Introduction

Internet Protocols
CSC / ECE 573
Fall, 2005
N. C. State University

Today's Lecture
I. Course Background
II. Course Overview
III. Internet Growth and Performance
IV. Basic Concepts and Terms
V. Ethernet Frames
VI. Defining Internet Standards

Syllabus and Calendar Are Online

Lecture Notes
⇒Will be online by noon of the preceding day (today was an exception)

COURSE BACKGROUND

“Your Instructor”
Expected Student Background

• Programming ability
  – (C / C++ advised, all code examples given in C)
• Course in Operating Systems
• Introduction to Computer Networks
• Computer Science or Computer Engineering background

Student Survey

• Please fill out a card with...
  – Your neighbor’s name
  – How well your neighbor programs in C / C++
    (not at all, beginner, intermediate, advanced)
  – Your neighbor’s prior networking background
    • courses, projects
    • work experience

Textbooks

• Required: D. Comer, 
  Internetworking with 
  TCP/IP: Principles, 
  Protocols, and 
  Architectures, Volume I
  (5th ed.)

• Recommended: 
  D. Comer and 
  D.L. Stevens, 
  Internetworking with 
  TCP/IP: Client-Server 
  Programming and 
  Applications, Volume III
  (Linux or Windows edition)

Textbooks

A Protocol Specification Example

• We will refer frequently to IETF Requests for Comments

  • The ICMP specification
    (http://www.ietf.org/rfc/rfc0792.txt)
  • A “prettier” version
    (http://www.zvon.org/tmRFC/RFC792/Output/index.html)
Homework / Grading

<table>
<thead>
<tr>
<th>Activity</th>
<th>Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Homework</td>
<td>30%</td>
</tr>
<tr>
<td>Project</td>
<td>20%</td>
</tr>
<tr>
<td>Midterm exam</td>
<td>15%</td>
</tr>
<tr>
<td>Final Exam</td>
<td>30%</td>
</tr>
<tr>
<td>Participation</td>
<td>5%</td>
</tr>
<tr>
<td>TOTAL</td>
<td>100%</td>
</tr>
</tbody>
</table>

• Class participation: Encouraged!

Help

• My availability
• The TA: Juan Du
• The class message board
• Other students

Policy on Plagiarism

11. Thou shalt not copy…

The Project

• Implement an existing network protocol, and test it – e.g., TCP, RIP, DNS
• Implement an existing application-level protocol – e.g., IMAP, SSH, HTTP
• Implement a new protocol described in a recent research paper, and write the specification
• Design, specify, implement, and test (!) a replacement for TCP to use in an interplanetary Internet

Course Objectives

• Learn about the most important Internet protocols, including their…
  1. function
  2. performance and design tradeoffs
  3. implementation
• Learn how to write protocol specifications
• Learn how to program client-server applications using the sockets API
• Be able to analyze Internet traffic
Topics We Study

1. ARP / RARP
2. IPv4 classful and classless addresses, subnetting
3. IP
4. ICMP
5. UDP, TCP
6. Sockets API and client-server programming
7. Routing: RIP, OSPF, BGP
8. DHCP
9. DNS

Topics We Study (cont’d)

10. Multicast
11. RTP and VoIP
12. IPSec
13. IPv6
14. Mobile IP

Why Has the TCP/IP Protocol Suite Been So Successful?

- My opinion…
  - A single, unifying layer (IP)
  - An open, highly dynamic standards process
  - Emphasis on practicality and simplicity
  - Emphasis on scalability, extensibility, instead of maximum features or efficiency
- “Working code and rough consensus”
- Will it last?

A Little History

- Started as a research network by the US government (DARPA really did invent the Internet)
- Transitioned to commercial operation in the mid-1990s
- Some references
  - http://www.isoc.org/internet/history/

A Few Highlights

- 1961 – First paper on packet switching
- 1969 – 4-node ARPANET (UCLA+SRI+UCSB+Utah, 50 Kbps)
- 1969 – First RFC
- 1971 – First real application in use (email)
- 1975 – Ethernet invented
- 1980-81 – UDP, IPv4, TCP RFCs adopted
- 1984 – DNS introduced
- 1986 – IETF and IRTF started
- 1988 – First Internet worm released

A Few Highlights (cont’d)

- 1991 – WWW protocols created, first web server
- 1993 – first web browser (Mosaic)
- 1994 – IPv6 effort started
- 1995 – Internet backbone taken over by commercial service providers
- 2000 – Major attacks over the Internet become common
Who Owns the Internet?

- Countries operate national networks, usually in a non-competitive environment
- Network service providers (commercial carriers) provide the “backbone” bandwidth
- Companies and organizations build their own private networks (intranets) and connect to the Internet
- Internet service providers (ISPs) provide access links to individual customers

Internet Growth and Performance

How Many Computers Connect to the Internet?

Routing Table Growth

How Much Traffic Is There?

- Really difficult to answer, lots of debate about what the real numbers are
- One prediction (2001):

<table>
<thead>
<tr>
<th>Year</th>
<th>2001</th>
<th>2003</th>
<th>2005</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total traffic (Mbps)</td>
<td>2,264,000</td>
<td>8,816,000</td>
<td>35,264,000</td>
</tr>
<tr>
<td>Price ($/month/Mbps)</td>
<td>200</td>
<td>98</td>
<td>48</td>
</tr>
</tbody>
</table>

Internet Share by Country
### Map of Intercontinental Bandwidth (2001)

![Map of Intercontinental Bandwidth](image)

### Who “Peers” with Whom?

![Who “Peers” with Whom?](image)

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### What Applications Use the Internet?

- Example measured from one set of backbone links...

<table>
<thead>
<tr>
<th>Protocol</th>
<th>% of Traffic (Bytes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Web</td>
<td>11 - 90%</td>
</tr>
<tr>
<td>P2P+unknown</td>
<td>0% - 80%</td>
</tr>
<tr>
<td>Streaming</td>
<td>0% - 26%</td>
</tr>
<tr>
<td>Mail</td>
<td>0% - 6%</td>
</tr>
<tr>
<td>File transfer</td>
<td>0% - 7%</td>
</tr>
<tr>
<td>Other</td>
<td>5% - 21%</td>
</tr>
</tbody>
</table>

- Typically over 80% of Internet traffic uses TCP

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### How Big Are Packets?

![Packet size cdf](image)

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### How Long / Large Are Connections?

- Most are short and small
  - 40-70% last less than 2 seconds
  - 90% of flows transfer less than 1 KB
- Only 1% last more than 15 minutes

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### Internet Performance Example

- 99.98% network uptime
- Avg. internet latency (one way) < 40 ms.
  - (speed of light: halfway around globe = 65ms)
- Avg packet loss rate < 0.05%
**How Many Routers Are Traversed on a Typical “Path”?**

![Graph showing IP path lengths vs. number of routers traversed]

**Security Trends**

![Bar chart showing security incidents over years]

**Some Basic Concepts and Terms**

**Terminology**

- *An internet:* any interconnected networks
  - *An intranet:* all owned and operated by a single organization

- **The Internet:** “A collection of networks and routers that spans the globe and uses the TCP/IP protocols to form a single, cooperative virtual network.”
  - packet-switched, connectionless

**Terminology (cont’d)**

- A *datagram* (or packet) is the unit of transmission in the TCP/IP protocol suite
  - has one header, contains source and destination addresses

**Protocols**

- Protocol specifications generally contain...
  1. purpose
  2. formats of messages exchanged (syntax)
  3. interpretation of message contents (semantics)
  4. actions taken upon receipt of messages (state machine)
  5. how to handle errors
Layers of the TCP/IP Protocol Suite

- **Application Layer**: Ex.: FTP, E-mail, HTTP, …
- **Transport Layer**: Ex.: TCP, UDP
- **Network Layer**: Ex.: IP
- **Link Layer**: Ex.: Ethernet

“Anything over IP, IP over Anything”

TCP/IP Encapsulation and Decapsulation

TCP/IP Demultiplexing (Decapsulation)

Example: Two Networks Connected by a Router

“Layering Considered Harmful?”

- **Yes!**
  - Why?
- **No!**
  - Why not?
Capturing and Analyzing Traffic: Ethereal

- Free, available on most platforms (Windows, Linux, Unix)
- "Captures" traffic from a network
- Analyzes and displays traffic in convenient form
  - understands 100’s of protocols
  - very convenient filters for isolating traffic of interest

Download at http://www.ethereal.com

Ethernet Framing And Packet Sizes

HW1

- Online now, due next Tuesday
- Ethereal
- Getting help

Ethernet

- 2 Versions: RFC 894 ("Ethernet"), IEEE 802.3
- Speeds: 10 Mb/s, 100 Mb/s, 1 Gb/s, 10 Gb/s

Ethernet Frames

- Link layer (MAC) addresses = 48 bits
- $2^{48} = 3$ quadrillion addresses

Maximum IP Packet Sizes

- MTU = maximum transmission unit
  - a function of the link layer

<table>
<thead>
<tr>
<th>Network</th>
<th>MTU (bytes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>FDDI</td>
<td>4352</td>
</tr>
<tr>
<td>RFC 894</td>
<td>1500</td>
</tr>
<tr>
<td>IEEE 802.3</td>
<td>1492</td>
</tr>
<tr>
<td>X.25</td>
<td>576</td>
</tr>
</tbody>
</table>

- If an IP packet exceeds the MTU, it must be split up (fragmented) before transmission, and reassembled later
Defining Internet Standards

Who Makes the Rules?

- IETF (Internet Engineering Task Force)
  - develops standards (solutions to short- and medium-term needs)
- IETF composed of “Areas”
  1. Applications Area
  2. General Area
  3. Internet Area
  4. Operations and Management Area
  5. Routing Area
  6. Security Area
  7. Transport Area

IETF (cont’d)

- Areas are composed of “Working Groups”
  - August 2005: 123 working groups (some more active than others)
- Other groups: IAB, ISOC, IRTF, IANA, IESG, Regional Registries, DNS root server operators, …

Standards Making Process

The IRTF or an IETF BOF ("birds of a feather") group solicits ideas, identifies a need

An IETF Working Group is created, charged with developing a proposal

Proposals are presented, debated, revised, expanded

Prototypes are implemented, tested

Interoperability tests are conducted

Experience with real users

IETF: a Meritocracy?

- Open, no-fee membership
- Published goals, milestones, and proposals
- No formal voting; disputes resolved by discussion and demonstration (mostly)
  - mailing lists and 3-a-year meetings
- Standardization only after several implementations

Internet Drafts and RFCs

- Internet drafts
  - working documents
  - only valid for 6 months (expire after that)
- "Request for Comments", since 1969
  - numbered sequentially (August 2005: #4150)
RFC 2026: "The Internet Standards Process"

- Standards status ("maturity level")
  - Proposed Standard
    - Ex.: Network Address Translation – Protocol Translation
  - Draft Standard
    - Ex.: Lightweight Directory Access Protocol
  - Internet Standard
    - Ex.: IP, UDP
- Other types of RFCs
  - Best current practices
  - Experimental
  - Informational

Summary

- Welcome to the class! You’re in good hands 😊
- The Internet isn’t perfect but it works and is here to stay
- The layered approach wins most of the time
- Internet performance characteristics today
  - Low utilization
  - Low loss rate
  - Low latency
  - High availability
- Security threats are a major concern
- Ethernet frames support 1500 byte transfers (MTUs)

Next Lecture

- IP, version 4 (IPv4)