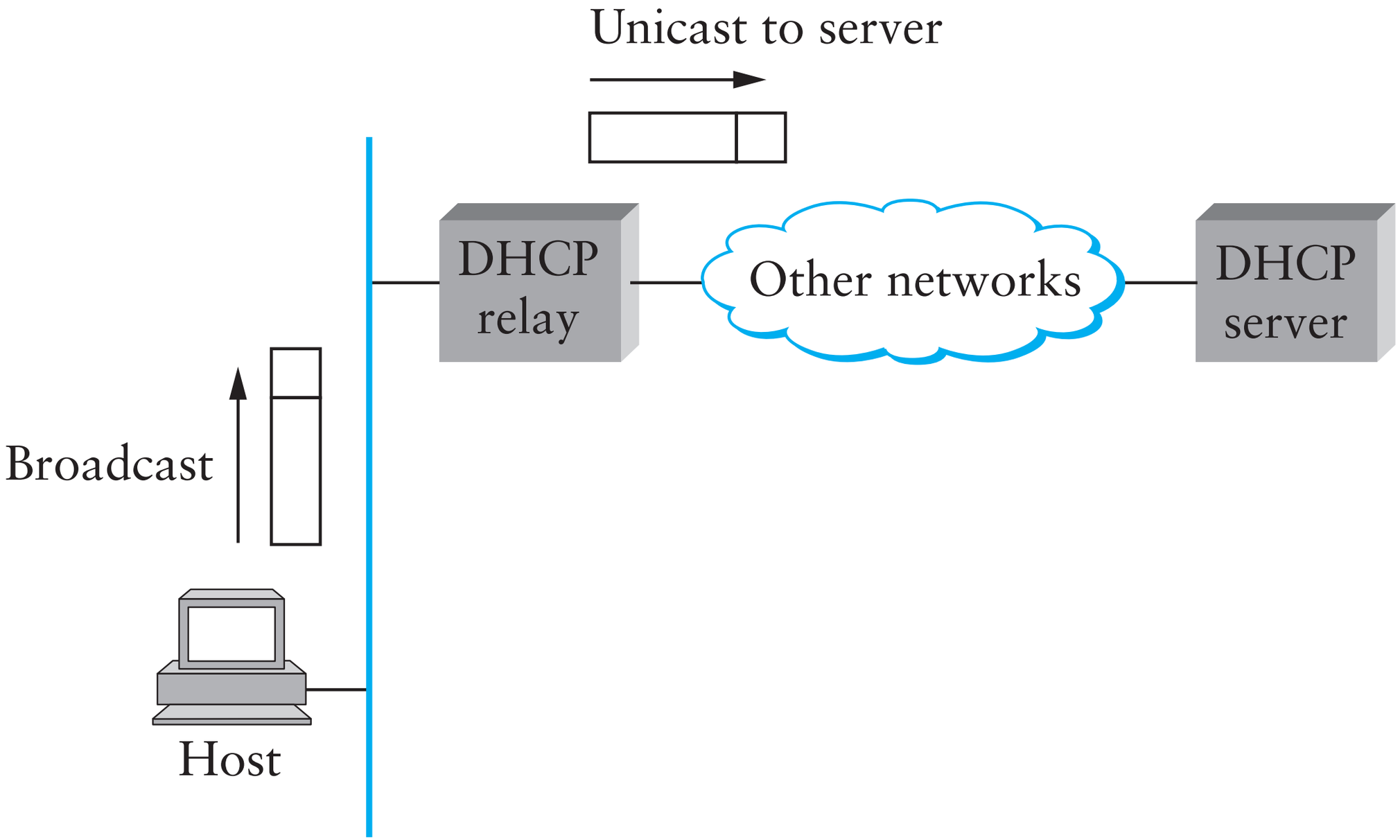
SUBNETS (scalability)
Local Addresses and Forwarding



SubnetNumber	SubnetMask	NextHop
128.96.34.0	255.255.255.128	Interface 0
128.96.34.128	255.255.255.128	Interface 1
128.96.33.0	255.255.255.0	R2

Dynamic Host Configuration Protocol (DHCP)



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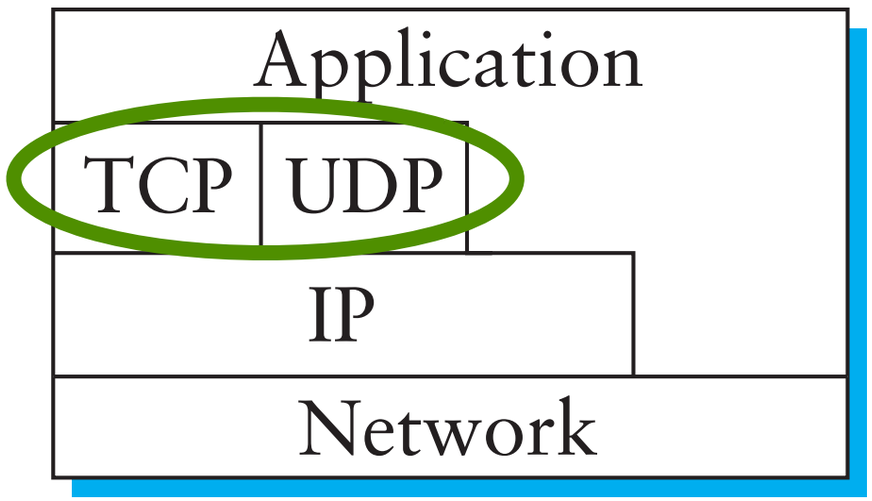
End-to-End Protocols



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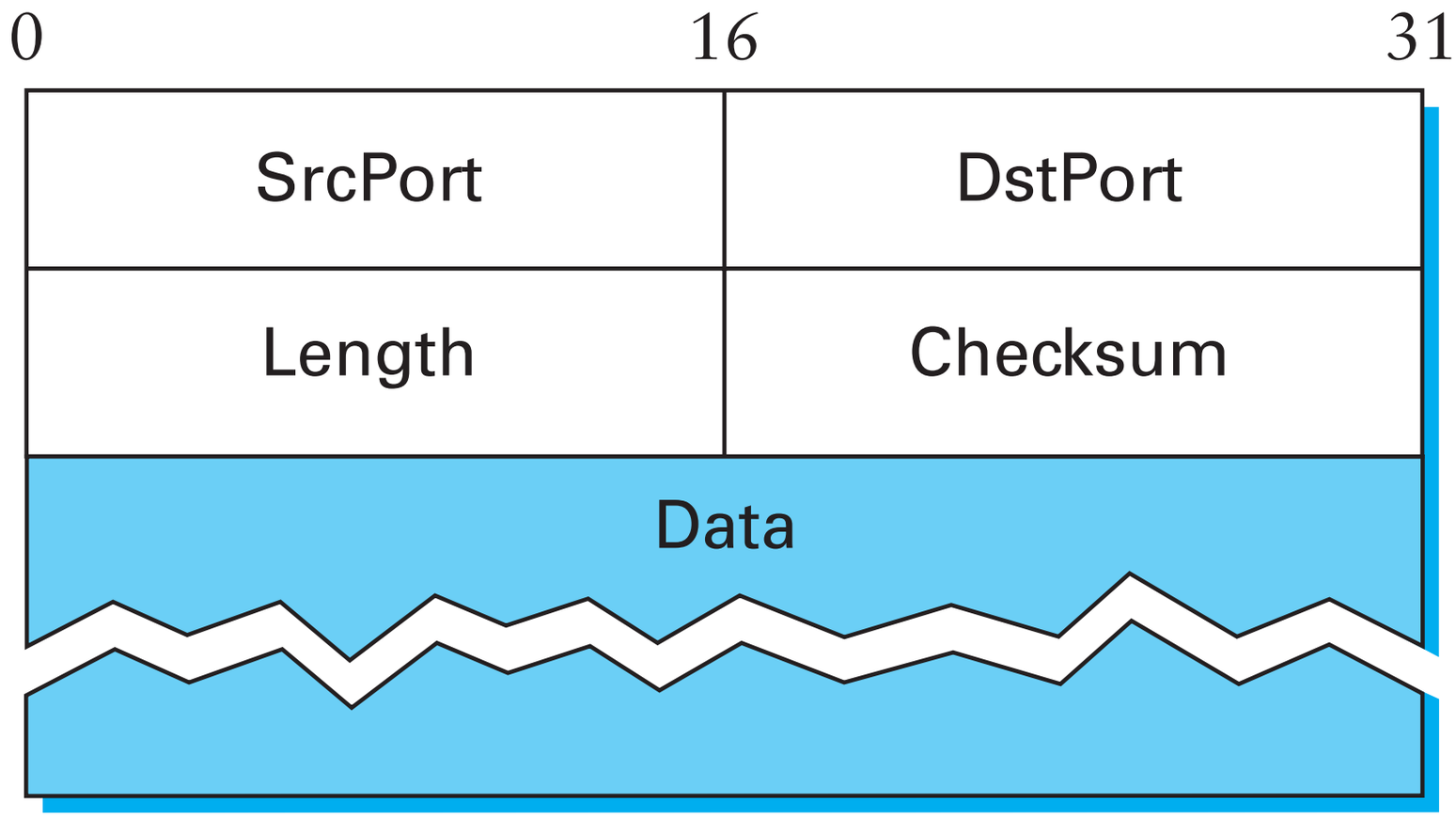
User Datagram Protocol (UDP)

Unreliable Datagrams (like postal mail)

- *no acknowledgment*
- *ports to distinguish between applications*



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UDP (Comer's definition)

The User Datagram Protocol (UDP) provides an unreliable connectionless delivery service using IP to transport messages between machines. It uses IP to carry messages, but adds the ability to distinguish among multiple destinations within a given host computer.

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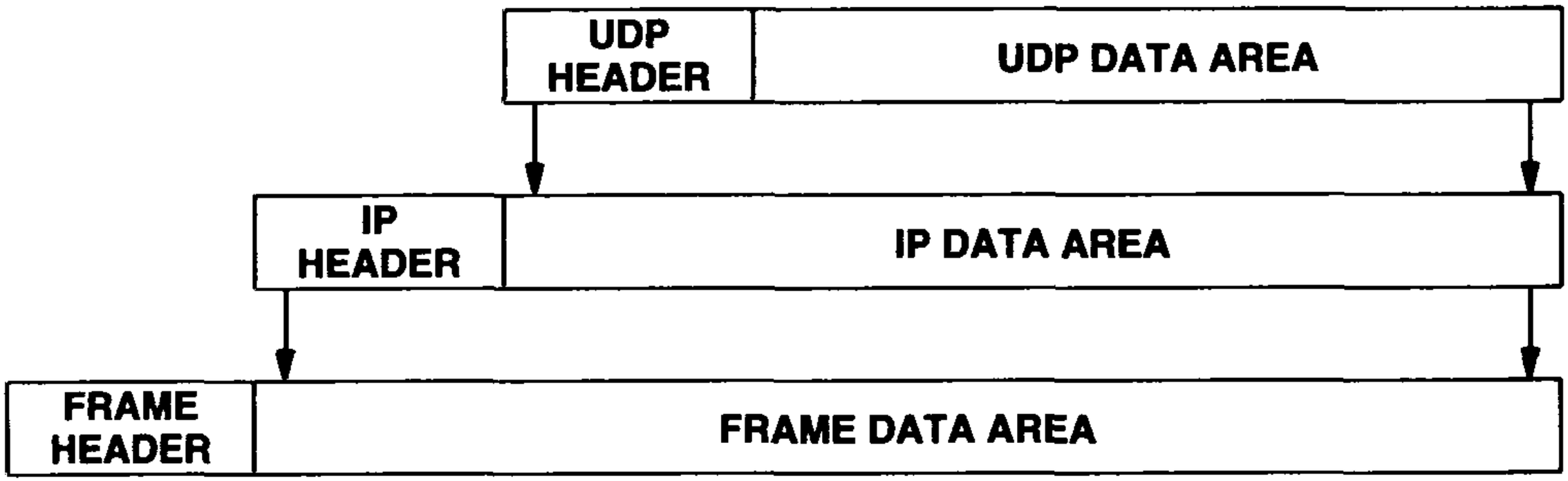
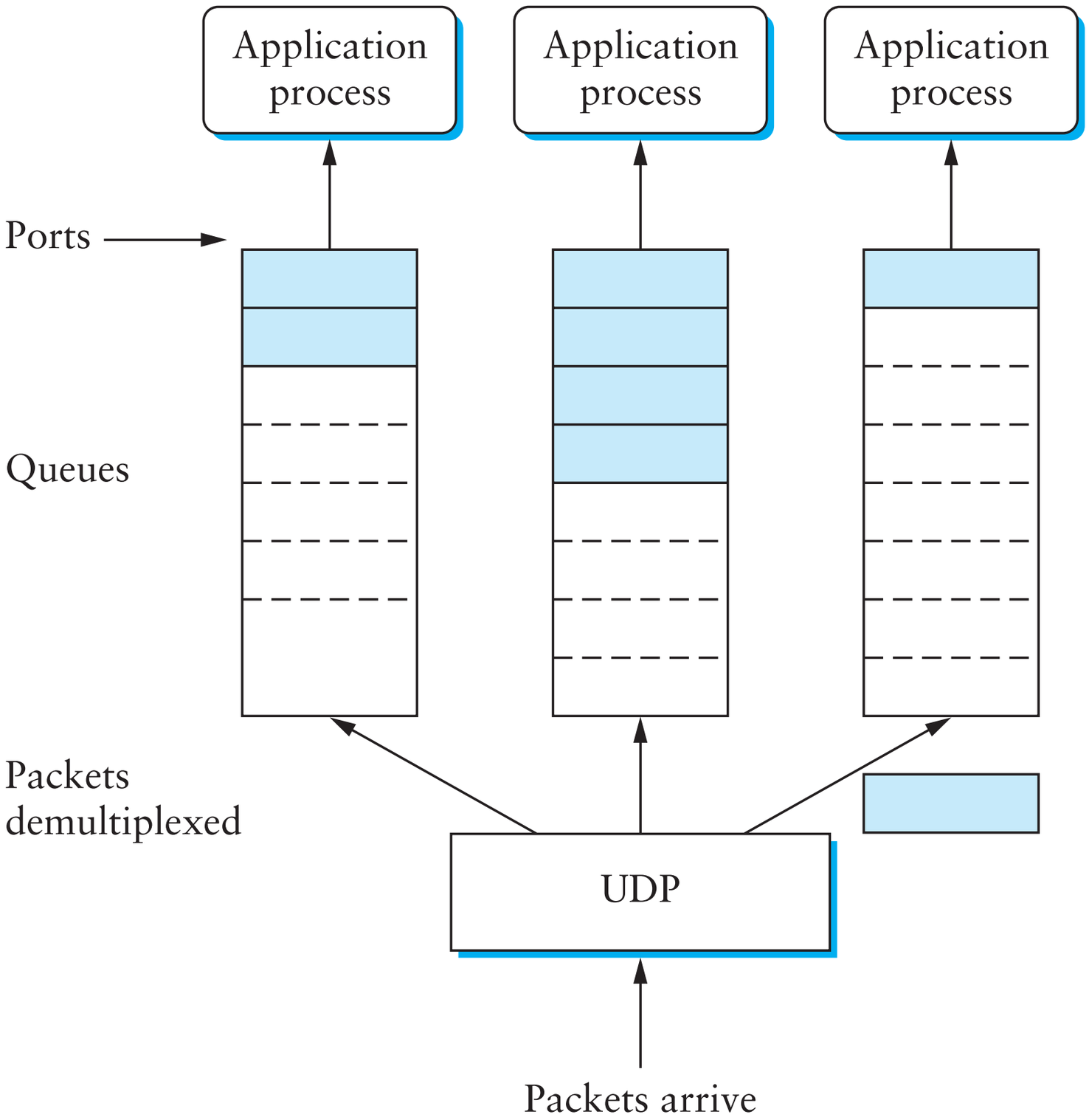
Encapsulation



Ports and Demultipexing



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Reserved Ports

Decimal	Keyword	UNIX Keyword	Description
0	-	-	Reserved
7	ECHO	echo	Echo
9	DISCARD	discard	Discard
11	USERS	systat	Active Users
13	DAYTIME	daytime	Daytime
15	-	netstat	Network status program
17	QUOTE	qotd	Quote of the Day
19	CHARGEN	chargen	Character Generator
37	TIME	time	Time
42	NAMESERVER	name	Host Name Server
43	NICNAME	whois	Who Is
53	DOMAIN	nameserver	Domain Name Server
67	BOOTPS	bootps	BOOTP or DHCP Server
68	BOOTPC	bootpc	BOOTP or DHCP Client
69	TFTP	tftp	Trivial File Transfer
88	KERBEROS	kerberos	Kerberos Security Service
111	SUNRPC	sunrpc	Sun Remote Procedure Call
123	NTP	ntp	Network Time Protocol
161	-	snmp	Simple Network Management Proto
162	-	snmp-trap	SNMP traps
512	-	biff	UNIX comsat
513	-	who	UNIX rwho daemon
514	-	syslog	System log
525	-	timed	Time daemon

Transmission Control Protocol (TCP)

Reliable

Byte-stream oriented (as opposed to Datagram oriented)

Virtual Circuit Connection

Buffered Transfer

Unstructured Stream

Full Duplex Connection

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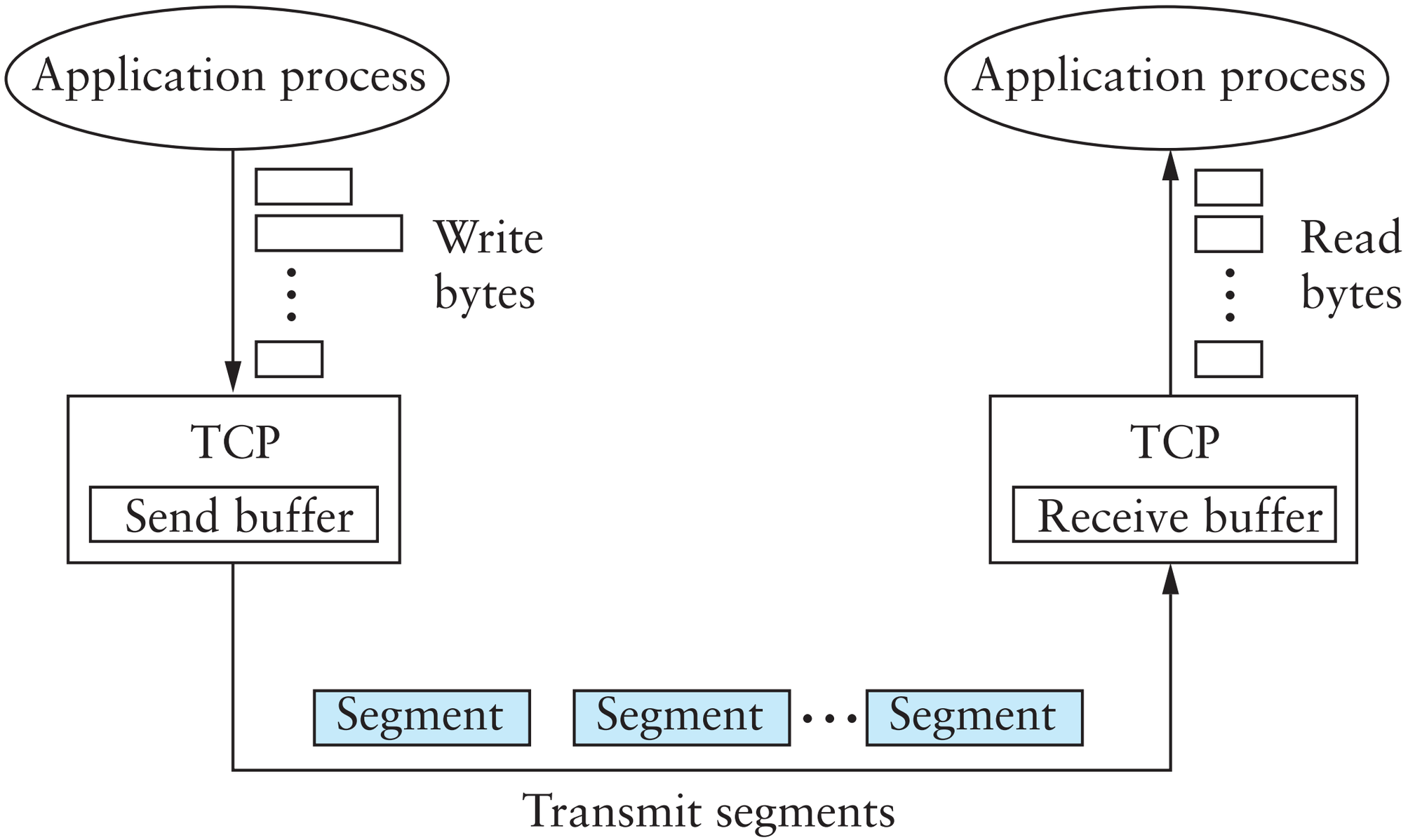
Transmission Control Protocol (TCP)

Reliable
Byte-stream oriented (as opposed to Datagram oriented)



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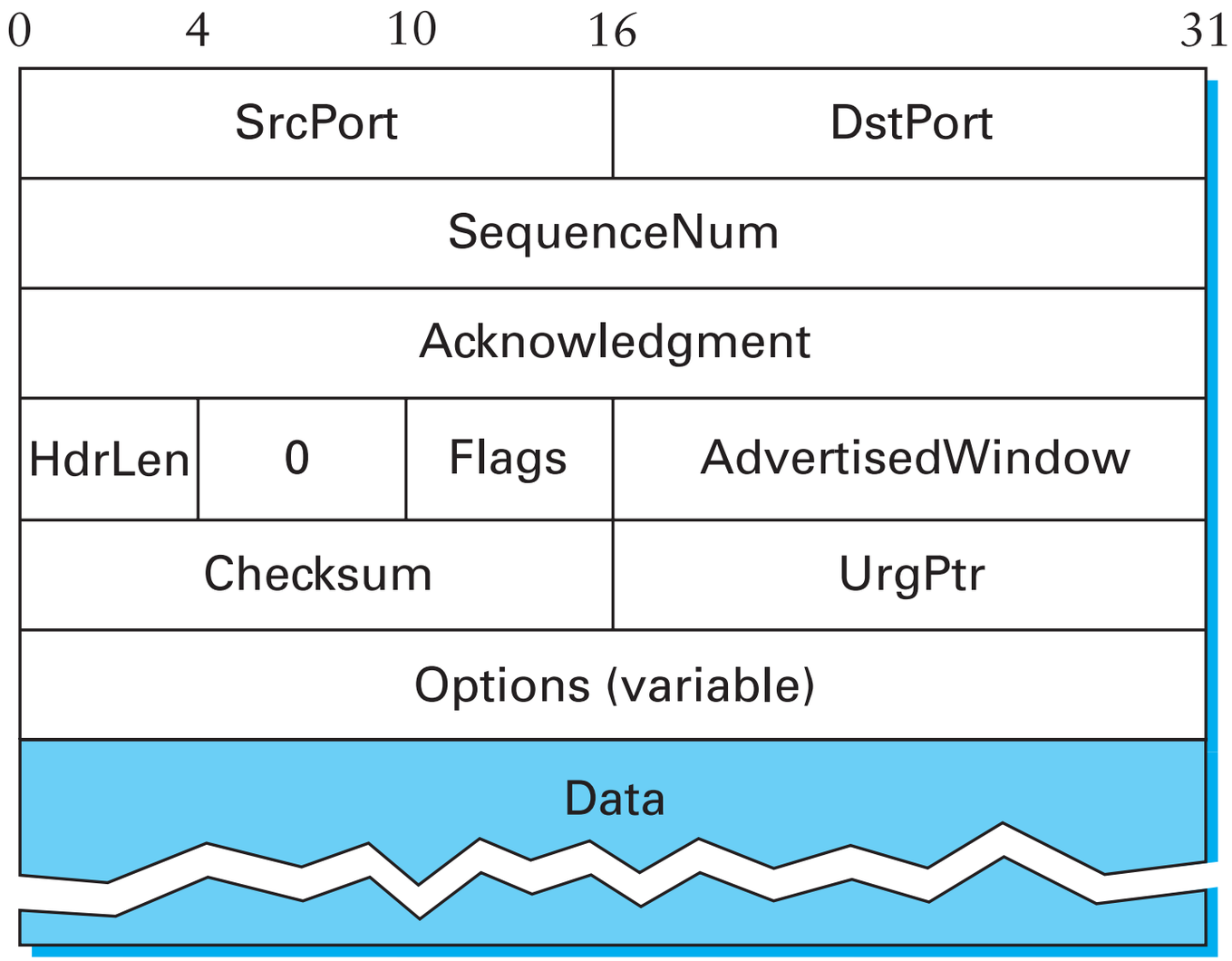
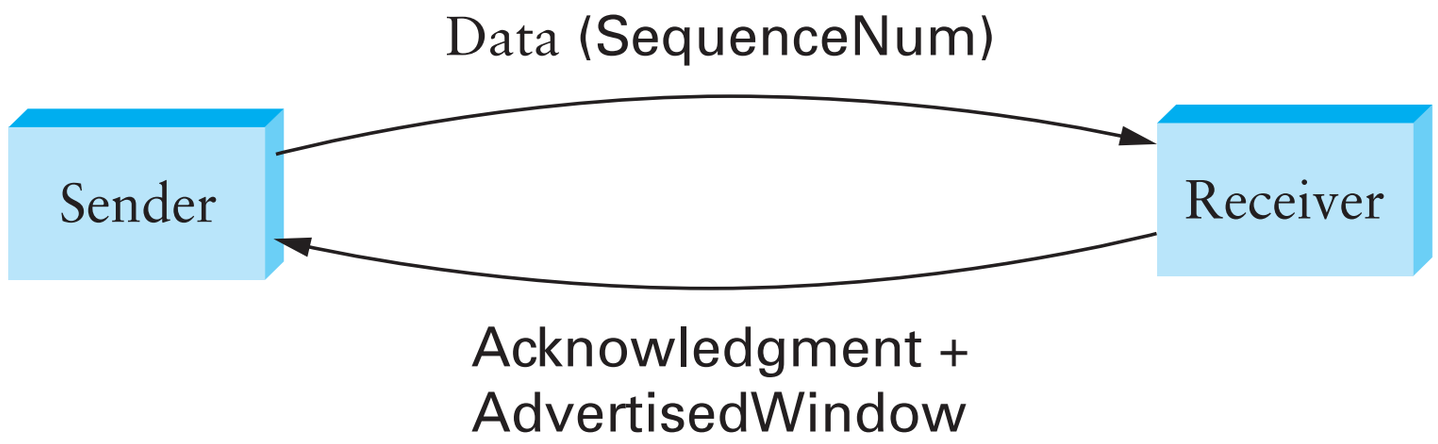
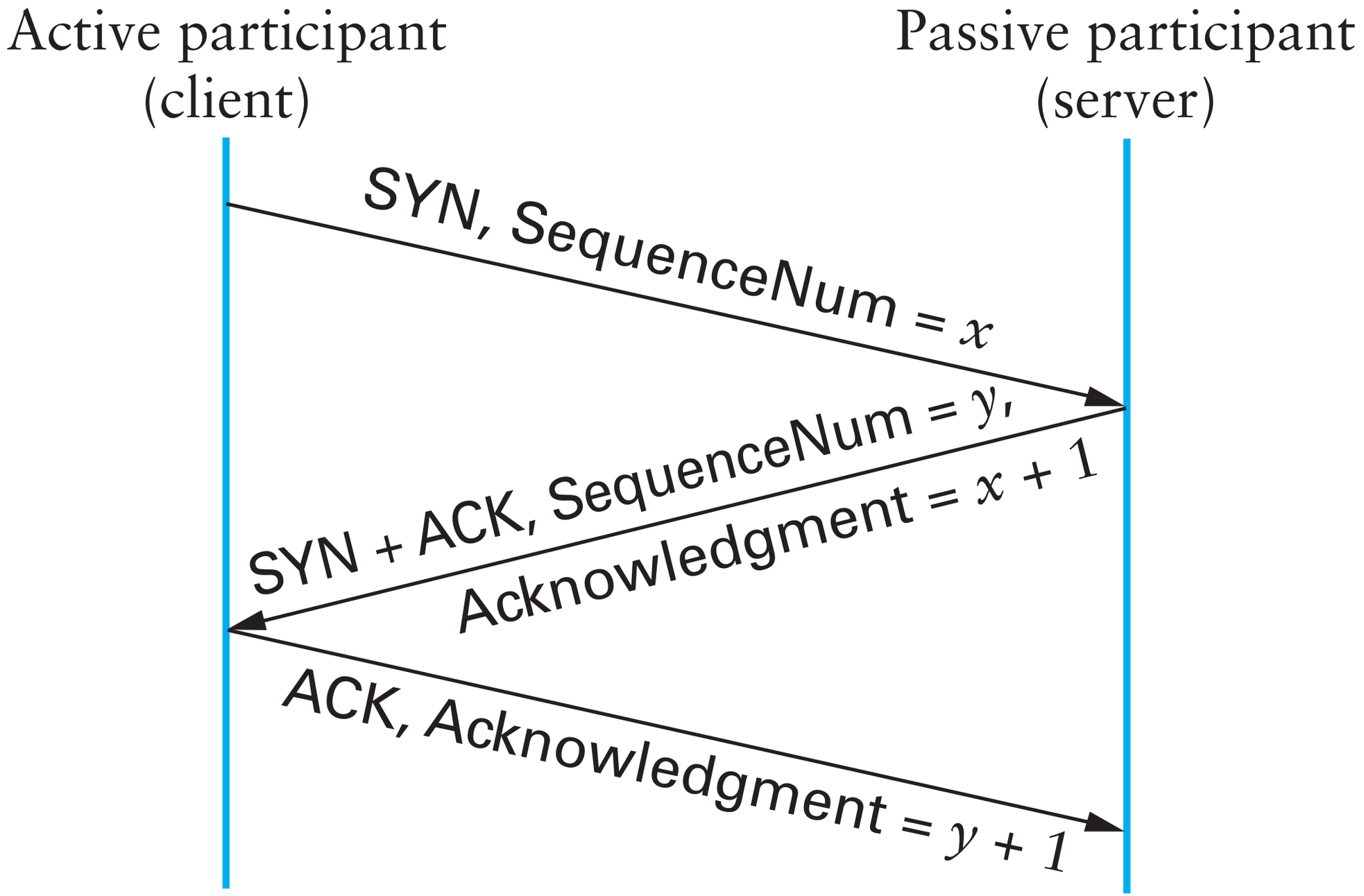
Header


0
4
10
16
31
SrcPort
DstPort
SequenceNum
Acknowledgment
HdrLen
0
Flags
AdvertisedWindow
Checksum
UrgPtr
Options (variable)
Data


Data (SequenceNum)
Sender
Receiver
Acknowledgment +
AdvertisedWindow

Connection Establishment and Termination
Three-way Handshake



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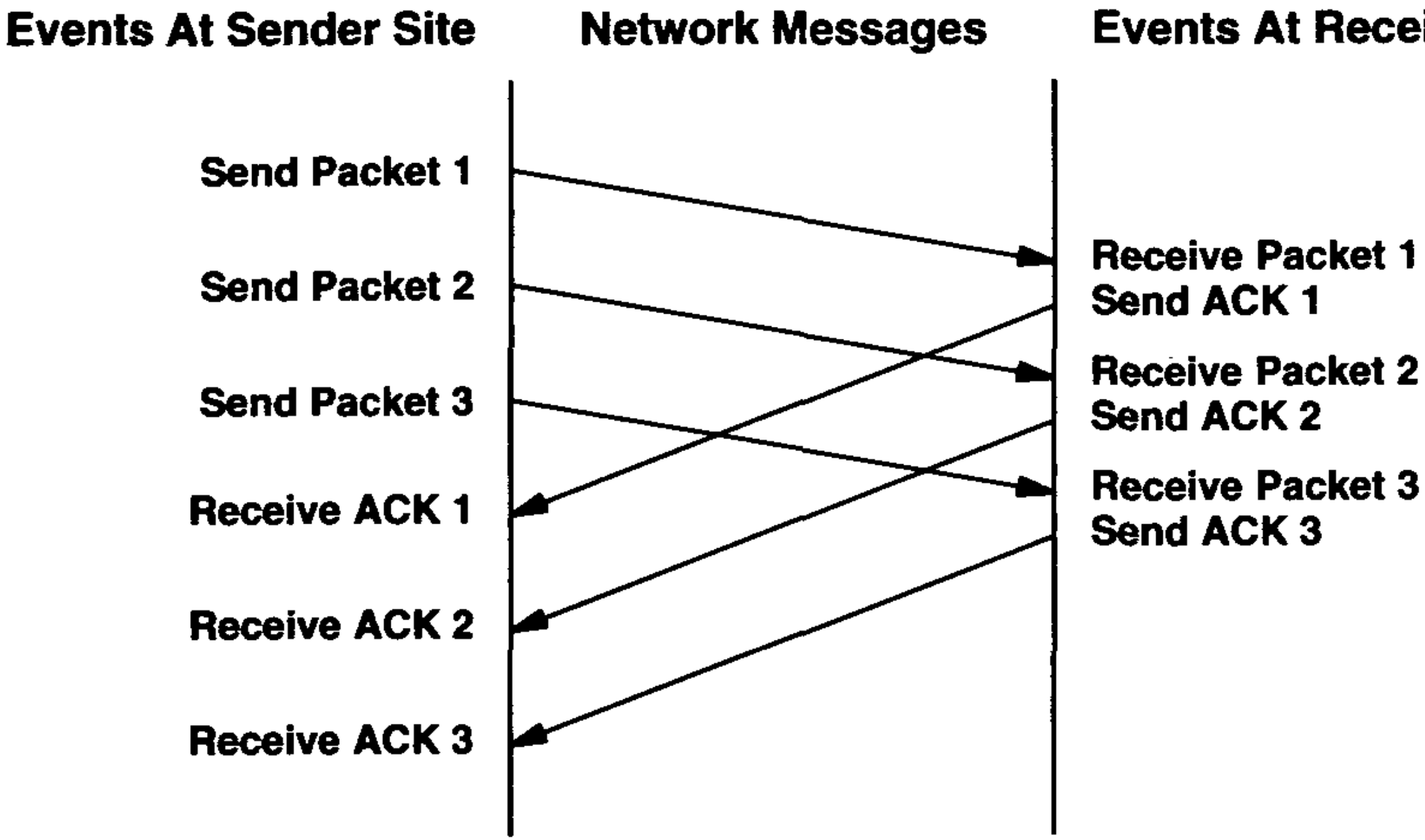
Under the Hood



TCP vs UDP for Audio and Messages

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Music Through Messages

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Open Sound Control (OSC)

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What's OSC

Networking protocol for real-time musical control information

Introduced by CNMAT (UC Berkeley) in 1997

Transport-independent (UDP, TCP, WiFi, serial connections, and within applications)

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OSC Messages

Address:

URL-style

Arguments:

strings, floats, ints, binary numbers, “blobs”, etc.

/nmp2010/JPC/freq 2220.02

address *argument*

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Argument Types

i	int32
f	float32
s	OSC-string
b	blob (binary data)
h	int64
t	Time Tag
d	float64
s	symbol

c	ASCII character
r	RGBA color
m	MIDI Message
T	TRUE
F	FALSE
N	nil
I	infinitum

Address Space

Every address space is application-specific

Symbolic names of features, parameters…
Arbitrary arrangement into tree structure

OSC standard proscribes nothing

+ *Utterly flexible*
– *No automatic "plug and play"*

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Time

"Bundle" - group of messages

Transmitted together

Must take effect atomically

Bundles have time-tags saying when messages should take effect

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Demo Pd Patch

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Credits

Some networking images taken from:

- Peterson, *"Computer Networks"*, 3rd edition

- Comer, *"Internetworking with TCP/IP"*, Vol. 1, 4th edition

OSC slides Inspired from:

- Wright, *"Brief Overview of OSC and its Application Areas"*, OSC Conference 2004