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
IF THE COMPUTER IS TURNING THE WORLD INTO A GLOBAL VILLAGE,

AND I CAN'T FIGURE OUT HOW TO USE THE THING...

DOES THAT MAKE ME A GLOBAL VILLAGE IDIOT?

Reprinted with permission: Tribune Media Services.
NSFnet Backbone

San Diego, CA
Boulder, CO
Champaign, IL
Pittsburgh, PA
Ithaca, NY
Princeton, NJ
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
<table>
<thead>
<tr>
<th>Preamble</th>
<th>Destination Address</th>
<th>Source Address</th>
<th>Packet Type</th>
<th>Data</th>
<th>CRC</th>
</tr>
</thead>
<tbody>
<tr>
<td>64 bits</td>
<td>48 bits</td>
<td>48 bits</td>
<td>16 bits</td>
<td>368-12000 bits</td>
<td>32 bits</td>
</tr>
</tbody>
</table>

The format of a frame (packet) as it travels across an Ethernet.
CSU/DSU Router
Provider
dedicated line
Your Machine
Router CSU/DSU
Provider
Internet
LAN
Router CSU/DSU
dedicated line
Network and Transport Layer Protocols
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
A UDP datagram encapsulated in an IP datagram as it travels across the Internet.

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

<table>
<thead>
<tr>
<th>SOURCE PORT</th>
<th>DESTINATION PORT</th>
</tr>
</thead>
<tbody>
<tr>
<td>LENGTH</td>
<td>UDP CHECKSUM</td>
</tr>
</tbody>
</table>

The format of fields in the UDP datagram header.
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.
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.
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
**Comparison of Data Files**

<table>
<thead>
<tr>
<th>File Type</th>
<th>Description</th>
<th>Size</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>e-mail</strong></td>
<td>two page e-mail message</td>
<td>2.2 KB</td>
</tr>
<tr>
<td><strong>book</strong></td>
<td>Wizard of OZ, approx. 75 pgs.</td>
<td>240 KB</td>
</tr>
<tr>
<td><strong>picture</strong></td>
<td>Rome Reborn, picture</td>
<td>300 KB</td>
</tr>
<tr>
<td><strong>audio</strong></td>
<td>1 minute of audio</td>
<td>475 KB</td>
</tr>
<tr>
<td></td>
<td>1 minute high resolution video</td>
<td>2400 KB</td>
</tr>
</tbody>
</table>

- The diagram shows the comparison of data files in terms of size, with 'audio' having the largest size of 2400 KB, followed by 'video'.
- 'e-mail' is the smallest in terms of size, with a size of 2.2 KB.
- 'book' and 'picture' are of moderate sizes, with 'book' being slightly larger than 'picture' (240 KB vs. 300 KB).
Data flow is bottlenecked between Network B and C.
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.
Client Machine

<table>
<thead>
<tr>
<th>Register Proxy to remote machine</th>
</tr>
</thead>
<tbody>
<tr>
<td>Service Request</td>
</tr>
</tbody>
</table>

Proxy

Server Machine

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