Communication Protocols and Internet Architectures

Harvard University
CSCI S-I

Lecture #7

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Lecture Agenda

• Logistics and Q & A
• VLANs
• Domain Name Service
• Application Layer Protocols
• Midterm Review
• Three Minute Wrap-Up

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Course Logistics

- The midterm exam will be held next Wednesday July 27, 2005. Please see me if you have any questions about the logistics.
- A practice exam is posted on the course website.
- Homework #3 is due next Monday. Late homework will not be accepted.

Virtual LANs (VLANs)
802.1P & 802.1Q
Another Typical LAN Architecture

Internet Access

Enterprise Core Network

Accounting Dept

Sales Dept

Engineering Dept

140.247.32

140.247.34

140.247.36

Rational for Virtual LANs

- Groups of users within an organization are typically separated into their own IP networks (typically subnets) for network management, performance, security and other policy reasons.
- Users on LANs should be grouped by their community of interest (sales dept., engineering, accounting), not by their location in the building.
- However, users within a single community of interest are rarely located in the same part of a building.
- “Ethernet switches are easy, routers are hard.”
- Given all the above, how can we separate users via switches? What are the benefits to users and network administrators?
Virtual LANs

- “Switches are easy, routers are hard.” Given this, how can we separate users via switches? What are the benefits?
- Virtual LANs provide separate collision and broadcast domains for groups of users.
- Users are assigned to one or more VLANs automatically or via a management system.
- VLANs can span multiple switches and sites
- How do users on different VLANs talk to each other?
Virtual LANs

- VLANs are LAN segments (in the classic sense of the word) that can span multiple ethernet switches.
- VLANs provide separate collision and broadcast domains for each group of users.
- Users are assigned to one or more VLANs automatically or via a management system.
- Potential advantages of VLANs include:
  - Better isolation between groups of users: however it is incorrect to think that VLANs significantly improve network security.
  - Improved performance: the specific LAN performance requirements of each group can be met more easily.
  - Improved performance: VLANs provide multiple broadcast domains
  - Provides for more sophisticated network administration

Ethernet Switch and VLAN Topology

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Virtual LANs – 802.1p and 802.1q

- Ethernet priority and VLANs are distinct concepts, but they are intertwined by the technology.
- VLANs are identified by a 12 bit VLAN Identifier.
- Frame priority is marked by a 3 bit field, 0 to 7. This is known as Class of Service.
- Switches can and do, write or re-write, the priority field based on:
  - Port on the frame was received
  - MAC address of the sending station
  - Protocol – IP, IPX, etc.
  - IP Precedence field or DSCP
  - Other IP and/or TCP information
  - Combination of the above
Virtual LANs – some questions

• Can VLANs span multiple sites, such as different buildings on a campus?
• What is the best way to assign users to VLANs?
• How do users on different VLANs talk to each other?

Application Layer Protocols
Application Layer Software Schematic

<table>
<thead>
<tr>
<th>Appl. 1</th>
<th>Appl. 2</th>
<th>Appl. 2 (TCP)</th>
<th>Appl. 3 (UDP)</th>
<th>Appl. 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>TCP</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>UDP</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

IP Layer

Ethernet (Layers 1 and 2)

Domain Name System (DNS)

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Internet Domain Name System

- Hierarchical naming system where authority for coordinating individual names can be delegated to a particular partition in the name space.
- Classic top-most level uses a broad partition into categories (EDU, COM, GOV, MIL, NET, INT, ORG) or two letter country code. New TLDs defined in Nov. 2000.
- Domain Name Servers arranged in a tree structure satisfy requests for name/address mappings at a particular level.
- Names are mapped to 32 bit IPv4 addresses and of course there is support for IPv6 addresses.
- IP addresses can be mapped to names
  - *.*.*.*.in-addr.arpa
- Telephone numbers can also be mapped to IP addresses
  - *.*.*.*.e164.arpa

Partial DNS Name Space

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DNS Forward and Reverse Query
(The current Unix command for this is dig, but this is not yet available on Windows)

fas% nslookup
Default Server: noc.fas.harvard.edu
Address: 140.247.21.21

> www.mit.edu
Server: noc.fas.harvard.edu
Address: 140.247.21.21
Non-authoritative answer:
Name: DANDELION-PATCH.MIT.edu
Address: 18.181.0.31
Aliases: www.MIT.edu

> 18.181.0.31
Server: noc.fas.harvard.edu
Address: 140.247.21.21
Name: DANDELION-PATCH.MIT.EDU
Address: 18.181.0.31

DNS Simple Query using NSLOOKUP

fas% nslookup mit.edu
Server: noc.fas.harvard.edu
Address: 140.247.21.21

Non-authoritative answer:
Name: MIT.edu
Address: 18.72.0.70
fas%
DNS Resource Records (partial listing)

- A - specifies 32 bit IP address
- MX - mail exchange record
- NS - specifies authoritative name server for a domain
- PTR - record used for pointer queries
- CNAME - canonical name, provides alias functionality
- HINFO - specifies limited host information
- SRV – identifies a specific service
- NAPTR

DNS Address Resolution - load sharing

(The current Unix command for this is dig, but this is not yet available on Windows)

> www.ibm.com
Non-authoritative answer:
Name: www.ibm.com
Addresses: 129.42.17.99, 129.42.18.99, 129.42.19.99, 129.42.16.99

> www.ibm.com
Non-authoritative answer:
Name: www.ibm.com
Addresses: 129.42.19.99, 129.42.16.99, 129.42.17.99, 129.42.18.99

>
Harvard DNS MX Query

> set type=mx
> harvard.edu
Server: ns3.fas.harvard.edu
Address: 140.247.30.30

harvard.edu preference = 0, mail exchanger = netop3.harvard.edu
harvard.edu preference = 10, mail exchanger = netopc.harvard.edu
harvard.edu nameserver = ns.harvard.edu
harvard.edu nameserver = ns1.harvard.edu
harvard.edu nameserver = ns2.harvard.edu
netop3.harvard.edu internet address = 128.103.205.103
netopc.harvard.edu internet address = 128.103.201.112
ns.harvard.edu internet address = 128.103.201.100
ns1.harvard.edu internet address = 128.103.200.101
ns2.harvard.edu internet address = 128.103.1.1
>

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Sample DNS MX Query (part 1)

> set type=mx
> mit.edu
Server: ns3.fas.harvard.edu
Address: 140.247.30.30

Non-authoritative answer:
mit.edu preference = 100, mail exchanger = PACIFIC-CARRIER-ANNEX.mit.edu
mit.edu preference = 100, mail exchanger = FORT-POINT-STATION.mit.edu

Authoritative answers can be found from:
mit.edu nameserver = BITSY.mit.edu
mit.edu nameserver = STRAWB.mit.edu
mit.edu nameserver = W20NS.mit.edu
PACIFIC-CARRIER-ANNEX.mit.edu internet address = 18.7.21.83
FORT-POINT-STATION.mit.edu internet address = 18.7.7.76
BITSY.mit.edu internet address = 18.72.0.3
STRAWB.mit.edu internet address = 18.71.0.151
W20NS.mit.edu internet address = 18.70.0.160

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Sample DNS MX Query (part 2)

> lcs.mit.edu
Server: ns3.fas.harvard.edu
Address: 140.247.30.30

Non-authoritative answer:
lcs.mit.edu preference = 10, mail exchanger = fedex.ai.mit.edu
lcs.mit.edu preference = 1, mail exchanger = mintaka.lcs.mit.edu

Authoritative answers can be found from:
lcs.mit.edu nameserver = mintaka.lcs.mit.edu
lcs.mit.edu nameserver = OSSIEPEE.lcs.mit.edu
lcs.mit.edu nameserver = LAMPANG.lcs.mit.edu
lcs.mit.edu nameserver = fedex.ai.mit.edu
fedex.ai.mit.edu internet address = 192.148.252.43
mintaka.lcs.mit.edu internet address = 18.26.0.36
OSSIPEE.lcs.mit.edu internet address = 18.26.0.18
OSSIPEE.lcs.mit.edu internet address = 18.24.10.7
OSSIPEE.lcs.mit.edu

Sample DNS MX Query (part 3)

> ai.mit.edu
Server: ns3.fas.harvard.edu
Address: 140.247.30.30

Non-authoritative answer:
ai.mit.edu preference = 2, mail exchanger = fedex.ai.mit.edu
ai.mit.edu preference = 1, mail exchanger = life.ai.mit.edu

Authoritative answers can be found from:
ai.mit.edu nameserver = fedex.ai.mit.edu
ai.mit.edu nameserver = life.ai.mit.edu
ai.mit.edu nameserver = ALPHA-BITS.ai.mit.edu
ai.mit.edu nameserver = BEET-CHEX.ai.mit.edu
fedex.ai.mit.edu internet address = 192.148.252.43
life.ai.mit.edu internet address = 128.52.32.80
ALPHA-BITS.ai.mit.edu internet address = 128.52.32.5
BEET-CHEX.ai.mit.edu internet address = 128.52.32.22
>

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DNS Sample File (abridged)

DNS Related Files

networklandscape.com.forward
networklandscape.com.reverse.140.247.30
networklandscape.com.reverse.140.247.31

Printout of networklandscape.com.forward

@ IN SOA ns.networklandscape.com. root.ns.networklandscape.com. ( 97021601 ; serial
7200 ; refresh 2 hours
3600 ; retry 1 hour
3600000 ; expire 1 week
604800 ) ; min 1 week
IN NS unix1.networklandscape.com.

networklandscape.com IN MX 0 mail.networklandscape.com.
unix1 IN A 140.247.30.37
unix1 IN HINFO ops unix
marketing IN A 140.247.31.34
marketing IN HINFO marketing nt
www IN CNAME marketing.networklandscape.com.
web IN CNAME marketing.networklandscape.com.
mail IN CNAME unix1.networklandscape.com.

Domain Name System Architecture

- A Zone is a separately administered subtree of the DNS. A zone can be subdivided further.
- The administrator of a zone must provide multiple name servers which allow for no single point of failure
- Domain name servers communicate with each other to resolve requests (recursive or iterative resolution)
- Servers must know the addresses of the root servers.
- There are thirteen root servers
- Caching is used to reduce network traffic (TTL field is used)
- DNS uses both TCP and UDP

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DNS Address Resolution

But what is the IP address for this web site?

www.ai.mit.edu

DNS Address Resolution:
Would This Work?

Step 1: Query Harvard DNS
Step 2: DNS provides 18.181.0.31
Web request is sent.

Machine at Harvard with a web request for www.ai.mit.edu
DNS Address Resolution:

Step 1: Query Harvard DNS

Machine at Harvard with a web request for www.ai.mit.edu

DNS Root Server Query
DIG or NSLOOKUP

Windows> nslookup
Server: ns3.fas.harvard.edu
Address: 140.247.30.30

> root
Default Server: a.root-servers.net
Address: 198.41.0.4
IANA.org and ICANN.org

- IANA’s online databases keep track of important names and numbers from A to Z. These values are necessary for operation and growth of the Internet. (Of course, in the beginning, this used to be done via printed RFCs.)
- For example, IANA keeps track of protocol numbers (within IP) and port numbers (within TCP and UDP.)
- IANA originally kept track of IP addresses and domain names, but this function has been transitioned to ICANN.
- Check the ICANN web sites for current status.
- But who really registers domain names?

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New TLDs (Top-Level Domains)

- In Nov. 2000 the ICANN board decided on seven new TLDs
  - .aero - for the air-transport industry
  - .biz - for businesses
  - .coop - for cooperatives
  - .info - for all uses
  - .museum - for museums
  - .name - for individuals
  - .pro - for professions
- The first two of the seven TLDs (.biz and .info) became operational in the fall of 2001. It is difficult to keep track of the current status of the new TLDs.
**Telnet - Remote Login**

**TELNET**

- Provides a Network Virtual Terminal (NVT) to access a remote computer.
- Uses a single TCP connection and “in-band” signaling
- Simple 7-bit ASCII character device with keyboard and printer. End of line is sent as two character CR and LF.
- Command sequences delimited by IAC (Interpret As Command) byte.
- Telnet session starts with NVT assumption, followed by symmetric option negotiation
- Modes of operation are half-duplex, character at a time, line at a time and line mode.
- Data is not encrypted.
Email Protocols

SMTP Electronic Mail

- Email and its derivative applications drove the original growth of most corporate networks as well as the Internet.
- Mail systems provide for delayed delivery of messages and mail forwarding.
- Mail is comprised of three parts: the envelope, the headers and the body. All three use NVT ASCII characters.
- RFC 821 describes the Simple Mail Transfer Protocol
- SMTP uses a TCP connection for transport.
- RFC 822 describes the format of mail messages
- SMTP continues to change (RFC 1425, RFC 1522, MIME)
Simplified Mail System Architecture

Sender
User at terminal
User Agent
Queue of Mail to be Sent
MTA
TCP Connection
Port 25
File System

Receiver
User at terminal
User Agent
User Mailboxes
MTA
File System

Source and date: unknown

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Mail System Architecture

Sender
User Agent
MTA
MTA
MTA
MTA

Receiver
User Agent
MTA
MTA

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Simplified SMTP Procedure

>>> HELO Alpha.EDU
250 Beta.COM Hello Alpha.EDU, pleased to meet you
>>> MAIL FROM:<Smith@Alpha.EDU>
250 OK
>>> RCPT TO:<Jones@Beta.COM>
250 OK
>>> RCPT TO:<Green@Beta.COM>
550 No such user here
>>> RCPT TO:<Brown@Beta.COM>
250 OK
>>> DATA
354 Start mail input; end with <CRLF>,<CRLF>
>>> blah, blah, message goes here
>>> blah, blah, more message
>>> <CRLF>,<CRLF>
250 OK
>>> QUIT
221 Beta.COM delivering mail for you

Example from Comer

Reply Code Meanings

<table>
<thead>
<tr>
<th>Code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1yz</td>
<td>Positive preliminary reply, another reply to be sent</td>
</tr>
<tr>
<td>2yz</td>
<td>Positive completion reply, a new command can be sent</td>
</tr>
<tr>
<td>3yz</td>
<td>Positive intermediate reply, the command has been accepted but another command must be sent</td>
</tr>
<tr>
<td>4yz</td>
<td>Transient negative completion reply</td>
</tr>
<tr>
<td>5yz</td>
<td>Permanent negative completion reply</td>
</tr>
<tr>
<td>x0z</td>
<td>Syntax error</td>
</tr>
<tr>
<td>x1z</td>
<td>Information</td>
</tr>
<tr>
<td>x2z</td>
<td>Replies referring to the control or data connections</td>
</tr>
<tr>
<td>x3z</td>
<td>Authentication and accounting</td>
</tr>
<tr>
<td>x4z</td>
<td>Unspecified</td>
</tr>
<tr>
<td>x5z</td>
<td>Filesystem status</td>
</tr>
</tbody>
</table>
Typical Reply Codes with Possible Message String

125 - Data connection already open, transfer starting
214 - Help message, for human user
331 - Username OK, password required
452 - Error writing file
500 - Syntax error, unrecognized command
501 - Syntax error, invalid arguments

Sending Email via Telnet (part a)

Is03:~ % telnet courses.dce.harvard.edu 25
Trying 140.247.197.235...

Connected to barkley.dce.harvard.edu
(140.247.197.235).
Escape character is "^]".
220 barkley.dce.harvard.edu ESMTP Exim Mon, 24 Nov 2003 18:25:54 -0500
Sending Email via Telnet (part b)

ls03:~ %
ls03:~ % telnet courses.dce.harvard.edu 25
Trying 140.247.197.235...
Connected to barkley.dce.harvard.edu (140.247.197.235).
Escape character is '^]'.
220 barkley.dce.harvard.edu ESMTP
Exim Mon, 24 Nov 2003 18:25:54 -0500
MAIL FROM:<le@harvard.edu>
250 <le@harvard.edu> is syntactically correct
RCPT TO:<cscie131b@barkley.dce.harvard.edu>
250 <cscie131b@barkley.dce.harvard.edu> verified
DATA

Sending Email via Telnet (part c)

220 barkley.dce.harvard.edu ESMTP Exim Mon, 24 Nov 2003 18:25:54 -0500
MAIL FROM:<le@harvard.edu>
250 <le@harvard.edu> is syntactically correct
RCPT TO:<cscie131b@barkley.dce.harvard.edu>
250 <cscie131b@barkley.dce.harvard.edu> verified
DATA
354 Enter message, ending with "." on a line by itself
From: Len E
To: The TAs in the course
Dt: Wed, Dec 1, 1901
Re: Planning for the midterm
Dear TAs,

Should we include anything on the midterm on this new thing called a telephone?

... Len

250 OK id=1AOQ7C-0000CR-00
Sending Email via Telnet (part d)
Mail as Delivered (headers off)

Date: Mon, 24 Nov 2003 18:29:29 -0500
From: Len E
To: The TAs in the course

Dear TAs,

Should we include anything on the midterm on this new thing called a telephone?

... Len

Sending Email via Telnet (part e)
Mail as Delivered (headers on)

Return-path: <le@harvard.edu>
Envelope-to: cscie131b@barkley.dce.harvard.edu
Delivery-date: Mon, 24 Nov 2003 18:31:09 -0500
Received: from ls03.fas.harvard.edu [140.247.34.103] (evenchik)
  by barkley.dce.harvard.edu with smtp (Exim)
  for cscie131b@barkley.dce.harvard.edu
  id 1AOQ7C-0000CR-00; Mon, 24 Nov 2003 18:29:29 -0500
From: Len E
To: The TAs in the course
Dt: Wed, Dec 1, 1901
Re: Planning for the midterm
Message-id: <E1AOQ7C-0000CR-00@barkley.dce.harvard.edu>
Date: Mon, 24 Nov 2003 18:29:29 -0500

Dear TAs,

Should we include anything on the midterm on this new thing called a telephone?

... Len
Email Delivery Problems (Part 1a)

What can happen when the destination mail system is not available?

Return-Path: <MAILER-DAEMON@fas.harvard.edu>
Received: from localhost by smtp3.fas.harvard.edu
From: Mail Delivery Subsystem <MAILER-DAEMON@fas.harvard.edu>
To: <evenchk@fas.harvard.edu>
MIME-Version: 1.0
Content-Type: multipart/report; report-type=delivery-status;

Subject: Warning: could not send message for past 4 hours
Auto-Submitted: auto-generated (warning-timeout)

Email Delivery Problems (Part 1b)

What can happen when the destination mail system is not available?

----- The following addresses had transient non-fatal errors ----- 
<websupt@lab.dce.harvard.edu>

----- Transcript of session follows ----- 
451 4.4.1 <websupt@lab.dce.harvard.edu>... Deferred: Connection reset
Warning: message still undelivered after 4 hours
Will keep trying until message is 5 days old

Reporting-MTA: dns; smtp3.fas.harvard.edu
Arrival-Date: Thu, 25 Oct 2002 15:35:05 -0400 (EDT)
Action: delayed
Status: 4.4.2
Will-Retry-Until: Tue, 30 Oct 2002 15:35:05 -0400 (EDT)
….. a copy of the original message followed…. © 1998-2005 L. Evenchik
Email MTA Forwarding

Date: Sat, 1 Dec 2001 17:10:26 -0500 (EST)
From: cscie131b@barkley.dce.harvard.edu
To: len@alum.mit.edu
Subject: Message to test MTA forwarding
----
This is a test of forwarding by MTAs.
--

Email MTA Forwarding
(With header option turned on.)

Date: Sat, 1 Dec 2001 17:10:26 -0500 (EST)
To: len@alum.mit.edu
Subject: Message to test MTA forwarding
MIME-Version: 1.0
Content-Type: TEXT/PLAIN; charset=US-ASCII

This is a test of forwarding by MTAs.
--
Email MTA Forwarding

FORWARD 4
Received: from ALUM.MIT.EDU [18.7.21.81]
by smtp3.fas.harvard.edu with ESMTP id... 1 Dec 2001 17:10:29
Return-Path: <cscie131b@barkley.dce.harvard.edu>

FORWARD 3
Received: from smtp2.fas.harvard.edu [140.247.34.52])
by alum.mit.edu with ESMTP for <len@alum.mit.edu>
1 Dec 2001 17:10:28 -0500 (EST)
From: cscie131b@barkley.dce.harvard.edu

FORWARD 2
Received: from barkley.dce.harvard.edu [140.247.197.235]) by
smtp2.fas.harvard.edu with ESMTP 1 Dec 2001 17:10:28 -0500 (EST)

FORWARD 1
Received: from cscie131b by barkley.dce.harvard.edu with local-esmtp for
len@alum.mit.edu
id 16AIL4-0000PB-00; Sat, 01 Dec 2001 17:10:26 -0500
Date: Sat, 1 Dec 2001 17:10:26 -0500 (EST)
To: len@alum.mit.edu
Subject: Message to test MTA forwarding
MIME-Version: 1.0
Content-Type: TEXT/PLAIN; charset=US-ASCII
This is a test of forwarding by MTA.

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Email MTA Forwarding

FORWARD 4
Received: from ALUM.MIT.EDU [18.7.21.81]
   by smtp3.fas.harvard.edu with ESMTP id... 1 Dec 2001 17:10:29
Return-Path: <cscie131b@barkley.dce.harvard.edu>

FORWARD 3
Received: from smtp2.fas.harvard.edu [140.247.34.52])
by alum.mit.edu with ESMTP for <len@alum.mit.edu>
1 Dec 2001 17:10:28 -0500 (EST)
From: cscie131b@barkley.dce.harvard.edu

FORWARD 2 - not shown
FORWARD 1 - not shown

MIME

• Defines encoding rules to allow for non-ASCII messages. RFC 1521 is an extension to RFC 822
• Defines additional message headers within email message.
• Content-Transfer-Encoding defines how the body is wrapped for transmission. Schemes include: 7-bit ASCII, 8-bit characters, base64 encoding, quoted-printable, binary
• Content-Type describes the nature of the message. Types include: text, image, audio, video application, multipart
• Sub-types present for each Content-Type
Multiple Protocol Mail System Architecture

File Transfer - FTP
File Transfer Applications

- FTP is the basic Internet File Transfer Protocol. The application is included in almost all protocol stacks.
- In addition to its file transfer capabilities, FTP provides functionality for simple password based authentication and interactive file control.
- FTP uses two separate reliable TCP connections; one for control and one for data.
- FTP uses TELNET-like commands on the control connection.
- TFTP is a separate protocol that provides a very basic file transfer capability using UDP.

(Simplified FTP Model)

(Source and copyright held by W.R. Stevens from TCP/IP Illustrated, Volume 1, Fig. 27.1, Addison-Wesley, 1994)

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FTP Session Example (part 1)

FTP session details from logging into dcepea.dce.harvard.edu as the user CSCIE131B

connecting to 140.247.197.195 ...
Connected to 140.247.197.195 port 21

USER cscie131b
331 Password required for cscie131b.
PASS (hidden)
230-Please read the file README, it was last modified on Nov. 2, 1997
230 User cscie131b logged in.

PWD
257 "/extension/cscie131b" is current directory.

SYST
215 UNIX Type: L8
Host type (S): UNIX (standard)

FTP Session Example (part 2)

FTP session details for changing to the directory called framerelaydir on the remote system and then doing a listing of that directory.

CWD framerelaydir
250 CWD command successful.
PWD
257 "/extension/cscie131b/framerelaydir" is current directory.

PORT 140.247.197.34,4,127
200 PORT command successful.
LIST
150 Opening ASCII mode data connection for /bin/ls.
Received 724 bytes in 0.1 secs, (53.44 Kbps), transfer succeeded
226 Transfer complete.
FTP Port Usage

FTP Client

Port 1150
Port 1151 (passive open)

FTP Server

Port 21

PORT command going across FTP control connection

FTP Server doing active open of data connection

FTP Session Example (part 3)

FTP session details for getting a file called FTP.LOG and then sending a file called hello.gif to the remote system.

TYPE I
200 Type set to I.
PORT 140,247,197,34,4,61
200 PORT command successful.
RETR FTP.LOG
150 Opening BINARY mode data connection for FTP.LOG (1752 bytes).
Received 1752 bytes in 0.5 secs, (33.93 Kbps), transfer succeeded
226 Transfer complete.

PORT 140,247,197,34,4,62
200 PORT command successful.
STOR hello.gif
150 Opening BINARY mode data connection for hello.gif.
Transmitted 648 bytes in 0.1 secs, (60.00 Kbps), transfer succeeded
226 Transfer complete.
World Wide Web - HTTP

Application Layer Software Schematic
The Web (only the basics, part 1)

- HTTP is an application layer protocol used to move HTML pages
- Universal Resource Locators (URLs) identify a page somewhere in the world (3 part name: protocol, DNS name for machine, local ID)
- Each HTTP interaction is a single request followed by a MIME-like response.
- HTTP 1.1 commands include: get, post, put, options and delete
- Status message follow ASCII approach (1xx, 2xx, 3xx, etc.) seen in other app-layer protocols

GET Method (1)

fas% telnet lab.dce.harvard.edu 80
Trying 140.247.197.245...
Connected to dcepea.harvard.edu.
Escape character is '^]'.

GET / HTTP/1.1
Host: lab.dce.harvard.edu
GET Method (2)

HTTP/1.1 200 OK
Date: Mon, 26 Dec 2001 12:31:01 GMT
Server: Apache/1.3.12 (Unix) AuthMySQL/2.20
Last-Modified: Tue, 05 Oct 2001 20:40:29 GMT
ETag: "b006f-703-37fa623d"
Accept-Ranges: bytes
Content-Length: 1795
Content-Type: text/html

<!DOCTYPE HTML PUBLIC "-//W3C//DTD HTML 3.2 Draft//EN">
<html>
<head>
<title>
Harvard DCE: http://lab.dce.harvard.edu/
</title>
</head>
<body background="img/……………………etc…..."

GET Method (3)

fas% telnet lab.dce.harvard.edu 80
Trying 140.247.197.245...
Connected to dcepea.harvard.edu.
Escape character is '^]'.
GET / HTTP/1.1

HTTP/1.1 400 Bad Request
Date: Mon, 04 Dec 2000 22:28:21 GMT
Server: Apache/1.3.12 (Unix) AuthMySQL/2.20
Connection: close
Transfer-Encoding: chunked
Content-Type: text/html; charset=iso-8859-1

<!DOCTYPE HTML PUBLIC "-//IETF//DTD HTML 2.0//EN">
<HTML><HEAD>
The Web (only the basics - part 2)

- Local caching is almost always used
- Proxy servers act as a cache, and in combination with a firewall, can restrict out-bound access to web sites.
- HTTP v1.1 defines Host Header so that multiple IP addresses do not have to be assigned to server.
- Each HTTP interaction is a single request followed by a MIME-like response.
- HTTP 1.0 sent one entity per session. HTTP 1.1 defines persistent connection to improve performance

Multiple Protocol Mail System Architecture
Three Minute Wrap-Up

• Please write down the three or four major points that were discussed during the lecture.
• Note whether the material was presented clearly and/or how it should have been done differently.
• Ask any questions that I should address next time.
• Please do a Wrap-Up at the end of lecture and hand it in as you leave or fill out the form on the web site.
• Do not sign your form. (The form on the web site is also anonymous.)
• Thank you!