

CEDAR Tutorial Lecture

Introduction to Computer Networking

Yadunath Zambre
SRI International

Tutorial Lecture

Motivation

Overview of the Internet

Protocol Layering

Networking Hardware Infrastructure

Internet Protocols

Network Performance

Programming Interfaces

Applications

Perspectives from the Community

University of Michigan

MIT – Millstone Hill

University of Alaska

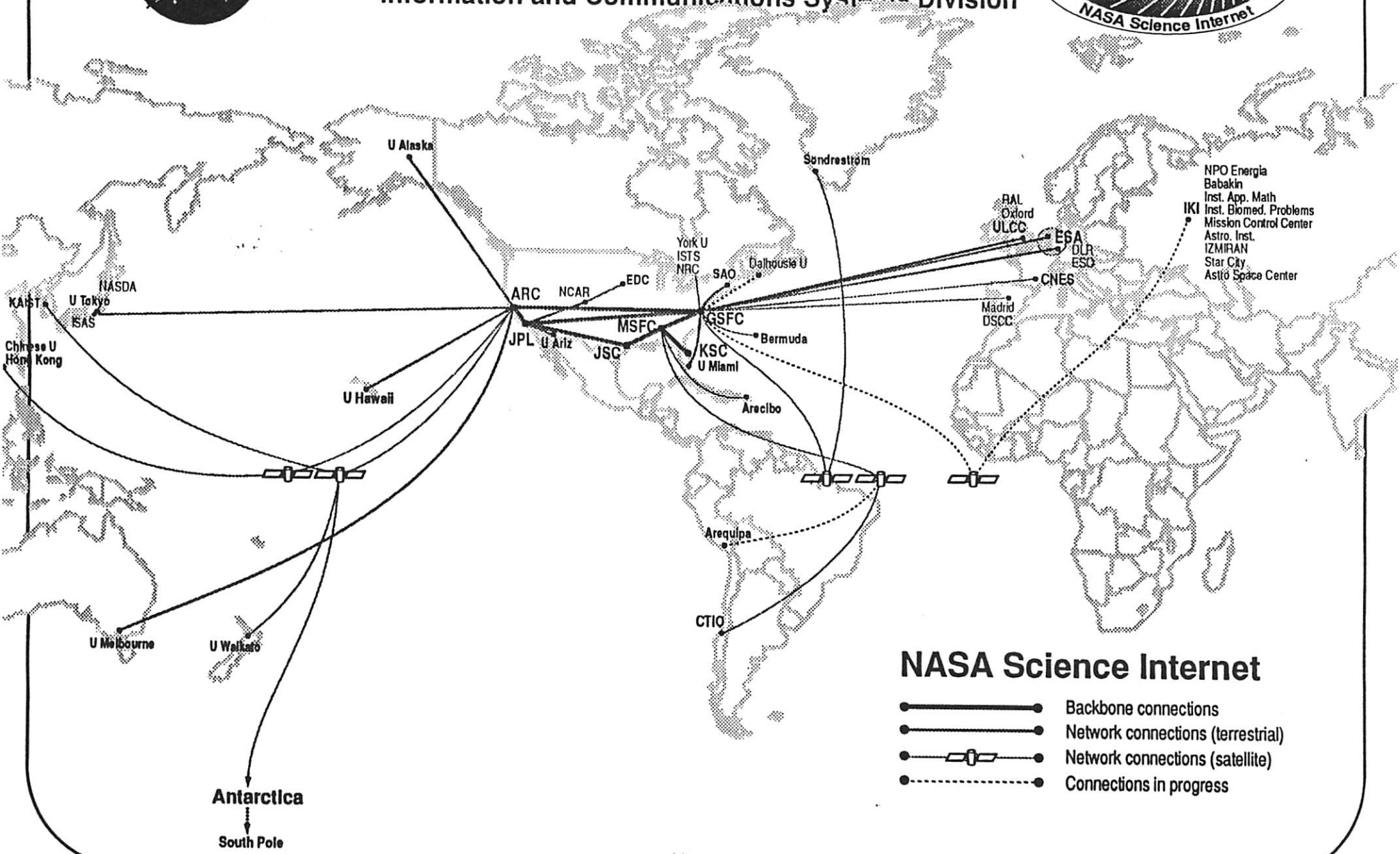
EISCAT



Reprinted with permission: Tribune Media Services.



NASA Science Internet Project Office Ames Research Center Information and Communications Systems Division



NASA Science Internet

- Backbone connections
- Network connections (terrestrial)
- Network connections (satellite)
- - - Connections in progress

Antarctica
South Pole

NPO Energia
Babakin
Inst. App. Math
Inst. Biomed. Problems
Mission Control Center
Astro. Inst.
IZMIRAN
Star City
Asti Space Center

RAL
Oxford
ULCC

ESA
DLR
ESO

CNES

Madrid
DSCC

Sondrestrom

York U
ISTS
NRC

SAO

EDC

MSFC

JSC

KSC

U Miami

Arecibo

Arequipa

CTIO

Bermuda

ARC

NCAR

JPL

U Ariz

U Alaska

U Hawaii

U Melbourne

U Waikato

NASDA

U Tokyo

ISAS

KAIST

Chinese U
Hong Kong

NSFnet Backbone

San Diego, CA

Boulder, CO

Champaign, IL

Pittsburgh, PA

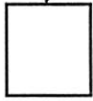
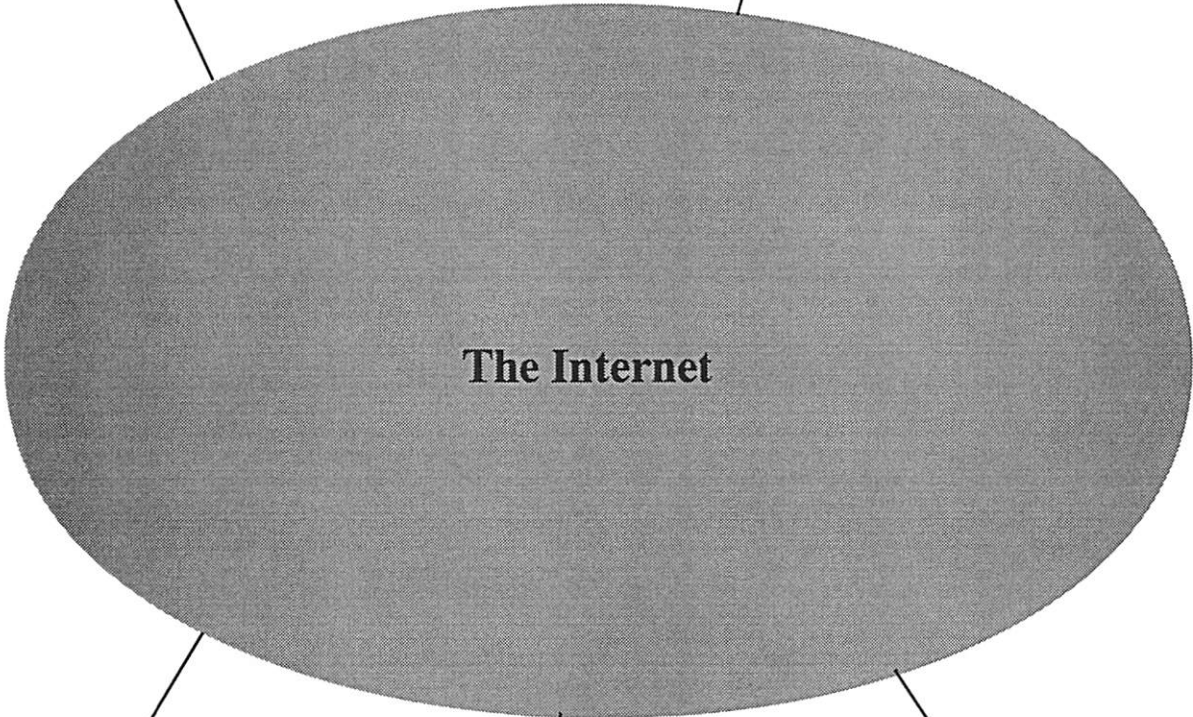
Ithaca, NY

Princeton, NJ

Bill



Al



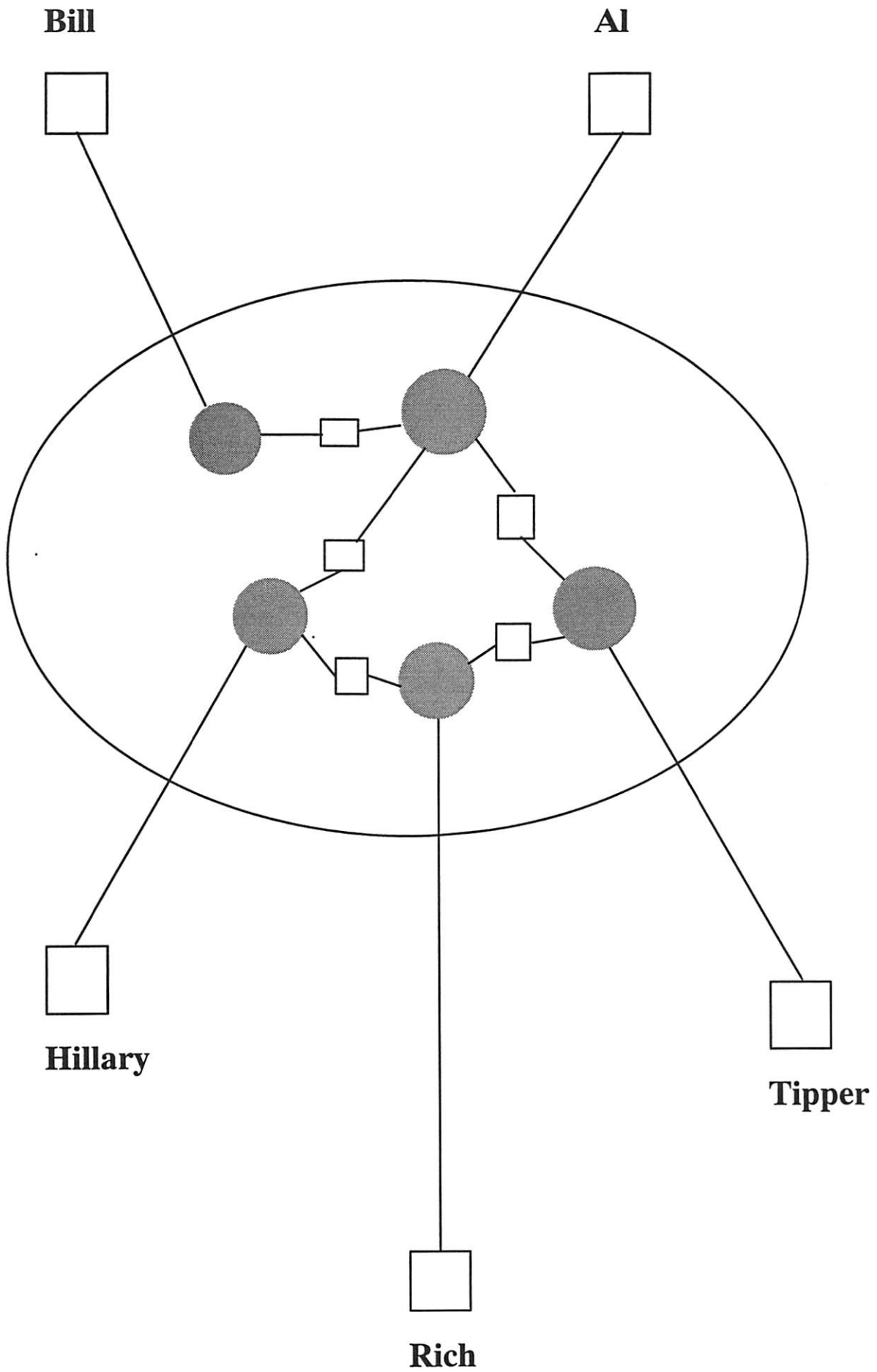
Hillary

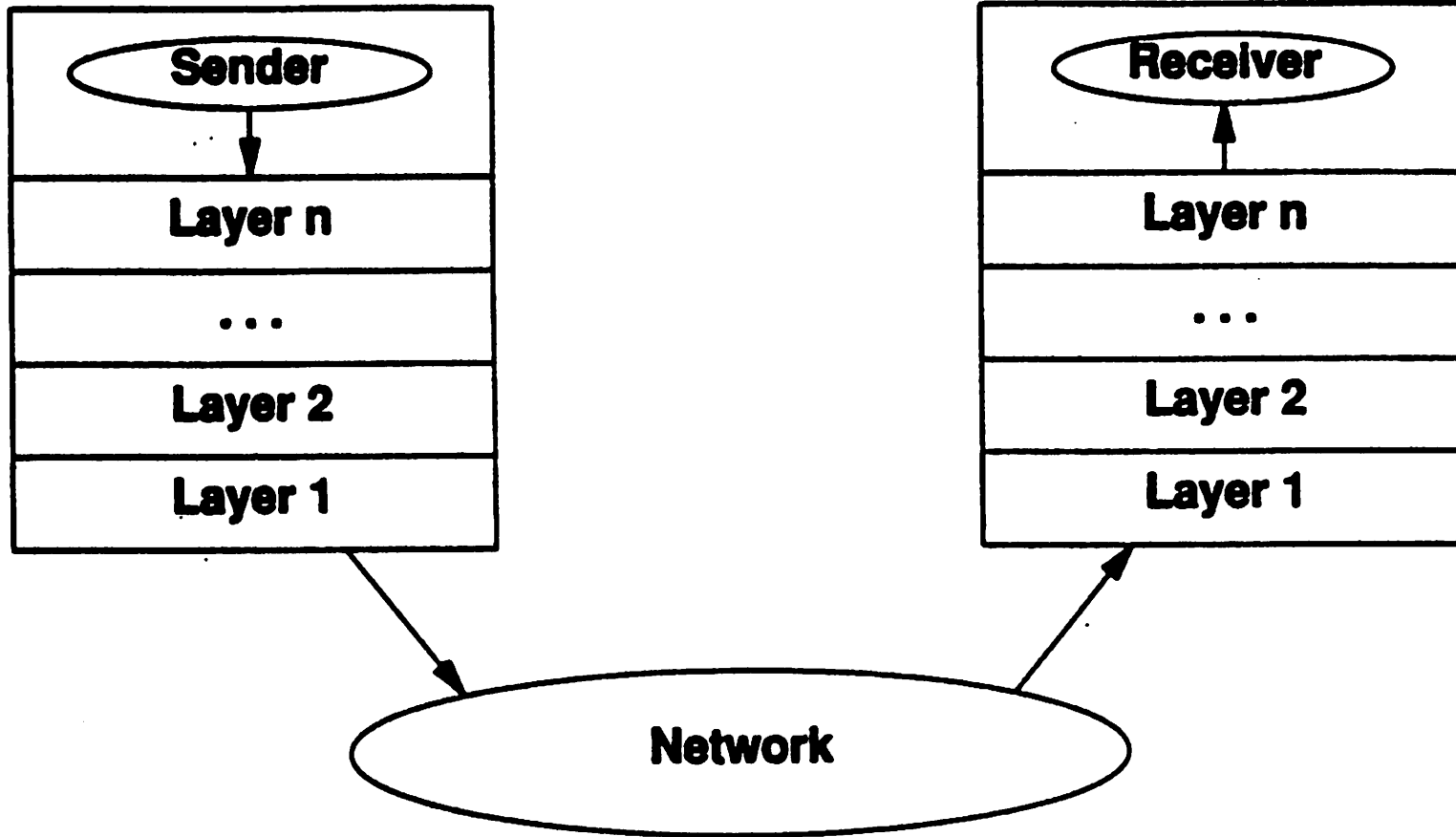


Tipper



Rich





Layer**Functionality****7****Application****6****Presentation****5****Session****4****Transport****3****Network****2****Data Link
(Hardware Interface)****1****Physical Hardware
Connection**

Protocols

TCP/IP – Internet Protocol

DECnet – Digital Equipment Corporation

IPX – Novell Netware

AppleTalk – Apple Computer

Underlying Hardware Technologies

Ethernet

FDDI (optical fiber)

ProNet-10 (token ring)

ATM (asynchronous transfer mode)

X.25

Serial line

ISDN

Ethernet

10 Mbps broadcast bus with distributed access control

Carrier sense network with collision detection

48 bit integer hardware addresses

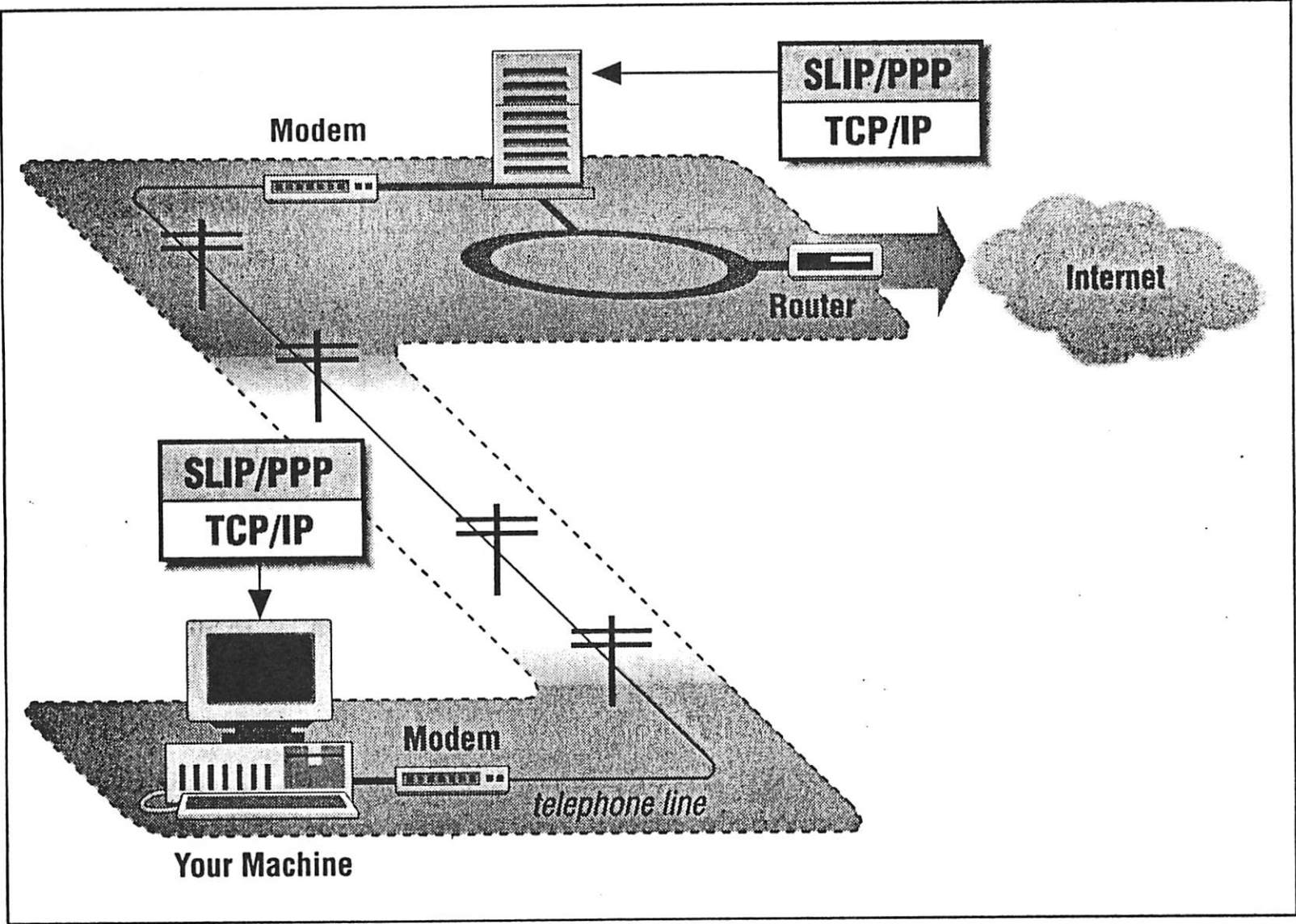
Ethernet frames are self identifying, containing receiver and sender addresses and frame type

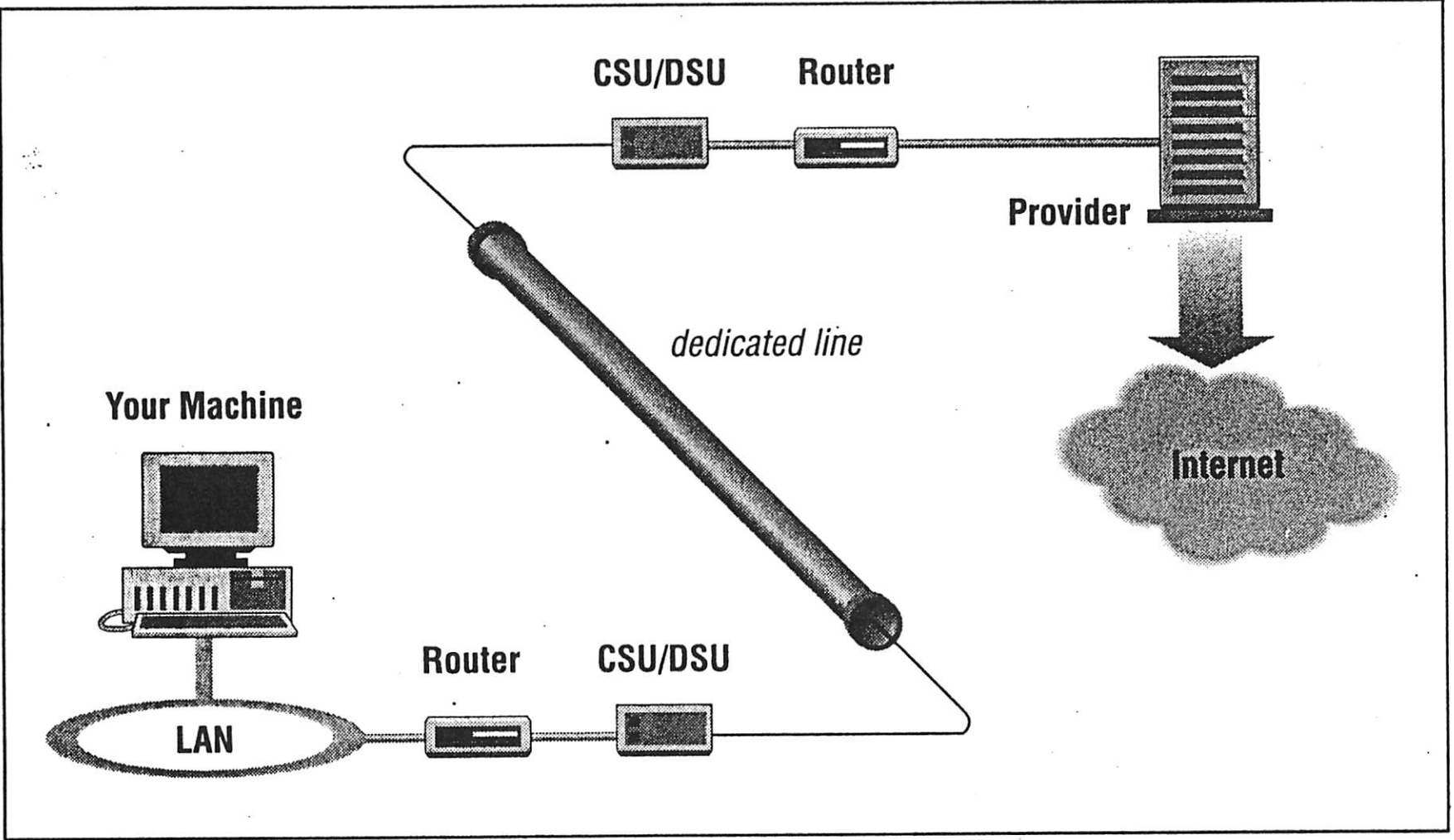
Allows multiple protocols on a single machine

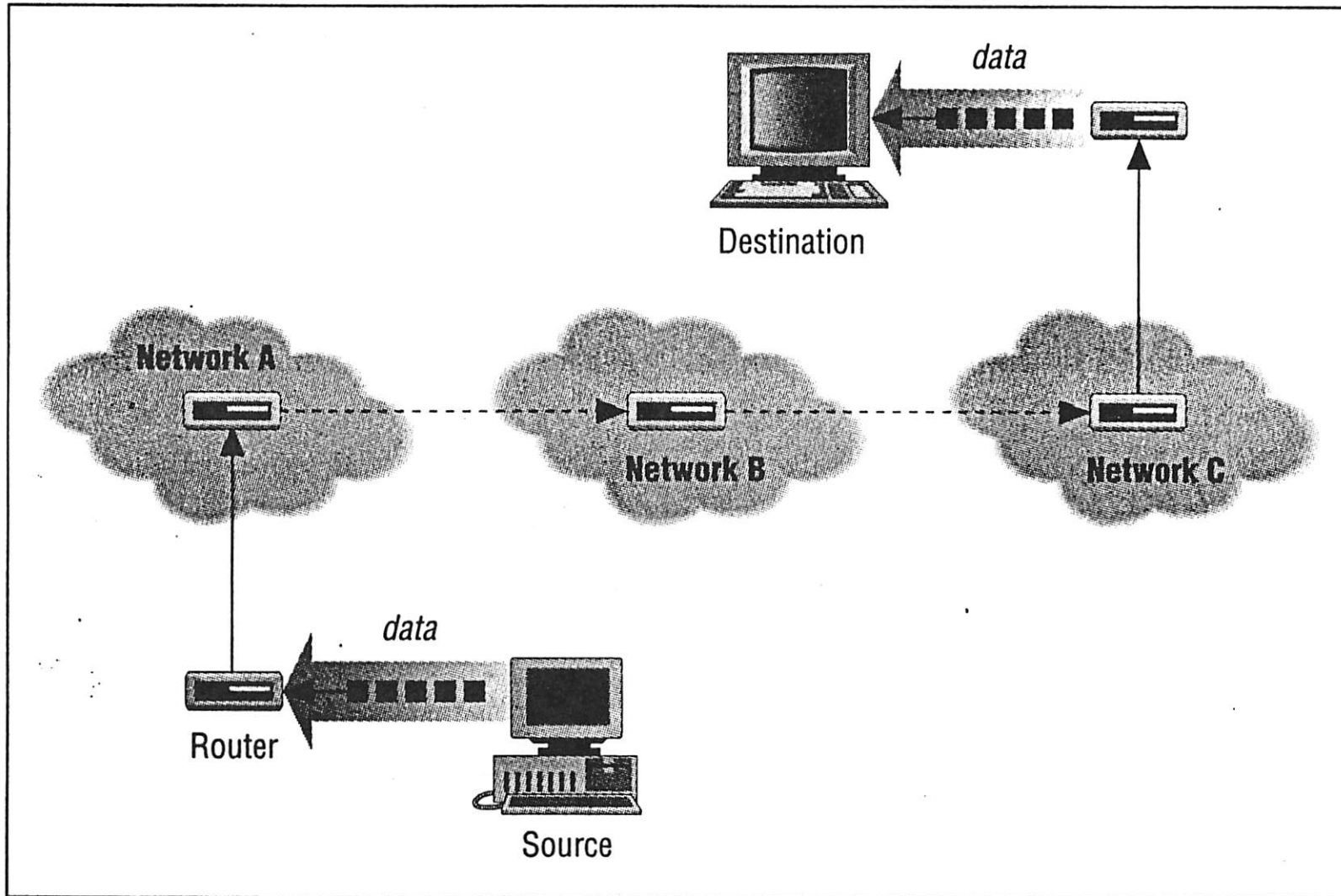
Allows multiple protocols on a single network

Preamble	Destination Address	Source Address	Packet Type	Data	CRC
64 bits	48 bits	48 bits	16 bits	368-12000 bits	32 bits

The format of a frame (packet) as it travels across an Ethernet.



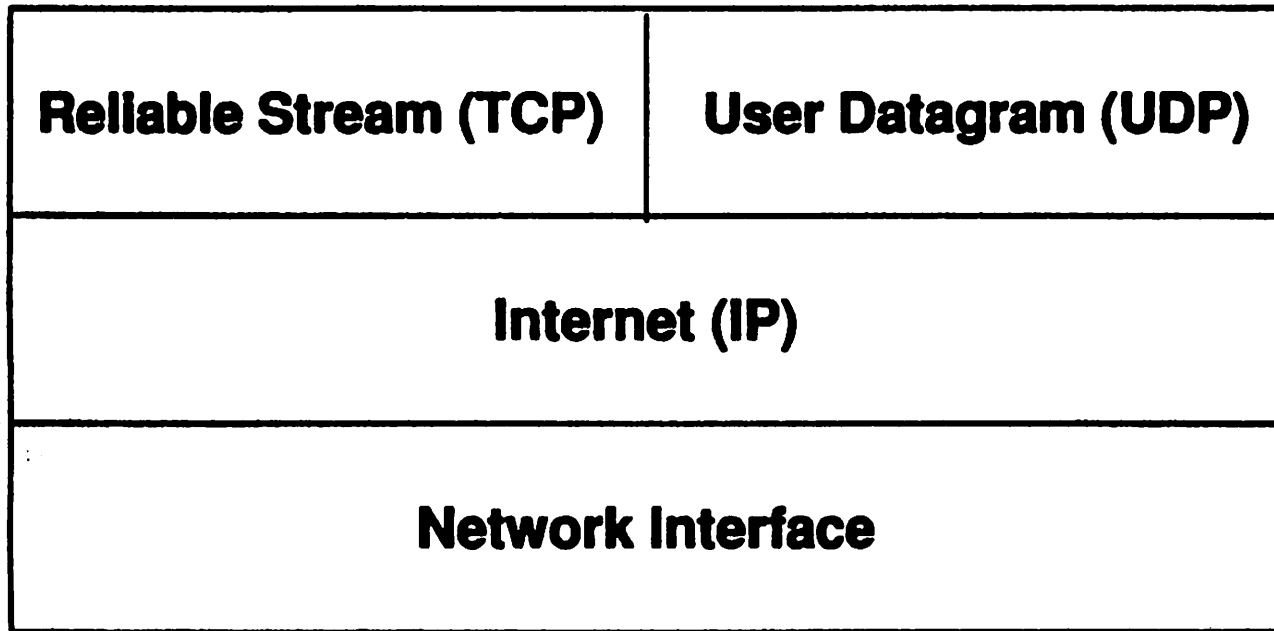




Network and Transport

Layer Protocols

Conceptual Layering



- The conceptual layering of UDP and TCP above IP. TCP provides a reliable stream service, while UDP provides an unreliable datagram delivery service. Application programs access both.

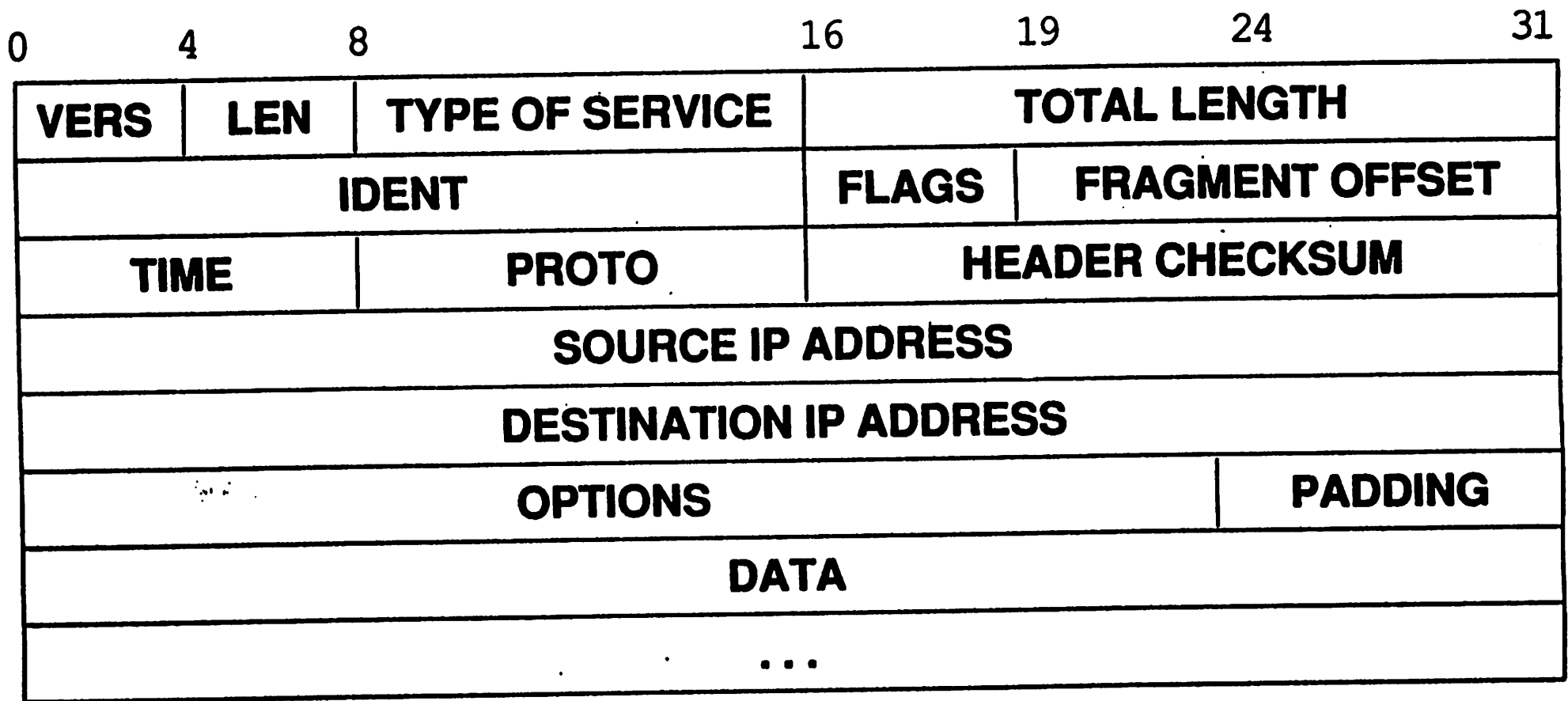
Internet Protocol

Connectionless Datagram Delivery

Unreliable, Best effort transport of datagrams

Hides underlying network (hardware) technologies

Analogous to network hardware



Format of an Internet datagram, the basic unit of transfer on the Internet.

User Datagram Protocol (UDP)

Unreliable connectionless delivery service

Uses IP

Adds the ability to distinguish among multiple destinations within a single host

Datagrams may arrive out of order or not at all

Reliable Stream Transport (TCP)

Connection oriented or virtual circuit service

Stream orientation

Full duplex

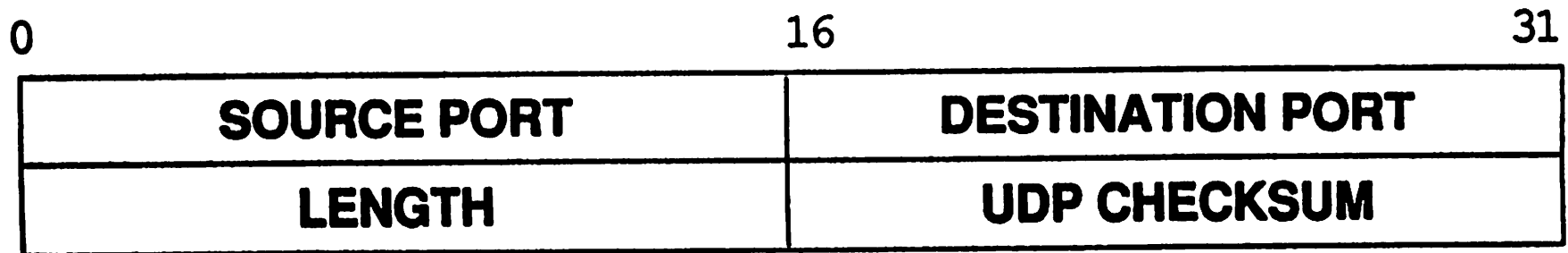
All data arrives in order. Guaranteed delivery

IP header	Complete UDP datagram treated as data by IP
------------------	--

A UDP datagram encapsulated in an IP datagram as it travels across the Internet.

UDP header	UDP data area
-------------------	----------------------

The two components of a UDP message. Such messages are called *user datagrams*.



The format of fields in the UDP datagram header.

0

8

16

31

SOURCE PORT			DESTINATION PORT		
SEQUENCE NUMBER					
ACKNOWLEDGEMENT NUMBER					
OFF.	RES.	CODE	WINDOW		
CHECKSUM			URGENT POINTER		
OPTIONS				PADDING	
DATA					
...					

The format of a TCP segment with a TCP header followed by data. Segments are used to establish connections as well as to carry data and acknowledgements.

Events At Sender Site

Network Messages

Events At Receiver Site

Send Packet 1

**Receive Packet 1
Send ACK 1**

**Receive ACK 1
Send Packet 2**

**Receive Packet 2
Send ACK 2**

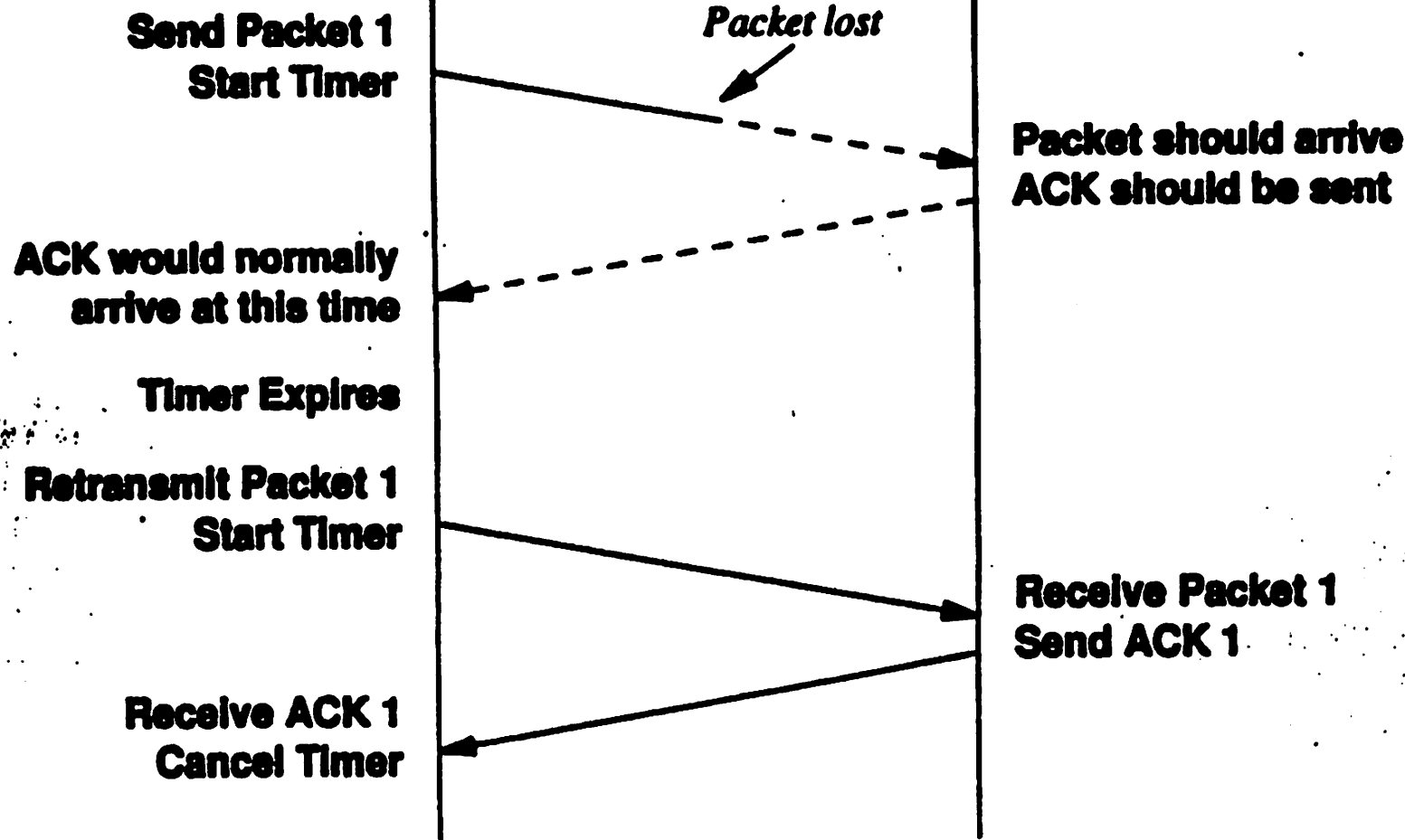
Receive ACK 2

A protocol using positive acknowledgement with retransmission in which the sender awaits an acknowledgement for each packet sent. Vertical distance down the figure represents increasing time and diagonal lines across the middle represent network packet transmission.

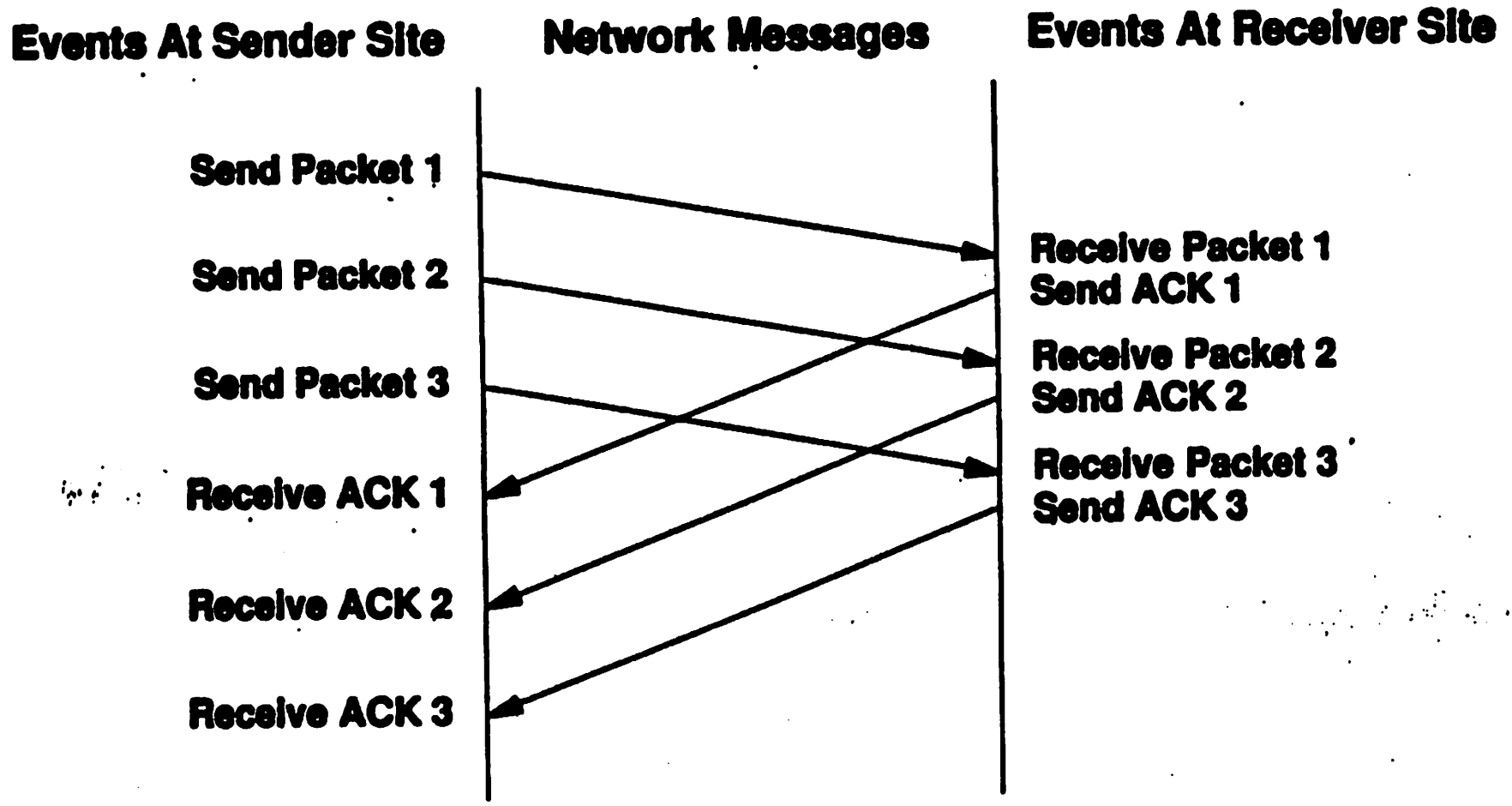
Events At Sender Site

Network Messages

Events At Receiver Site



Timeout and retransmission that occurs when a packet is lost. The dotted lines show the time that would be taken by the transmission of a packet and its acknowledgement, if the packet were not lost.



An example of three packets transmitted using a sliding window protocol. The key concept is that the sender can transmit all packets in the window without waiting for an acknowledgement.

Performance

Bandwidth

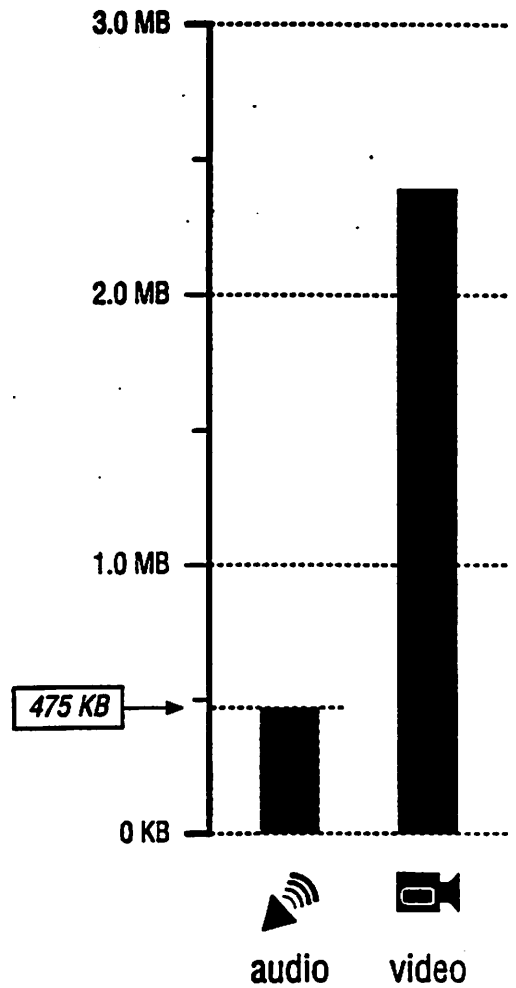
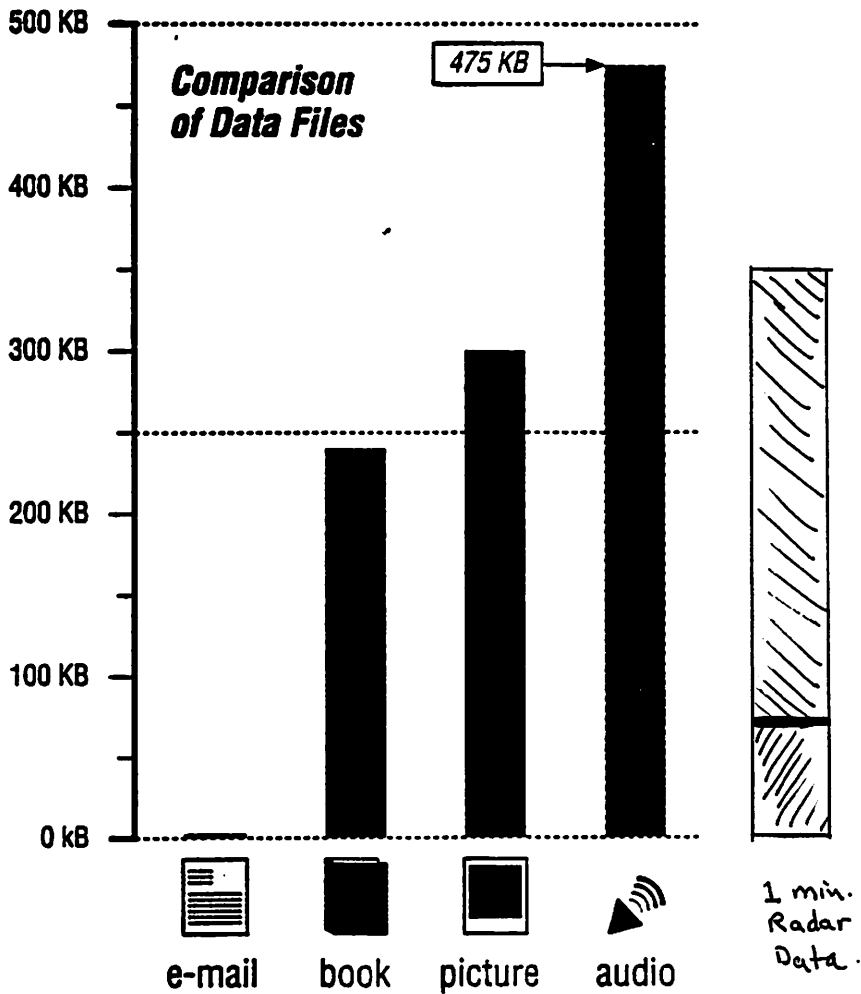
Actual throughput is seldom equal to the ideal bandwidth due to network congestion and packet loss

Latency/Delay

Important for real time applications such as conferencing

ping measures round trip delay

traceroute measures delays along a packet route



e-mail: two page e-mail message (2.2 KB)



book: Wizard of OZ, approx. 75 pgs. (240 KB)



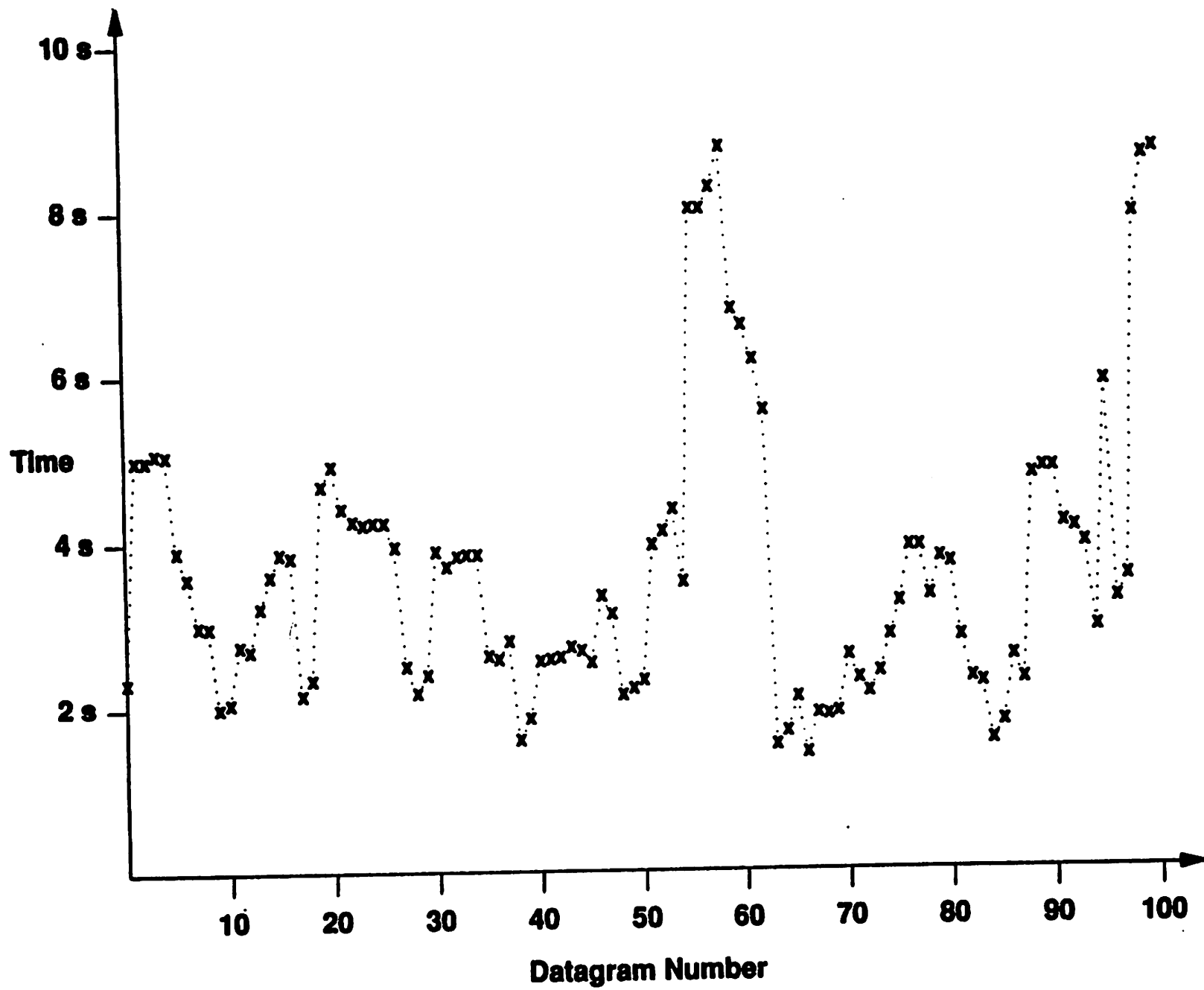
picture: Rome Reborn, picture (300 KB)

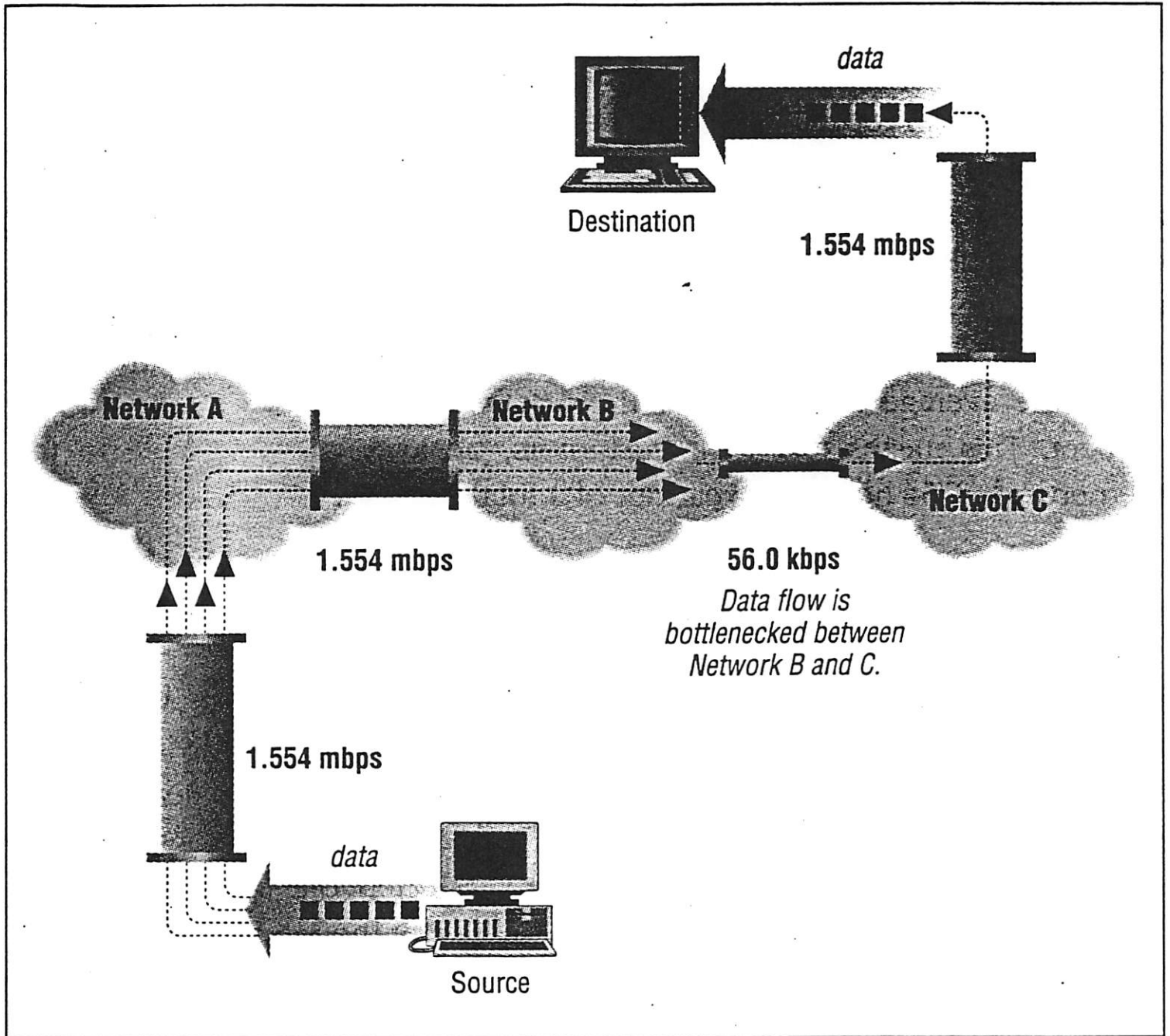


audio: 1 minute of audio (475 KB)



video: 1 minute high resolution video (2400 KB)





Programming Interfaces

Transport Level

BSD Sockets

Client/Server architectures

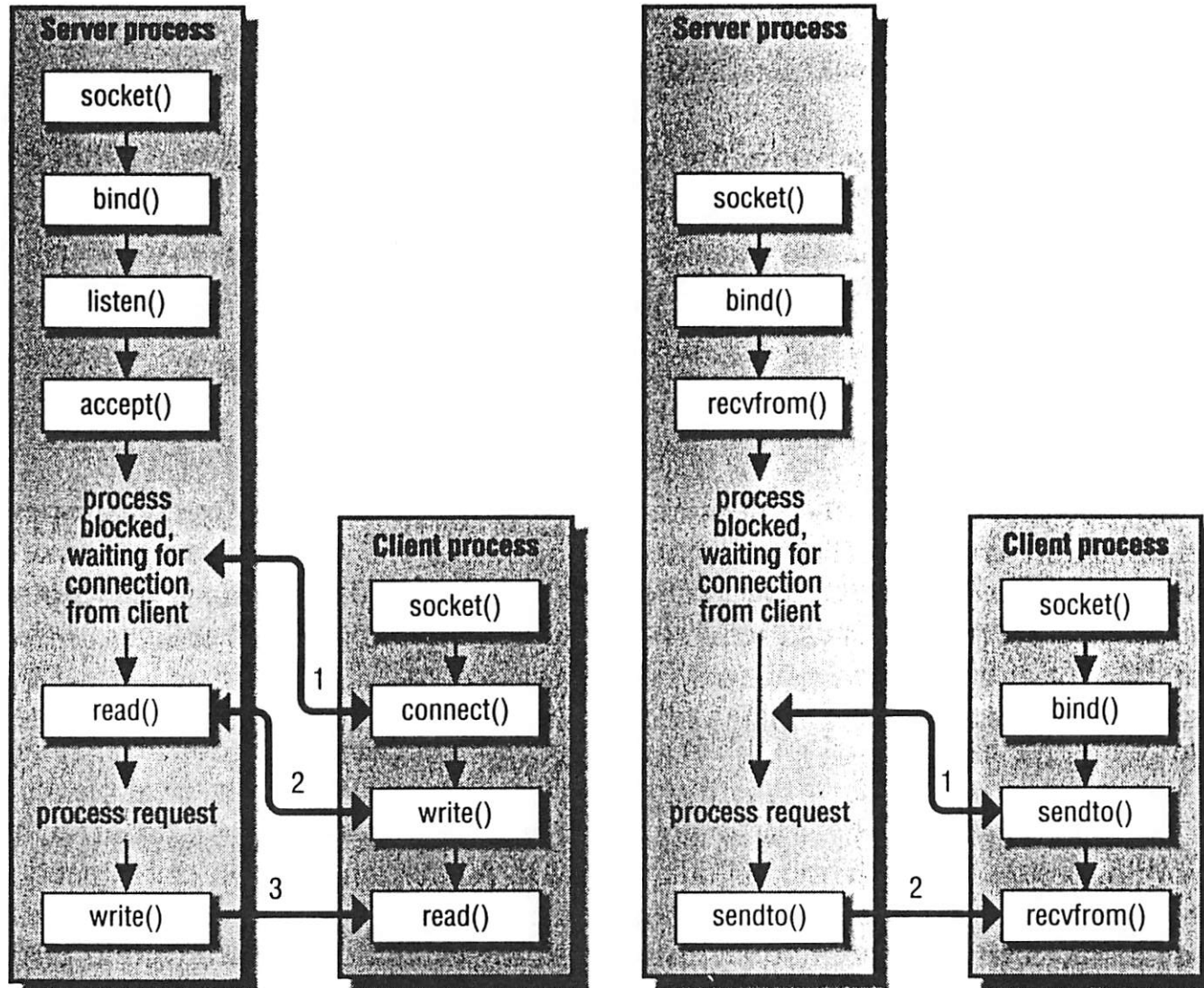
Session and Presentation Level

Remote Procedure Calls

XDR (external data representation)

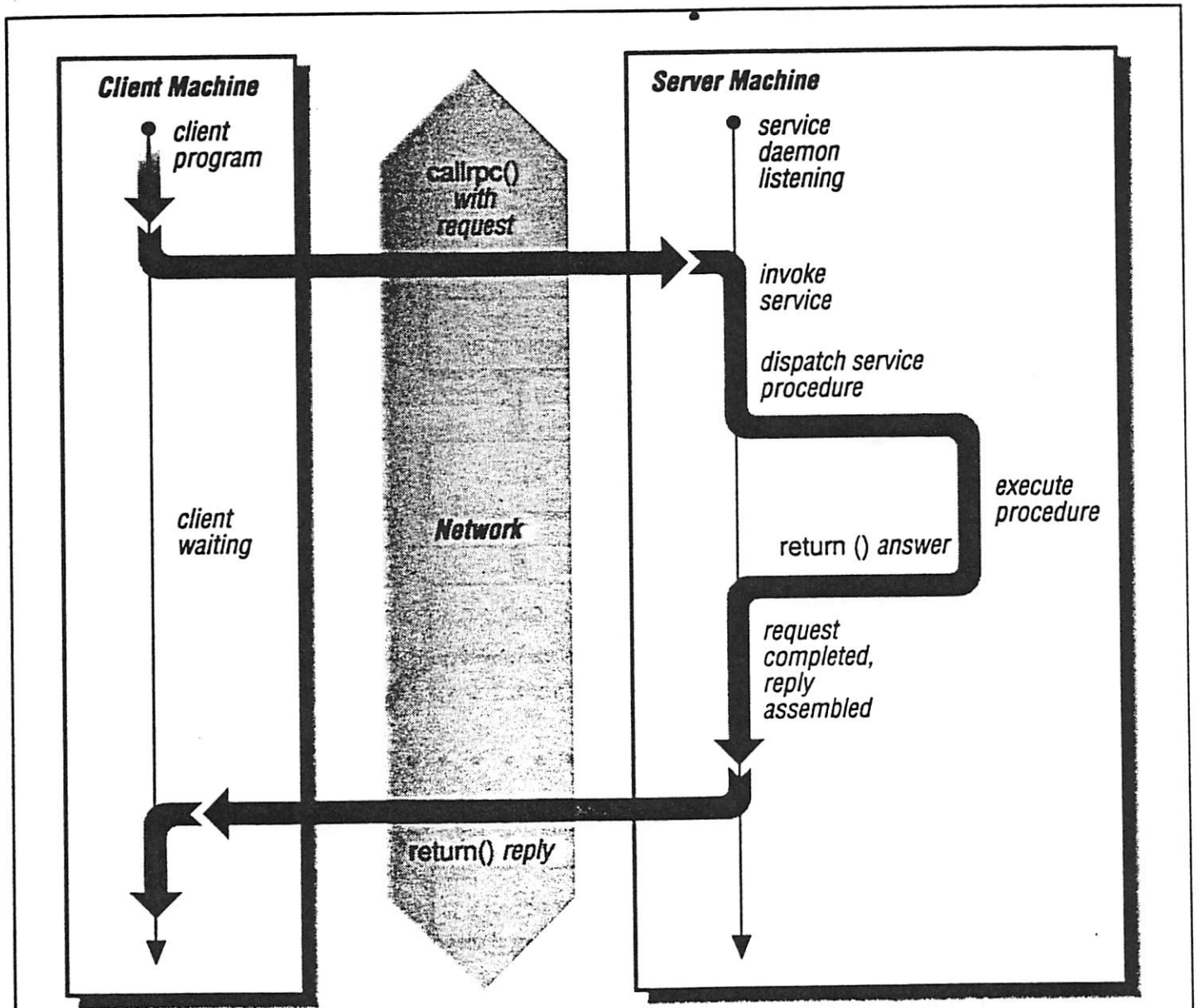
Application/Higher Level

Distributed Object Systems



The diagram above illustrates the socket calls used during a connection-oriented client/server communication, for example, when using the TCP transport.

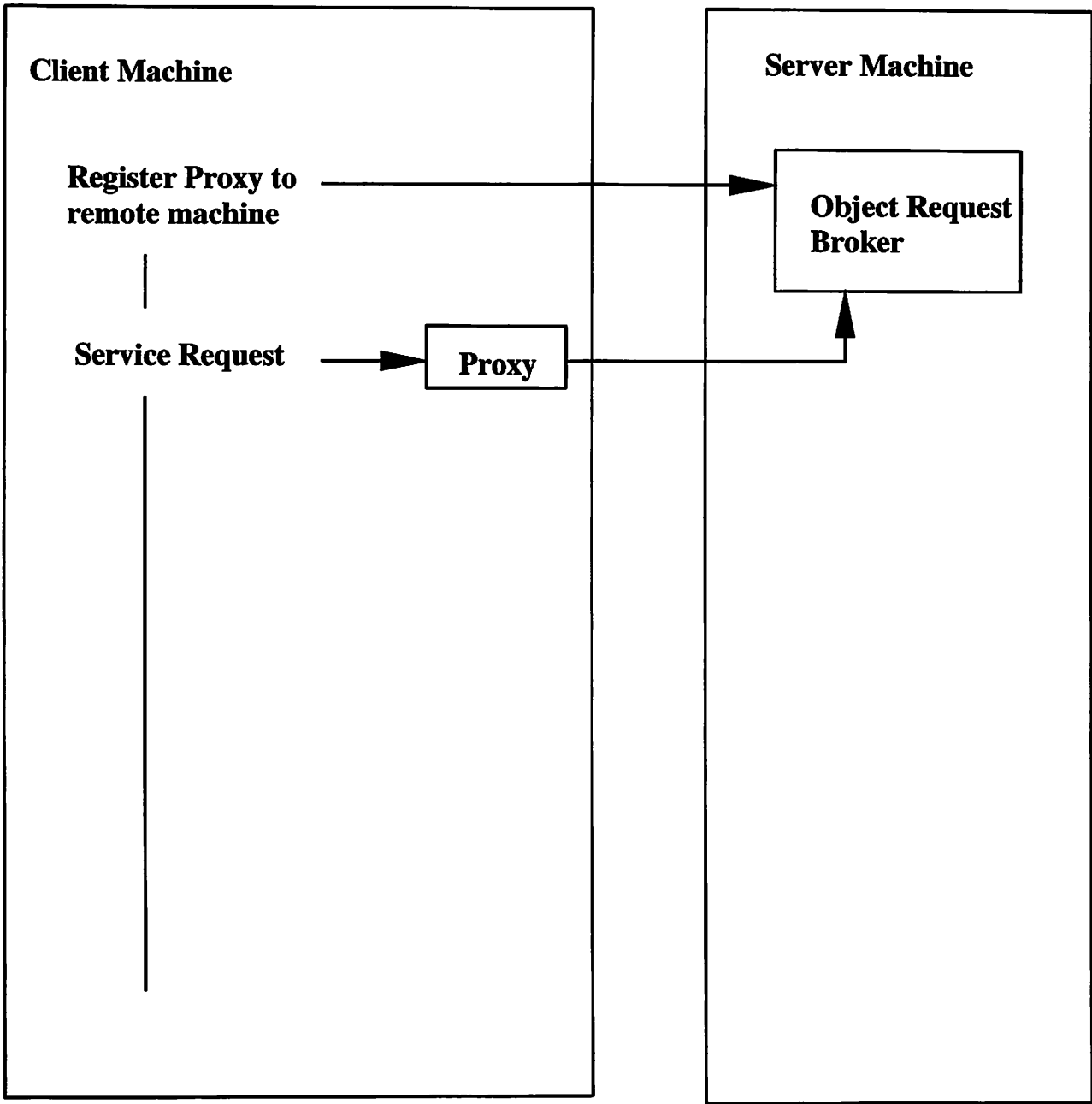
This schematic diagrams a connectionless transaction, for example, when using the UDP transport.



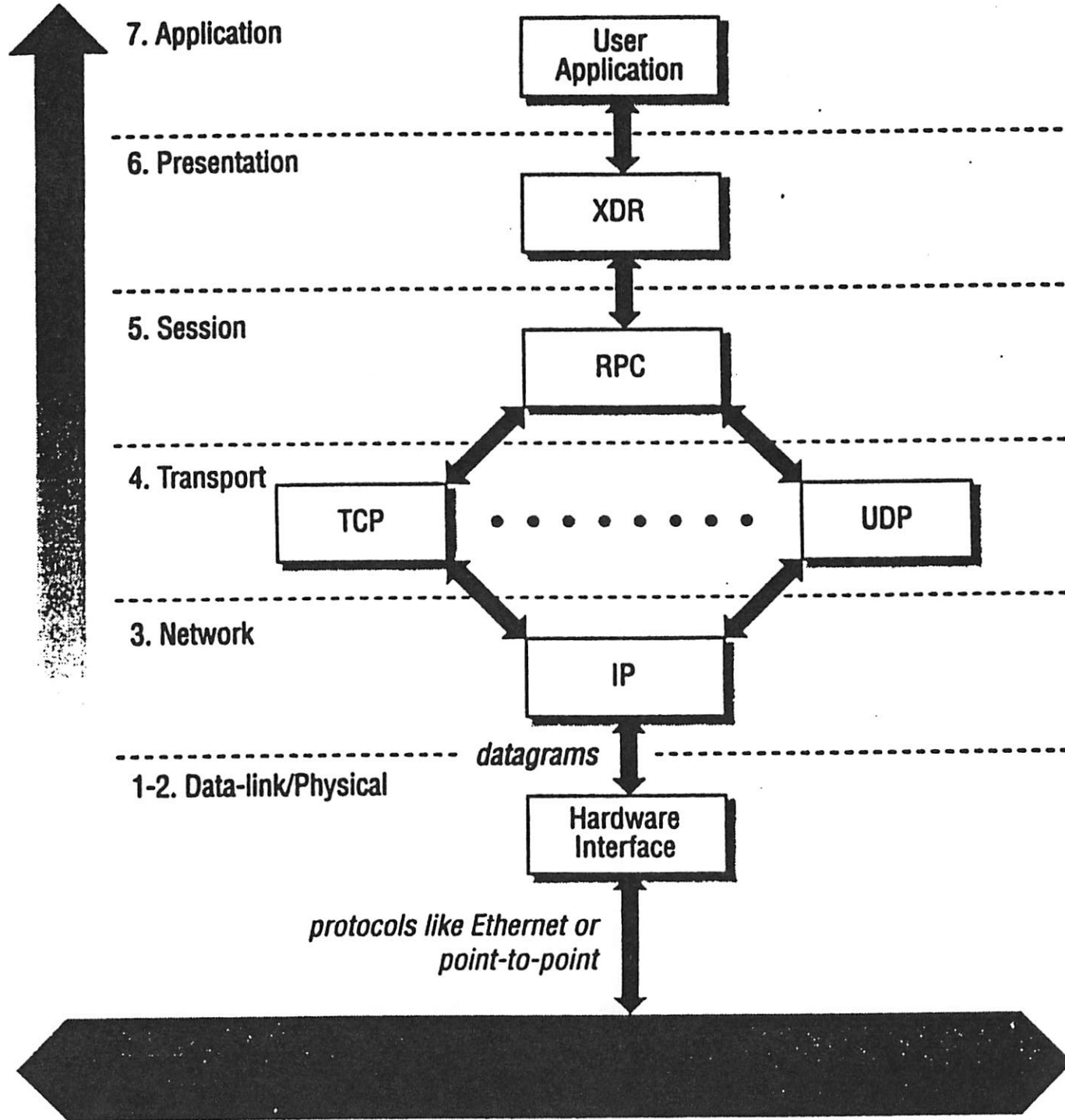
The client sends out a request over the network. The service daemon is constantly listening for requests. When a request is received, it invokes the service. The appropriate procedure is dispatched. The request is executed and the reply is returned over the network to the client.

The client machine is inactive between the time of the request and when it receives a reply.

The client and server machines may be the same.



OSI Layers



Language	Development Programmers	Maintenance Programmers	Total Programmers
Cobol	190,000	390,000	580,000
Object-Oriented: C++, Objective C, Smalltalk, etc.	135,000	30,000	165,000
C	132,000	77,000	209,000
Database/query languages	110,000	75,000	185,000
Fourth-generation languages/generators	110,000	75,000	175,000
All other languages	240,000	254,500	504,500
Totals	917,000	901,500	1,818,500

Application Level Services

FTP (file transfer protocol)

Telnet – remote login capability

Electronic Mail

Gopher

Archie

**Veronica (Very Easy Rodent–oriented Net–wide Index to
Computerized Archives)**

World Wide Web – Mosaic

New Applications

Telescience

Remote viewing of data

Remote control of an instrument

Collaboration Technology

Application Sharing

Sharing of data views amongst many parties

Sharing control of an application amongst many parties

Application Synchronization amongst many parties

Conferencing

Text Based

Audio

Video

MBone (Multicast Backbone)

Virtual network layered on portions of the physical internet

Provides the ability to send identical packets to multiple destinations simultaneously

Multicast kernel currently available on SGI, Sun computers

Production routers currently lack multicast ability.

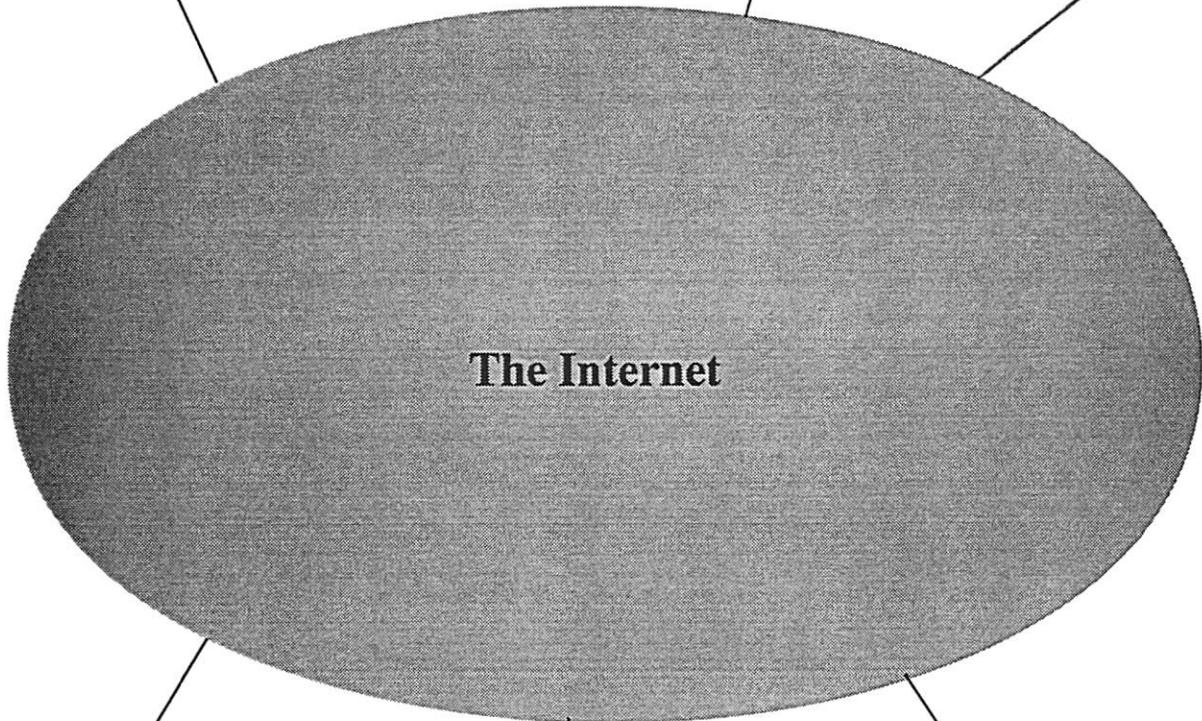
MBone applications include

nv – network video tool

vat – visual audio tool for multi-party audio conferencing

Bill

Al



The Internet

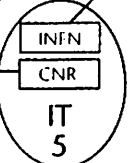
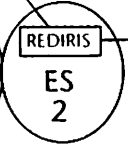
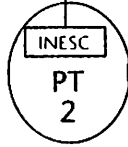
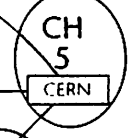
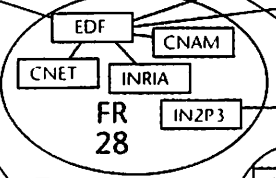
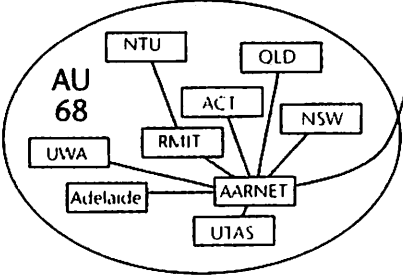
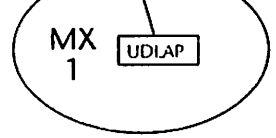
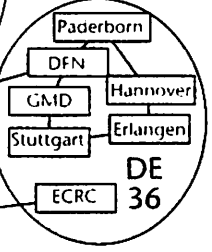
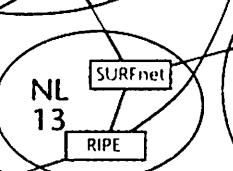
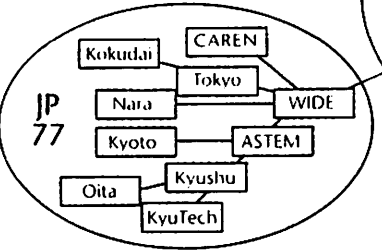
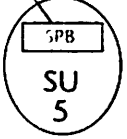
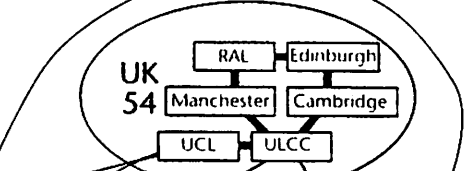
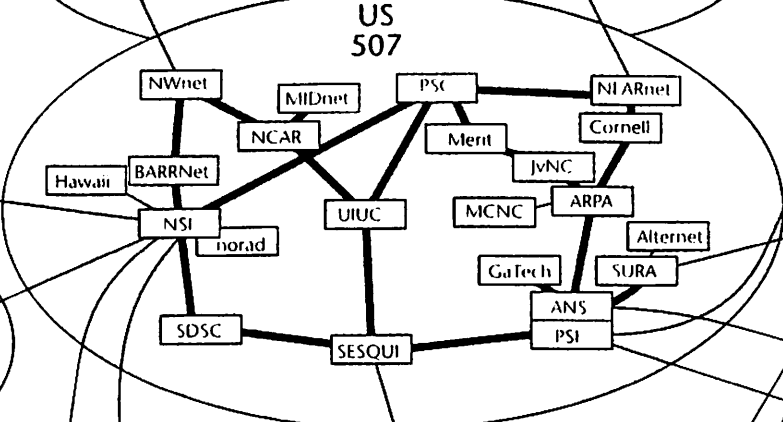
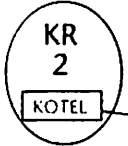
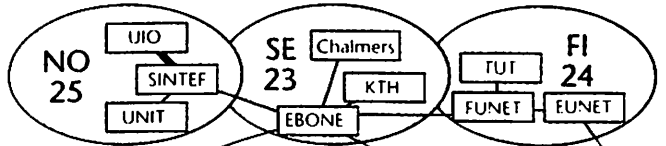
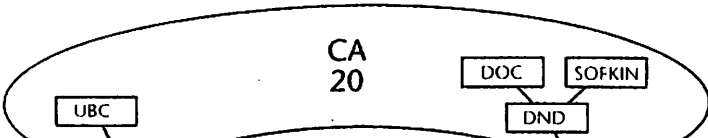
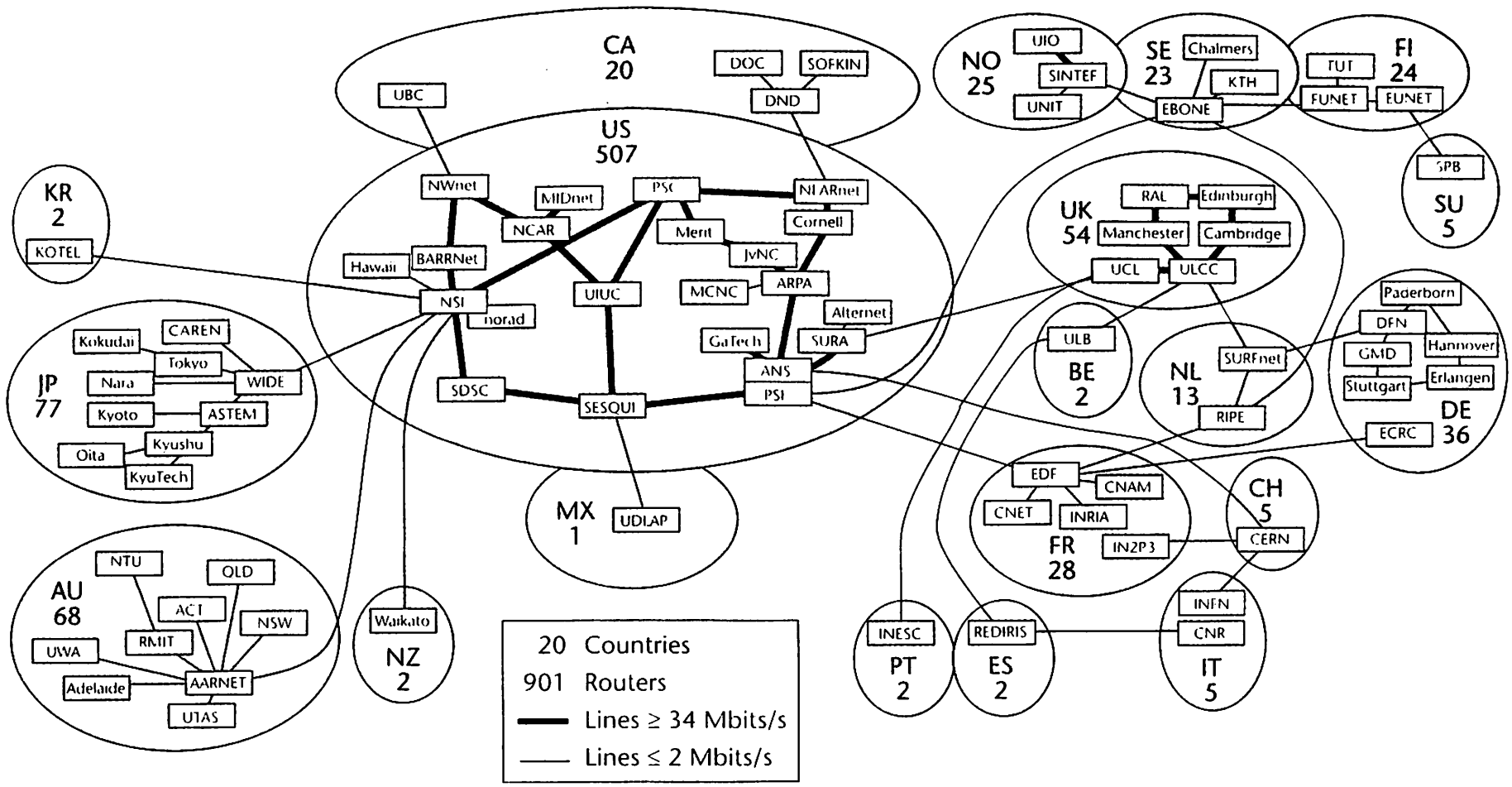


Hillary

Tipper



Rich



Standards

Network Protocols

TCP/IP – available on all machines

DECnet – available on DEC computers

**IPX/SPX – available on IBM compatible PCs and many
unix systems**

AppleTalk – available on Apple computers

Remote Procedure Call (RPC)

**ONC RPC – Sun Microsystems Open Network
Computing group**

**OSF DCE – Open Software Foundation Distributed
Computing Environment**

TIRPC – transport independent RPC

Distributed Object Systems

CORBA – common object request broker architecture

NeXTStep

Taligent

Microsoft – Project Cairo (Windows NT)

References

Power Programming with RPC,
John Bloomer, O'Reilly & Associates

Internetworking with TCP/IP, Volumes I, II, III
Douglas Comer and David Stevens,
Prentice Hall

Connecting to the Internet,
Susan Estrada, O'Reilly & Associates