Discussion Session #3

EE450: Computer Networks

Topic: Network Applications

Some network apps

- e-mail
- web
- instant messaging
- remote login
- P2P file sharing
- multi-user network games
- streaming stored video (YouTube)
- voice over IP
- real-time video conferencing
- cloud computing
- …
- …
-

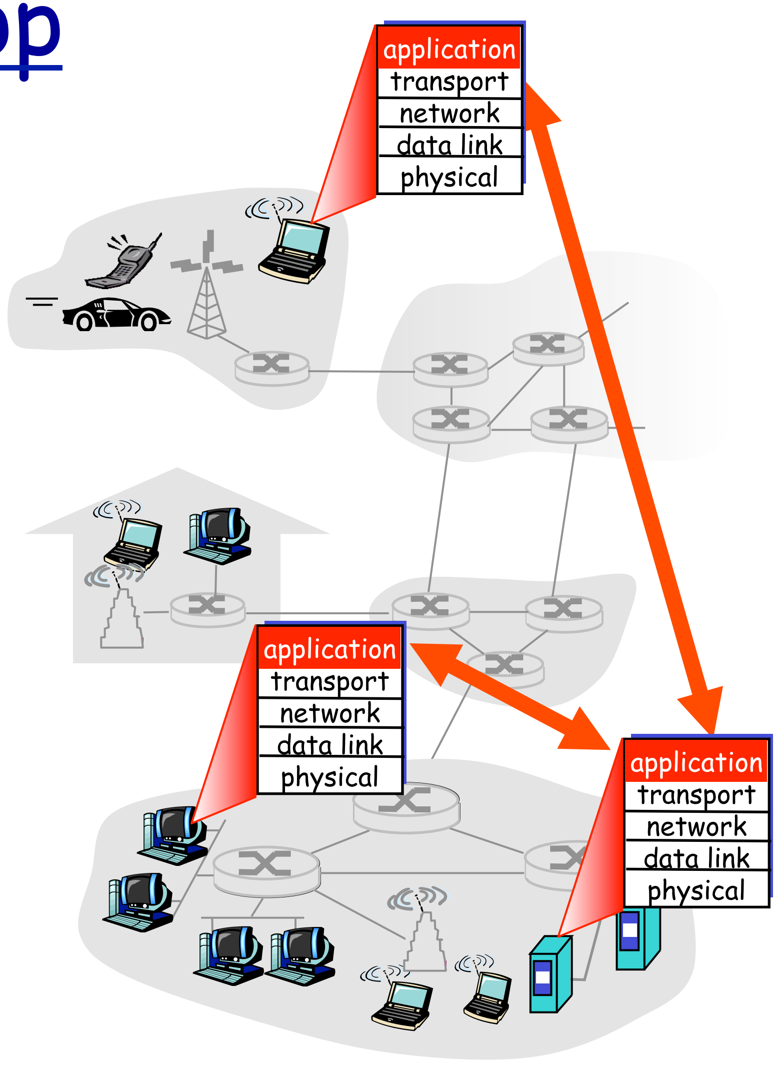
Creating a network app

write programs that

- run on (different) *end systems*
- communicate over network
- e.g., web server software communicates with browser software

No need to write software for network-core devices

- network-core devices do not run user applications
- applications on end systems allows for rapid app development, propagation



Processes communicating

process: program running within a host.

- within same host, two processes communicate using inter-process communication (defined by OS).
- processes in different hosts communicate by exchanging messages

client process: process that initiates communication

server process: process that waits to be contacted

- aside: applications with P2P architectures have client processes & server processes

Web and HTTP

First, a review...

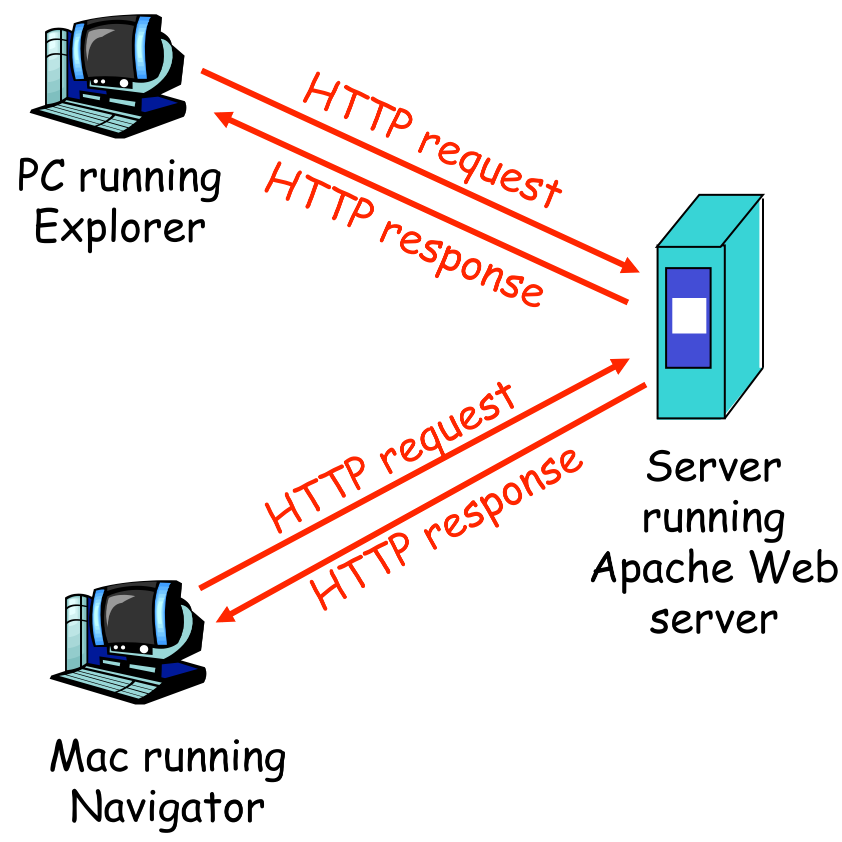
- web page consists of objects
- object can be HTML file, JPEG image, Java applet, audio file,...
- web page consists of base HTML-file which includes several referenced objects
- each object is addressable by a URL
- example URL:

$$\underbrace{\texttt{www.someschool.edu}}_{\text{host name}}\underbrace{\texttt{/someDept/pic.gif}}_{\text{path name}}$$

HTTP overview

HTTP: hypertext transfer protocol

- Web's application layer protocol
- client/server model
  - *client:* browser that requests, receives, "displays" Web objects
  - *server:* Web server sends objects in response to requests



HTTP overview (continued)

Uses TCP:

- client initiates TCP connection (creates socket) to server, port 80
- server accepts TCP connection from client
- HTTP messages (application-layer protocol messages) exchanged between browser (HTTP client) and Web server (HTTP server)
- TCP connection closed

HTTP is "stateless"

- server maintains no information about past client requests

aside

protocols that maintain "state" are complex!

- past history (state) must be maintained
- if server/client crashes, their views of "state" may be inconsistent, must be reconciled

HTTP connections

non-persistent HTTP

- at most one object sent over TCP connection.

persistent HTTP

- multiple objects can be sent over single TCP connection between client, server.

Nonpersistent HTTP

suppose user enters URL:

`www.someSchool.edu/someDepartment/home.index`

(contains text, references to 10 jpeg images)

1a. HTTP client initiates TCP connection to HTTP server (process) at www.someSchool.edu on port 80

1b. HTTP server at host www.someSchool.edu waiting for TCP connection at port 80. "accepts" connection, notifying client

2. HTTP client sends HTTP *request message* (containing URL) into TCP connection socket. Message indicates that client wants object someDepartment/home.index

3. HTTP server receives request message, forms *response message* containing requested object, and sends message into its socket

time

Nonpersistent HTTP (cont.)

4. HTTP server closes TCP connection.

5. HTTP client receives response message containing html file, displays html. Parsing html file, finds 10 referenced jpeg objects

6. Steps 1-5 repeated for each of 10 jpeg objects

time

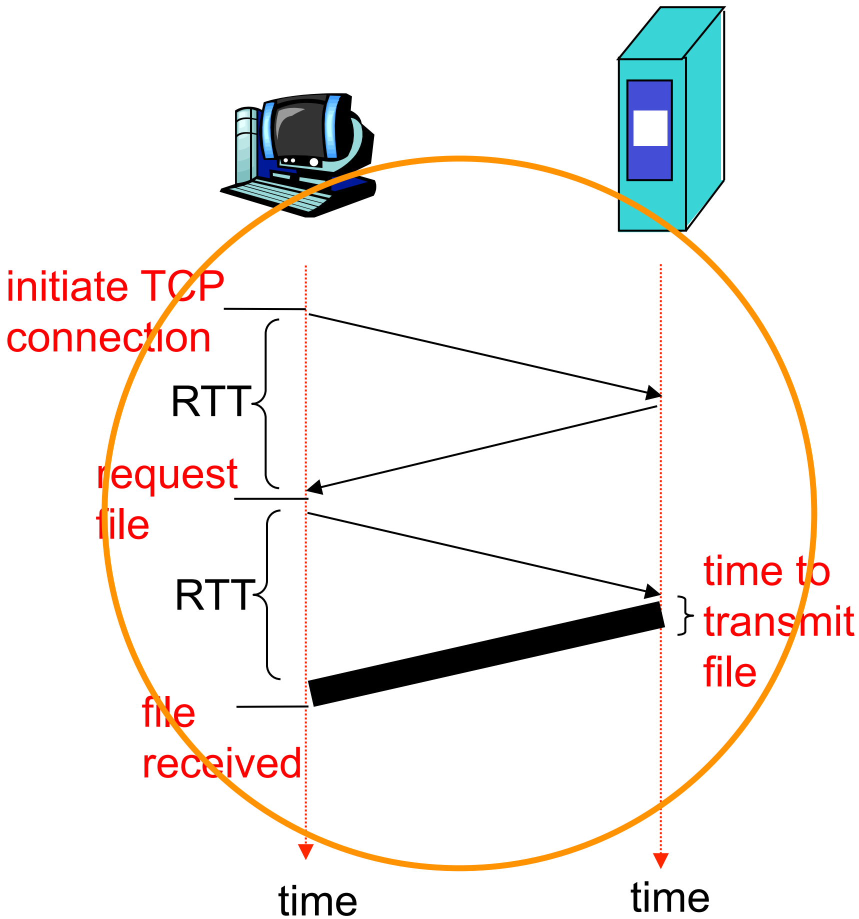
Non-Persistent HTTP: Response time

definition of RTT: time for a small packet to travel from client to server and back.

response time:

- one RTT to initiate TCP connection
- one RTT for HTTP request and first few bytes of HTTP response to return
- file transmission time

total = 2RTT+transmit time



Persistent HTTP

non-persistent HTTP issues:

- requires 2 RTTs per object
- OS overhead for *each* TCP connection
- browsers often open parallel TCP connections to fetch referenced objects

persistent HTTP

- server leaves connection open after sending response
- subsequent HTTP messages between same client/server sent over open connection
- client sends requests as soon as it encounters a referenced object
- as little as one RTT for all the referenced objects

HTTP request message

- two types of HTTP messages: *request, response*
- HTTP request message:
  - ASCII (human-readable format)

carriage return character

line-feed character

request line (GET, POST, HEAD commands)

header lines

carriage return, line feed at start of line indicates end of header lines

```
GET /index.html HTTP/1.1\r\n
Host: www-net.cs.umass.edu\r\n
User-Agent: Firefox/3.6.10\r\n
Accept: text/html,application/xhtml+xml\r\n
Accept-Language: en-us,en;q=0.5\r\n
Accept-Encoding: gzip,deflate\r\n
Accept-Charset: ISO-8859-1,utf-8;q=0.7\r\n
Keep-Alive: 115\r\n
Connection: keep-alive\r\n
\r\n
```

HTTP response message

status line
(protocol
status code
status phrase)

header
lines

data, e.g.,
requested
HTML file

```
HTTP/1.1 200 OK\r\n
Date: Sun, 26 Sep 2010 20:09:20 GMT\r\n
Server: Apache/2.0.52 (CentOS)\r\n
Last-Modified: Tue, 30 Oct 2007 17:00:02 GMT
   \r\n
ETag: "17dc6-a5c-bf716880"\r\n
Accept-Ranges: bytes\r\n
Content-Length: 2652\r\n
Keep-Alive: timeout=10, max=100\r\n
Connection: Keep-Alive\r\n
Content-Type: text/html;
   charset=ISO-8859-1\r\n
\r\n
data data data data data ...
```

HTTP response status codes

- status code appears in 1st line in server->client response message.
- some sample codes:

200 OK

- request succeeded, requested object later in this msg

301 Moved Permanently

- requested object moved, new location specified later in this msg (Location:)

400 Bad Request

- request msg not understood by server

404 Not Found

- requested document not found on this server

505 HTTP Version Not Supported

Trying out HTTP (client side) for yourself

1. Telnet to your favorite Web server:

```
telnet cis.poly.edu 80
```

opens TCP connection to port 80 (default HTTP server port) at cis.poly.edu. anything typed in sent to port 80 at cis.poly.edu

2. type in a GET HTTP request:

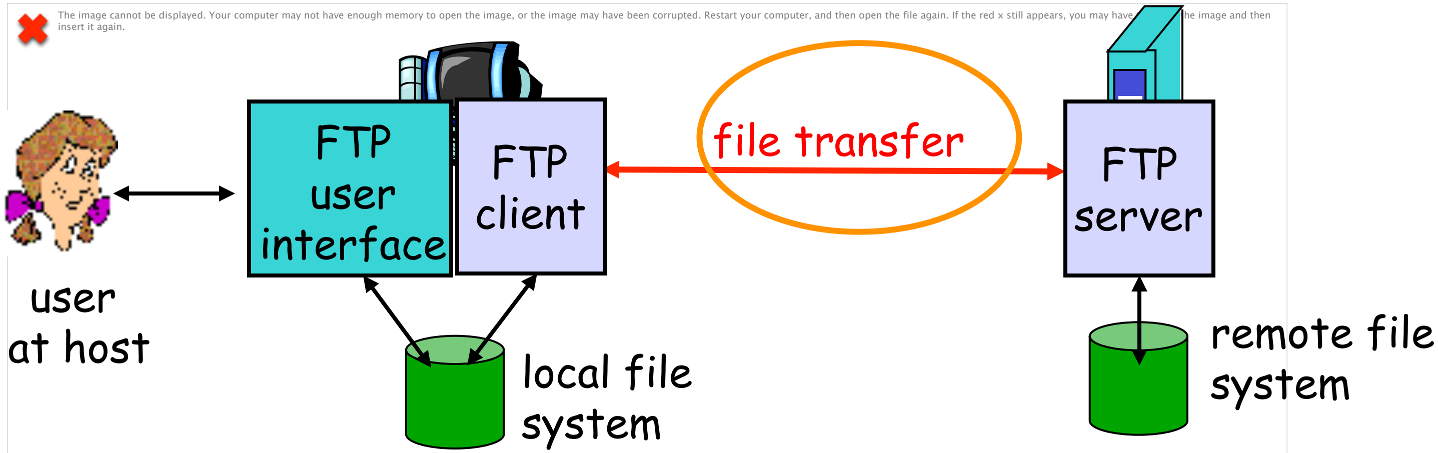
```
GET /~ross/ HTTP/1.1
Host: cis.poly.edu
```

by typing this in (hit carriage return twice), you send this minimal (but complete) GET request to HTTP server

3. look at response message sent by HTTP server!

(or use Wireshark!)

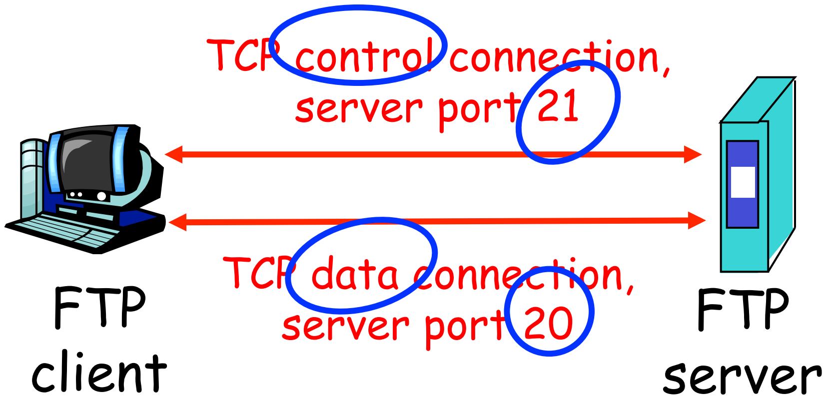
FTP: the file transfer protocol



- transfer file to/from remote host
- client/server model
  - *client:* side that initiates transfer (either to/from remote)
  - *server:* remote host
- ftp: RFC 959
- ftp server: port 21

FTP: separate control, data connections

- FTP client contacts FTP server at port 21, TCP is transport protocol
- client authorized over control connection
- client browses remote directory by sending commands over control connection.
- when server receives file transfer command, server opens 2nd TCP connection (for file) to client
- after transferring one file, server closes data connection.



- server opens another TCP data connection to transfer another file.
- control connection: "out of band"
- FTP server maintains "state": current directory, earlier authentication

FTP commands, responses

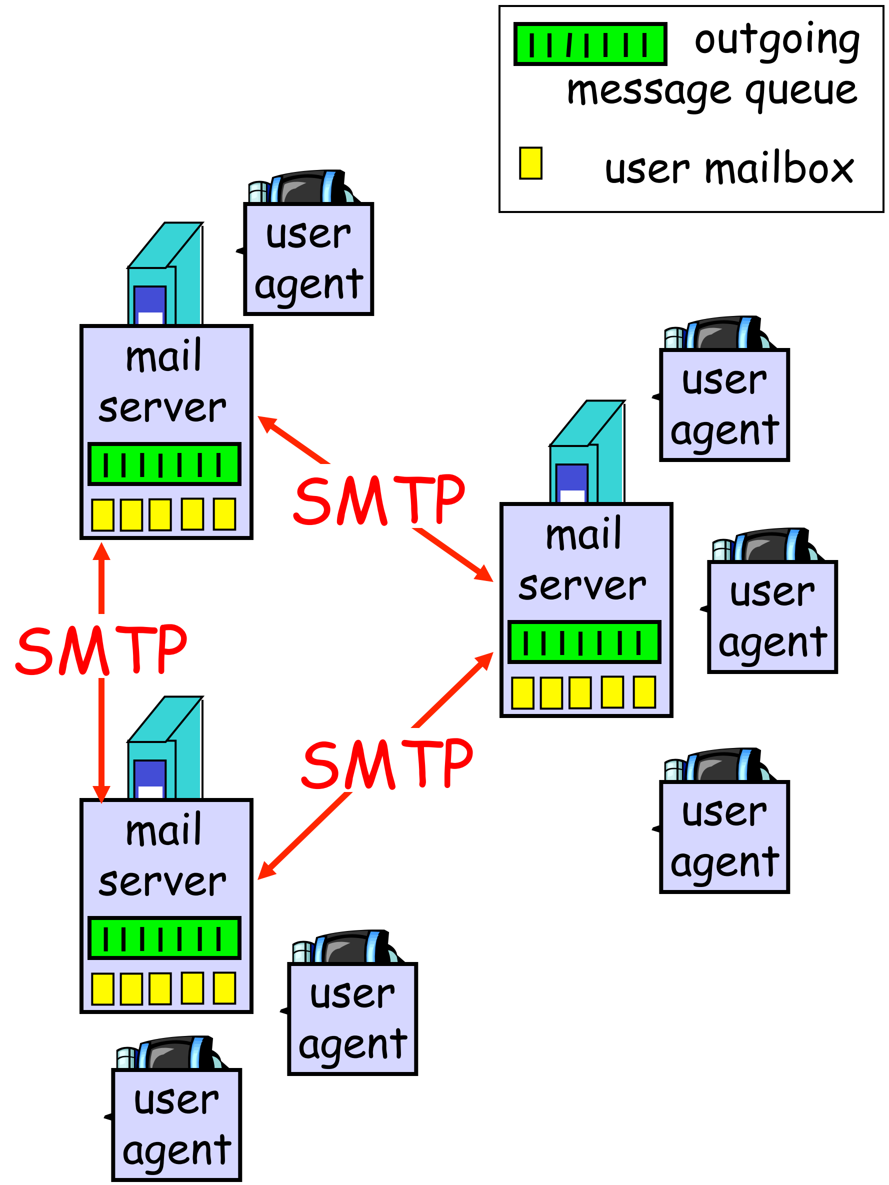
sample commands:

- sent as ASCII text over control channel
- `USER` ***`username`***
- `PASS` ***`password`***
- `LIST` return list of file in current directory
- `RETR filename` retrieves (gets) file
- `STOR filename` stores (puts) file onto remote host

sample return codes

- status code and phrase (as in HTTP)
- `331 Username OK, password required`
- `125 data connection already open; transfer starting`
- `425 Can't open data connection`
- `452 Error writing file`

Electronic Mail



Three major components:

- user agents
- mail servers
- simple mail transfer protocol: SMTP

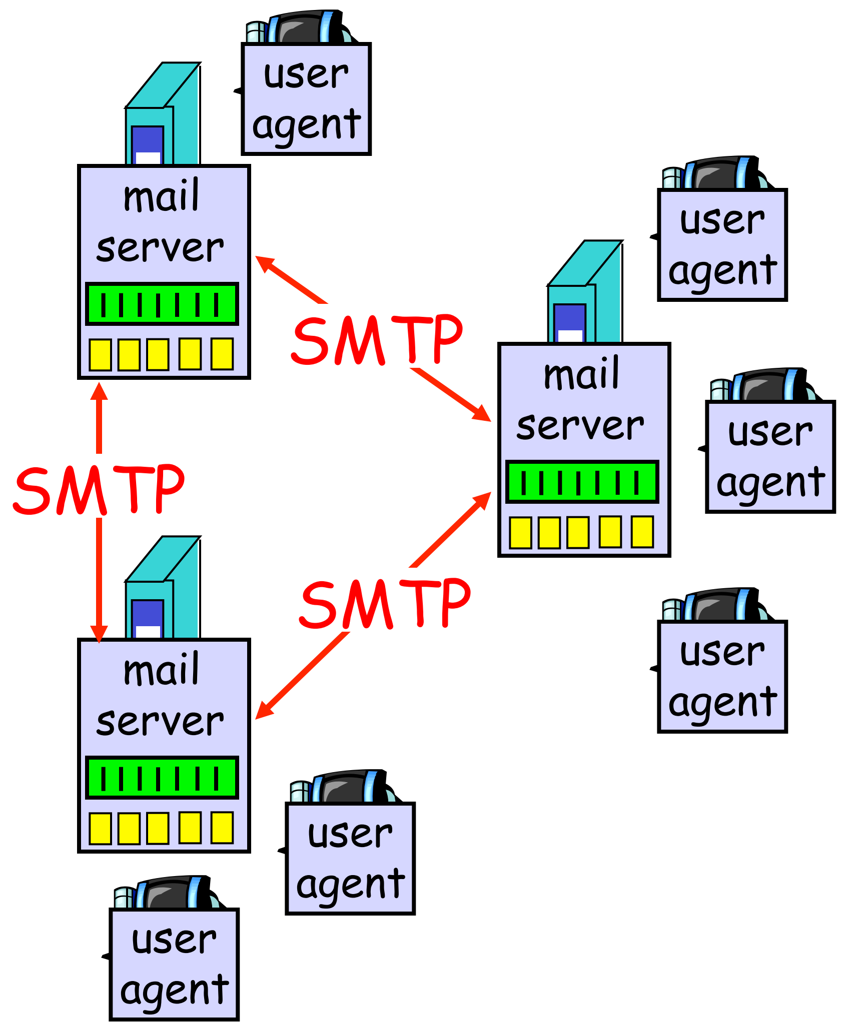
User Agent

- a.k.a. "mail reader"
- composing, editing, reading mail messages
- e.g., Outlook, elm, Mozilla Thunderbird, iPhone mail client
- outgoing, incoming messages stored on server

Electronic Mail: mail servers

Mail Servers

- mailbox contains incoming messages for user
- message queue of outgoing (to be sent) mail messages
- SMTP protocol between mail servers to send email messages
  - client: sending mail server
  - "server": receiving mail server



Electronic Mail: SMTP [RFC 2821]

- uses TCP to reliably transfer email message from client to server, port 25
- direct transfer: sending server to receiving server
- three phases of transfer
  - handshaking (greeting)
  - transfer of messages
  - closure
- command/response interaction
  - commands: ASCII text
  - response: status code and phrase
- messages must be in 7-bit ASCII

Scenario: Alice sends message to Bob

1) Alice uses UA to compose message and "to" `bob@someschool.edu`

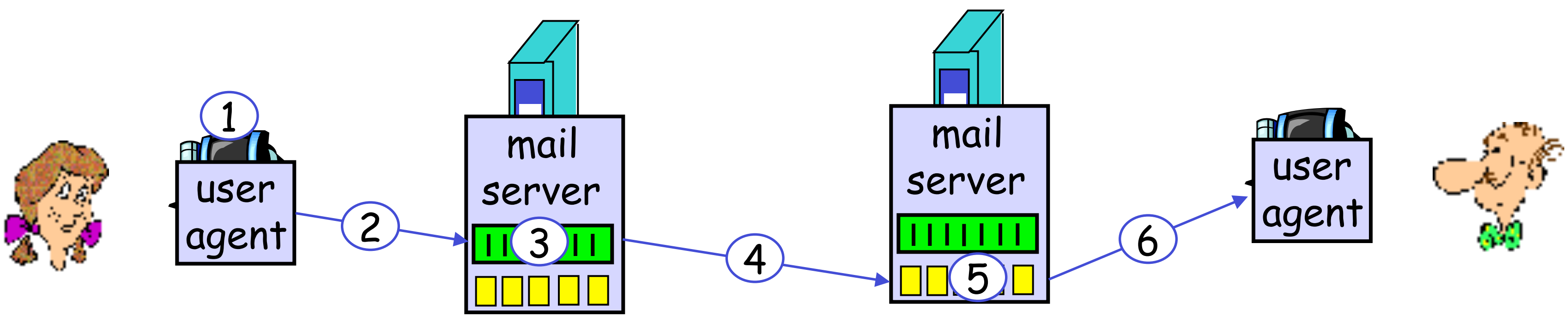
2) Alice's UA sends message to her mail server; message placed in message queue

3) Client side of SMTP opens TCP connection with Bob's mail server

4) SMTP client sends Alice's message over the TCP connection

5) Bob's mail server places the message in Bob's mailbox

6) Bob invokes his user agent to read message

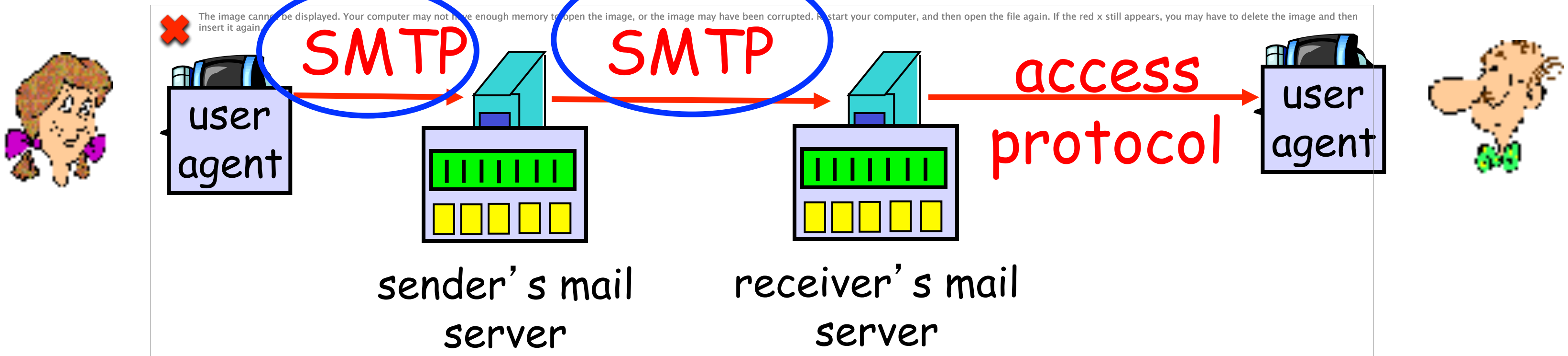


Try SMTP interaction for yourself:

- **`telnet servername 25`**
- see 220 reply from server
- enter HELO, MAIL FROM, RCPT TO, DATA, QUIT commands

above lets you send email without using email client (reader)

Mail access protocols

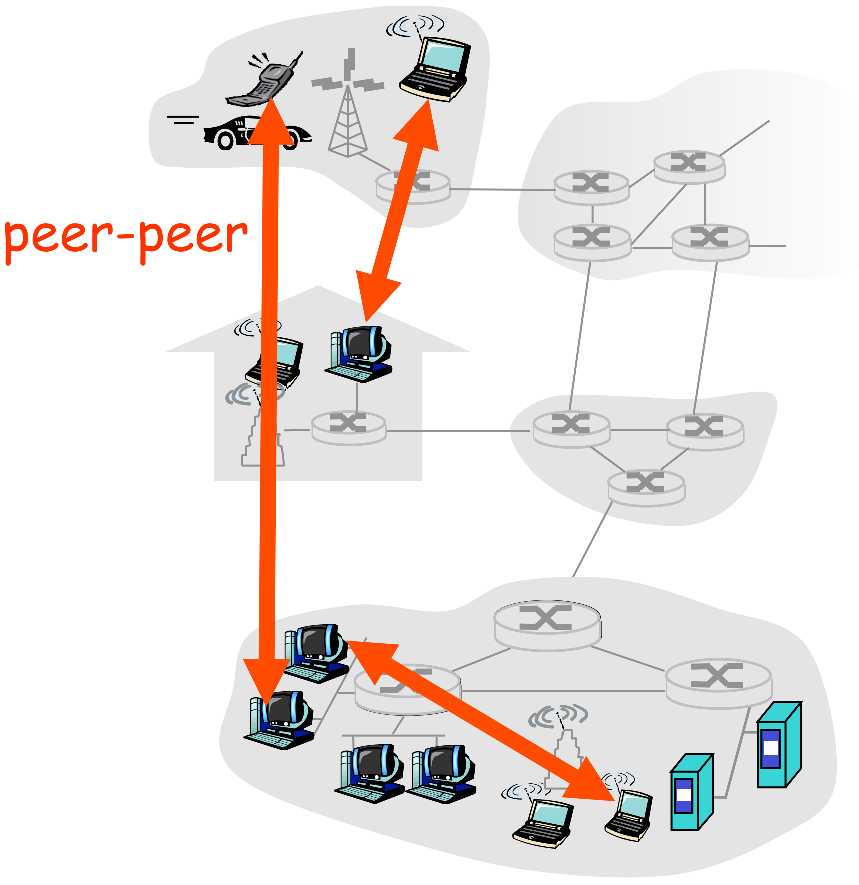


- SMTP: delivery/storage to receiver's server
- mail access protocol: retrieval from server
  - POP: Post Office Protocol [RFC 1939]
    - authorization (agent <-->server) and download
  - IMAP: Internet Mail Access Protocol [RFC 1730]
    - more features (more complex)
    - manipulation of stored msgs on server
  - HTTP: gmail, Hotmail, Yahoo! Mail, etc.

Difference between POP & IMAP: https://help.aol.com/articles/what-is-the-difference-between-pop3-and-imap

Pure P2P architecture

- *no* always-on server
- arbitrary end systems directly communicate
- peers are intermittently connected and change IP addresses

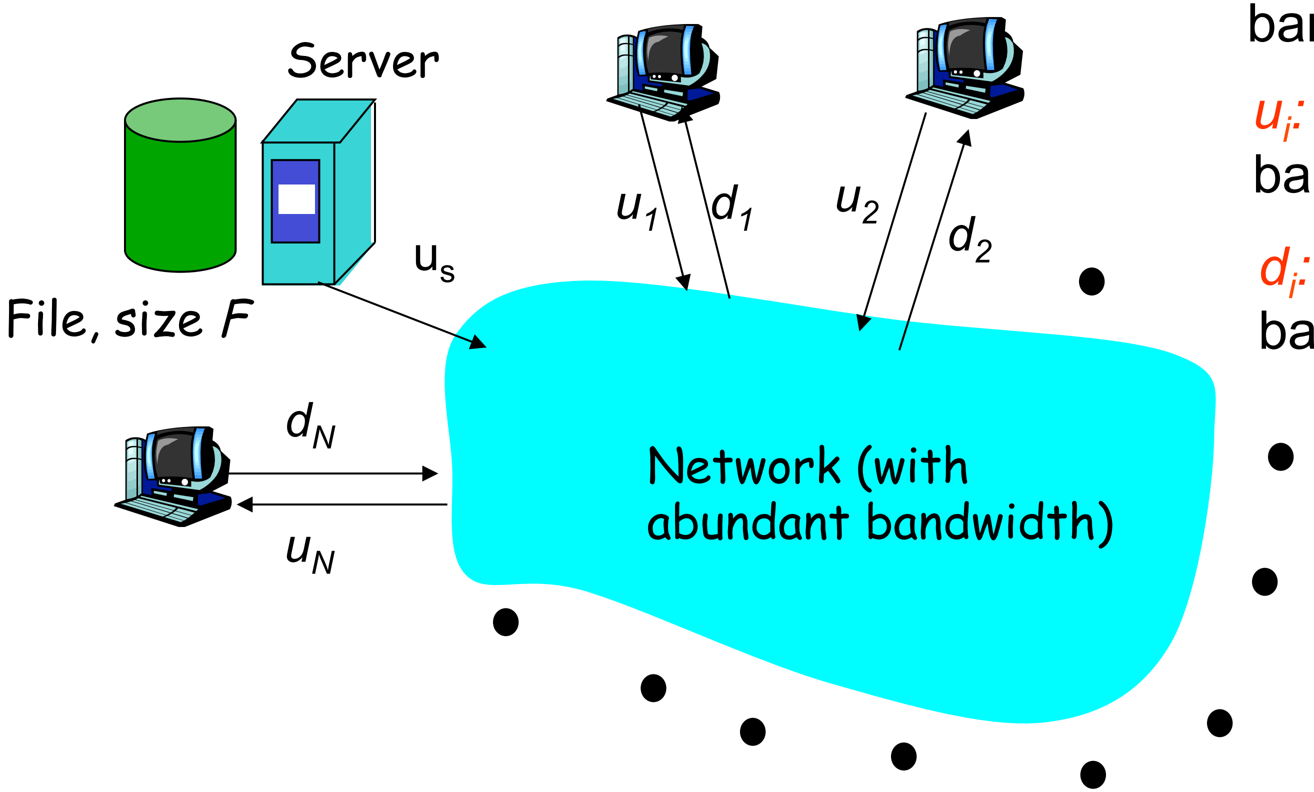


Three topics:

- file distribution
- searching for information
- case Study: Skype

File Distribution: Server-Client vs P2P

Question : How much time to distribute file from one server to N *peers*?



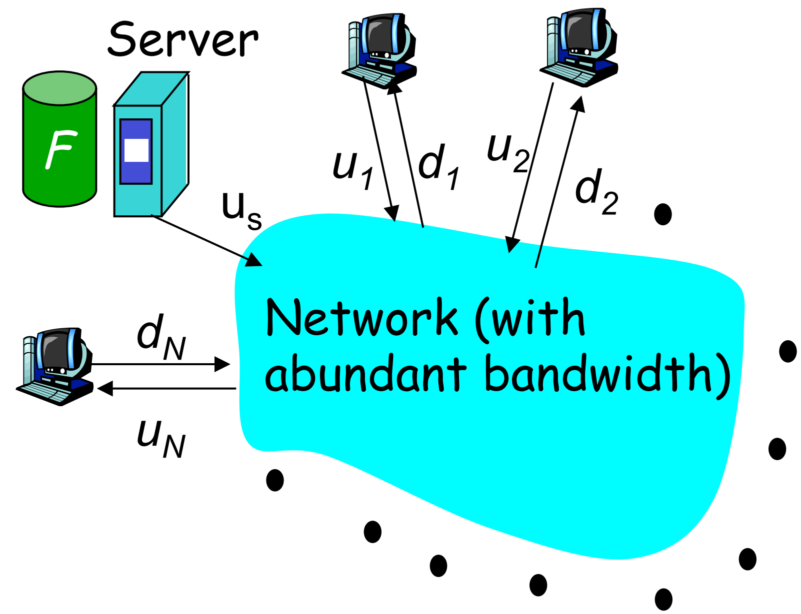
u_s: server upload bandwidth

u_i: peer i upload bandwidth

d_i: peer i download bandwidth

File distribution time: server-client

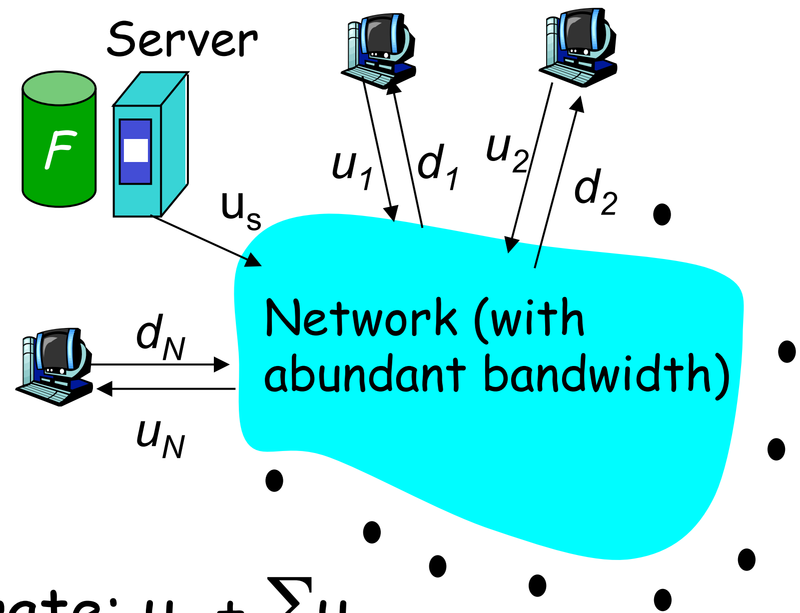
- server sequentially sends N copies:
  - NF/u_s time
- client i takes F/d_i time to download



Time to distribute F
to N clients using client/server approach $= d_{cs} = \max\left\{ NF/u_s, F/\min_i(d_i) \right\}$

increases linearly in N (for large N)

File distribution time: P2P

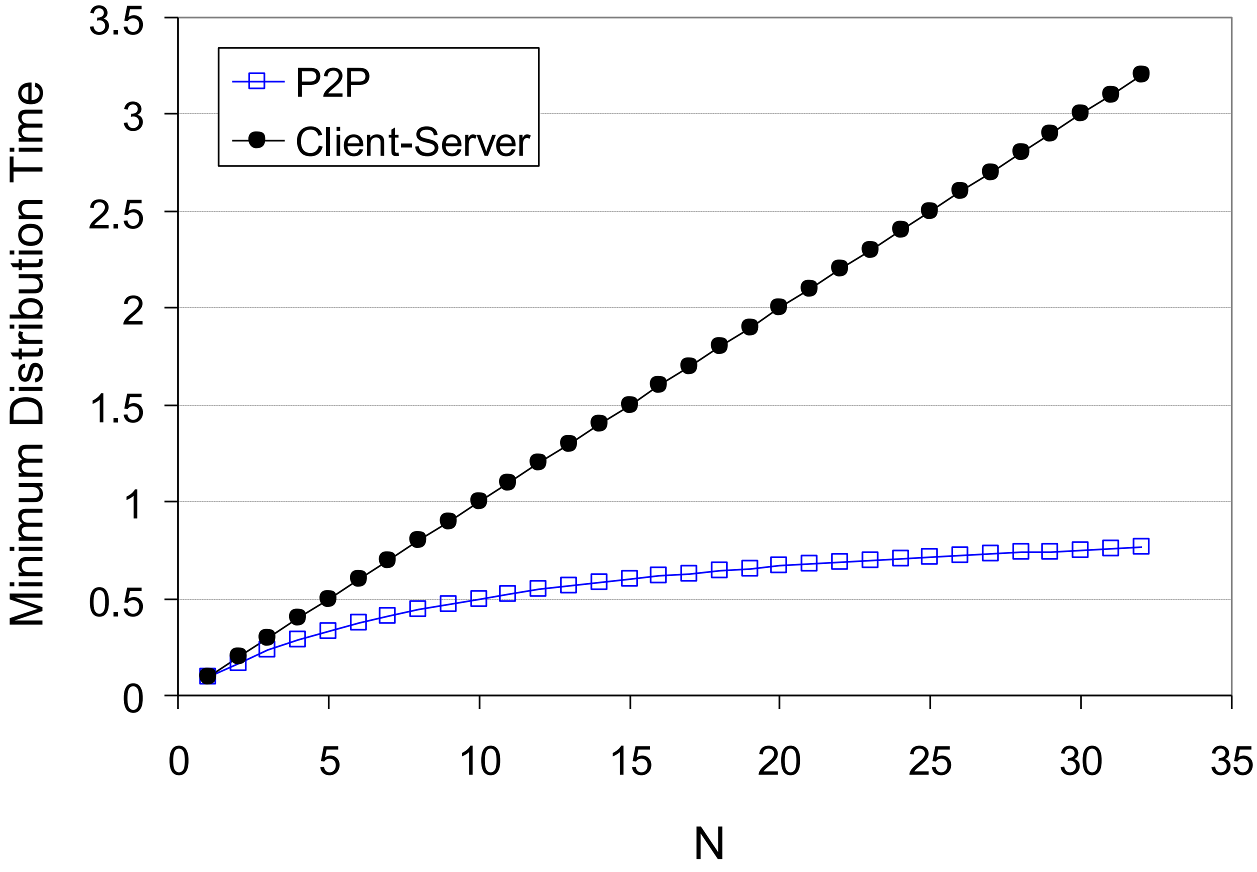


- server must send one copy: F/u_s time
- client i takes F/d_i time to download
- NF bits must be downloaded (aggregate)
  - fastest possible upload rate: $u_s + \Sigma u_i$

$$d_{P2P} = \max \{ F/u_s, F/\min_i(d_i), NF/(u_s + \Sigma u_i) \}$$

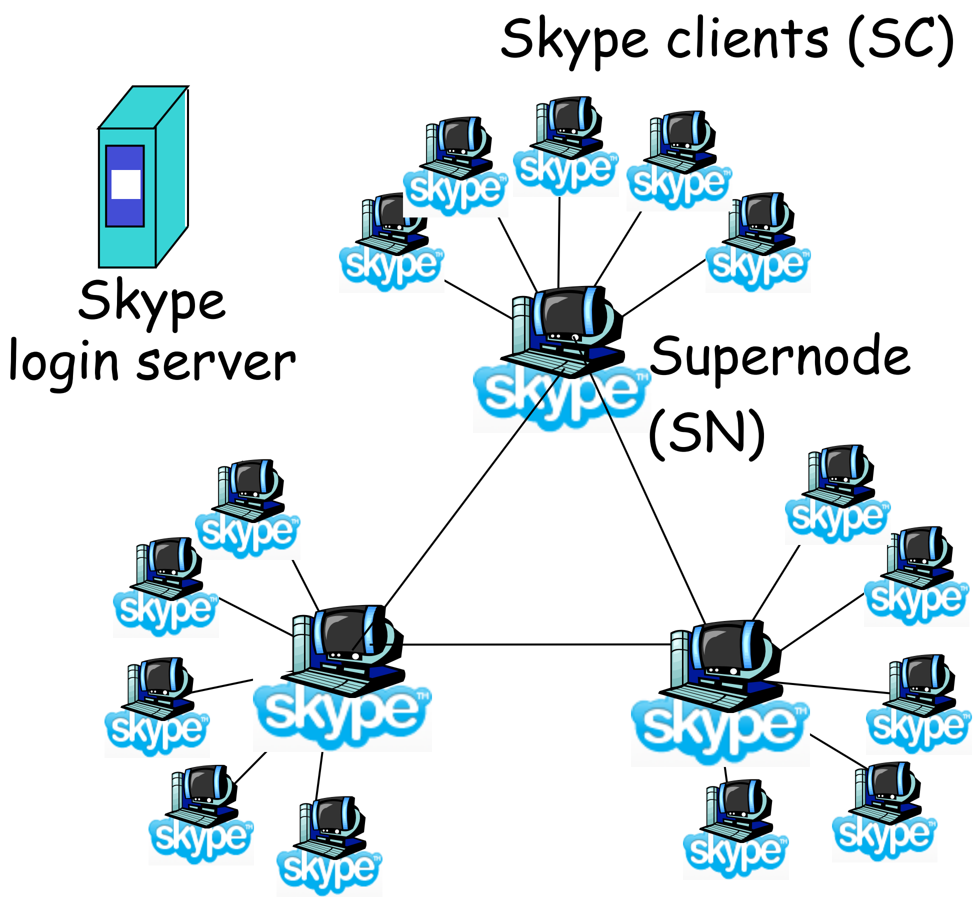
Server-client vs. P2P: example

Client upload rate = u, F/u = 1 hour, $u_s = 10u$, $d_{min} \geq u_s$



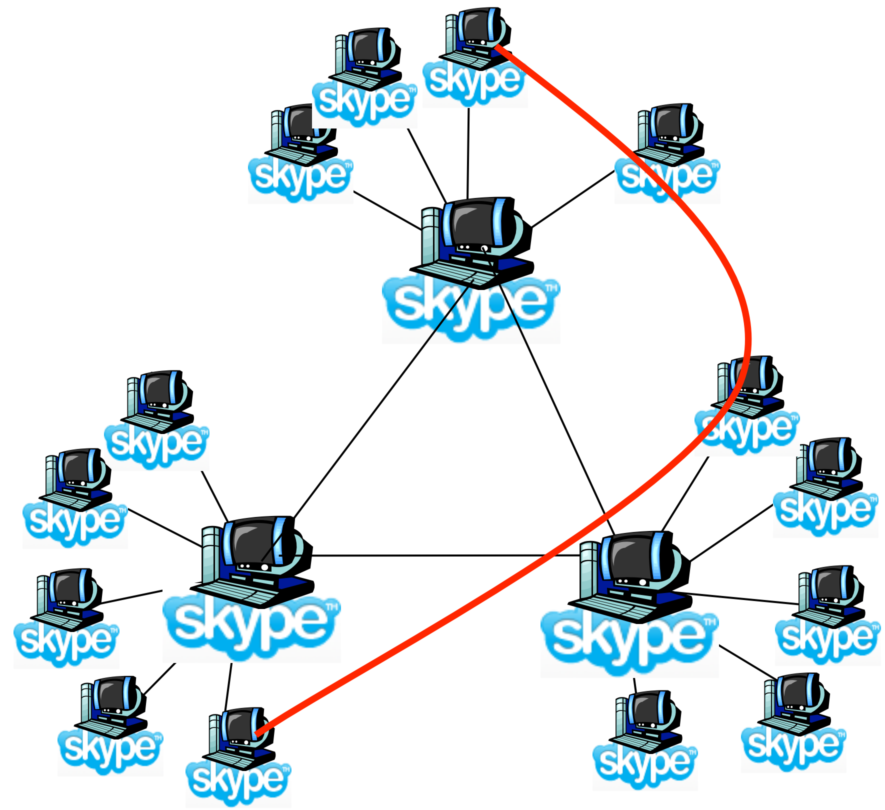
P2P Case study: Skype

- inherently P2P: pairs of users communicate.
- proprietary application-layer protocol (inferred via reverse engineering)
- hierarchical overlay with SNs
- Index maps usernames to IP addresses; distributed over SNs



Peers as relays

- problem when both Alice and Bob are behind "NATs".
  - NAT prevents an outside peer from initiating a call to insider peer
- solution:
  - using Alice's and Bob's SNs, *relay* is chosen
  - each peer initiates session with relay.
  - peers can now communicate through NATs via relay



A Brief Introduction To

WIRESHARK

Formerly known as ETHEREAL

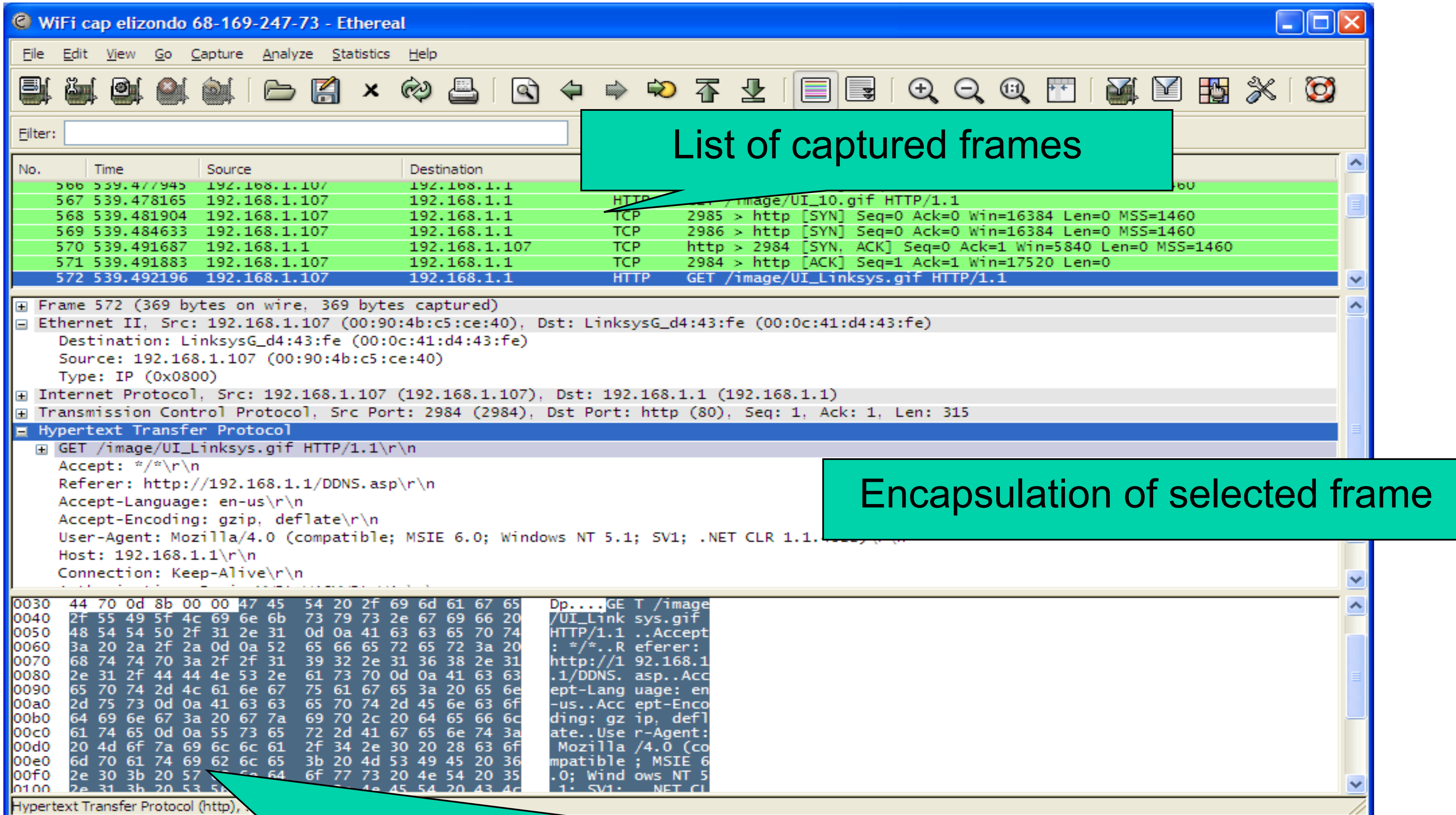
So Ethereal, Is it?

- Actually, it's WireShark to you! ☺
- A powerful GUI based Network Protocol Analyzer
- Runs on common o/s platforms: Linux, Unix, Mac, MS Windows
- Provides the ability to directly analyze network communications on your PC
- Supports most protocols and media, more than 472 currently
- It is free!

What it does:

- Allows interactive examination of data arriving at, and leaving from, the Network Adapter on your host machine
- Displays source and destination IP addresses, ports, message types, and message contents
- Also allows selective filtering of particular frames for specific analysis

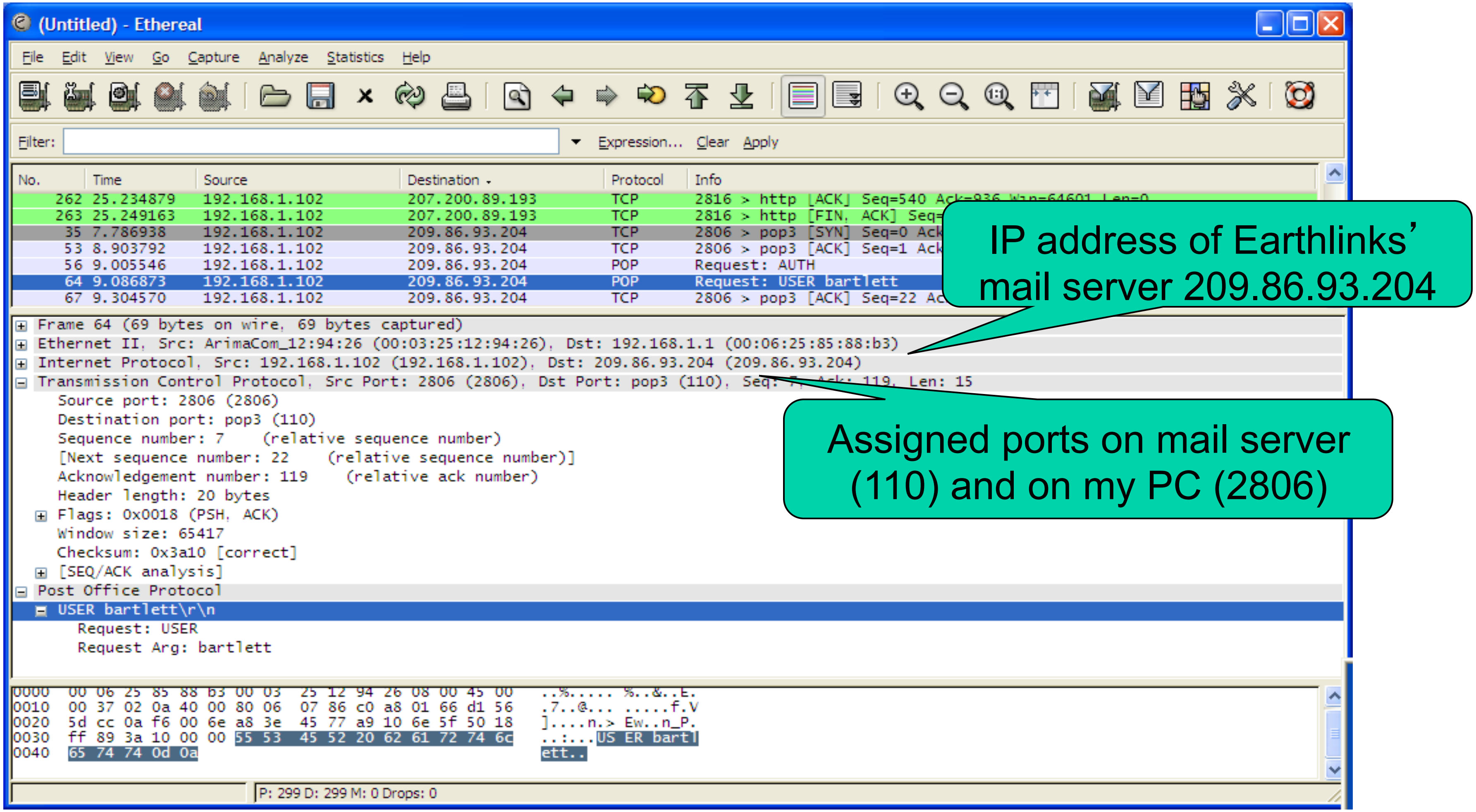
Screen shot of the GUI



Raw data from Physical (PHY) layer in HEX plus ASCII Text equivalent

- Screenshot presents the intercepted data in Hexadecimal representation at bottom of screen (Binary would not be efficient for display purposes!)
- Shows the encapsulation of different layers of the communication: addressing, ports, message type, payload
- Can expand (decodes or translates) each part of protocol into form meaningful to humans
- Particular example shows GET image request

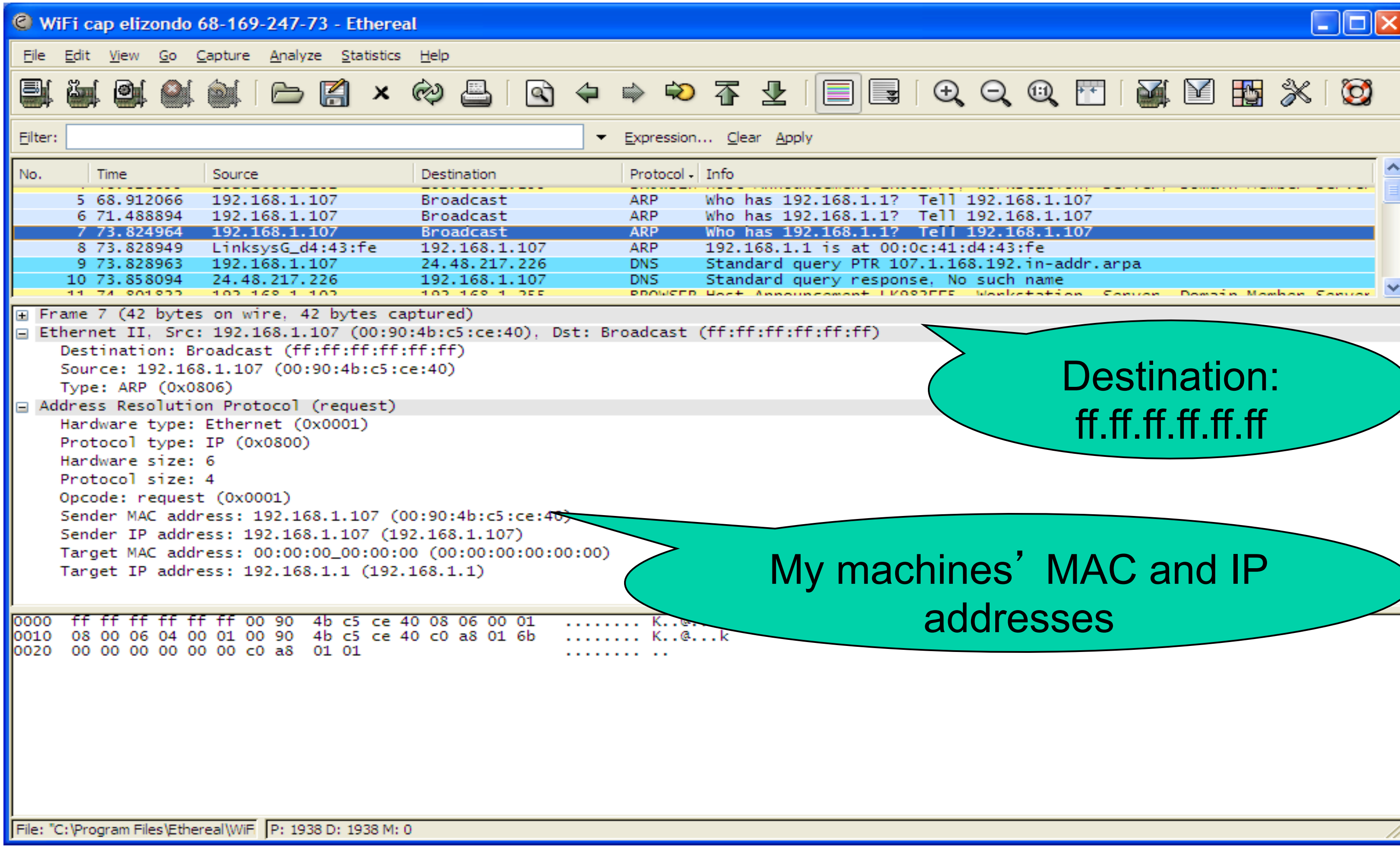
Example of connection to email server



Email server connection comments

- The frame (#64 in this capture) shows that it is 69 bytes in length
- This particular frame is part of a connection to an email server using Post-Office-Protocol
- This is a request to the mail server identifying my user name
- You can see the destination port on the mail server is 110 (a good example of a well known port number), and the port opened on my machine is 2806
- Notice the Checksum field and Window size

Example of Address Resolution Protocol event (housekeeping)



Details of ARP event

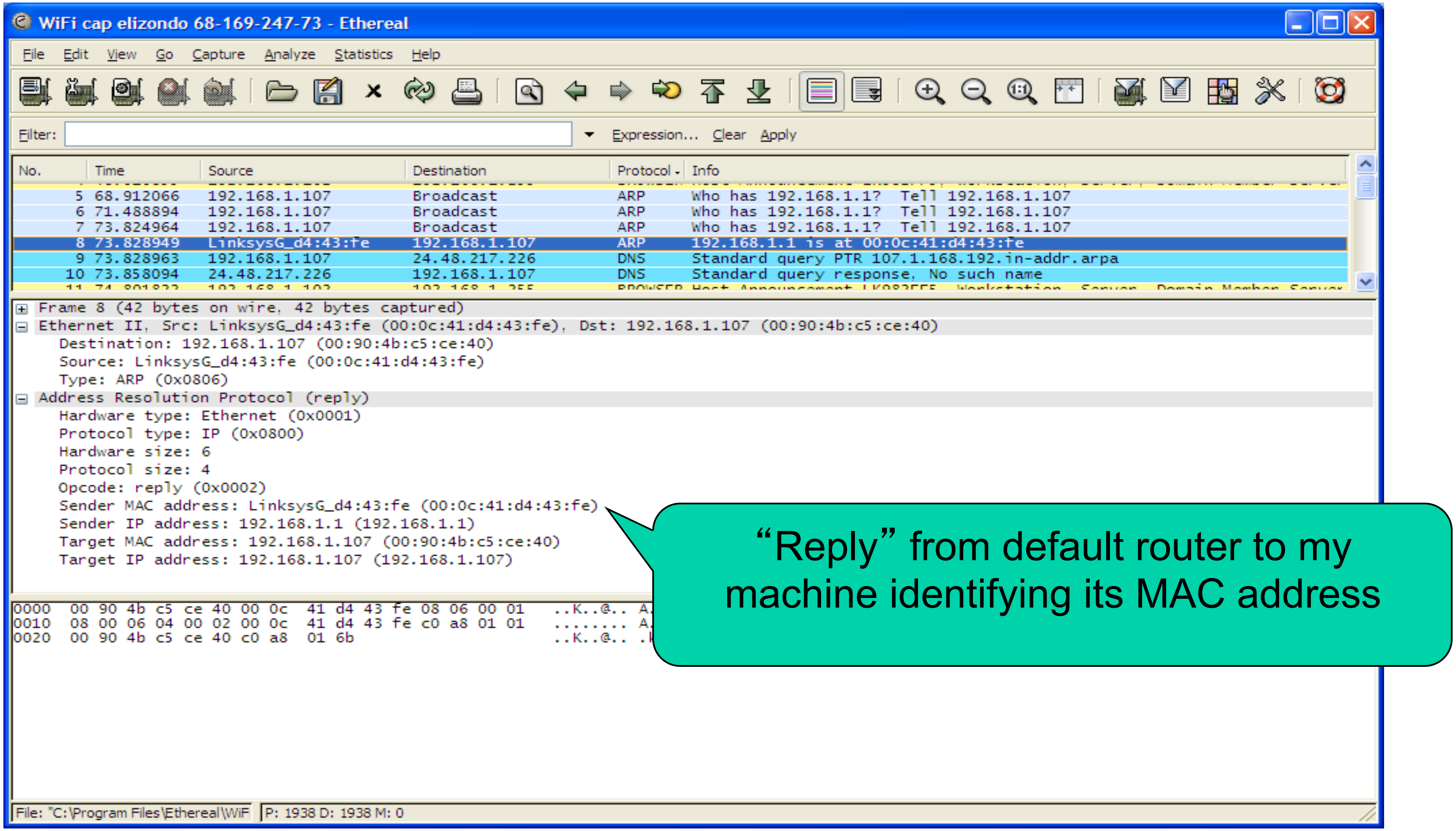
An example of how the network finds out MAC addresses

In the first slide, my machine is trying to find the MAC address of 192.168.1.1 (default router)

So it sends a "WHO HAS" broadcast message to MAC address ff.ff.ff.ff.ff.ff

Part of the message frame contains my machine's MAC address, hopefully for the default router to reply to

ARP continuation



ARP continued..

- The very next frame is the reply from the router telling my machine of the router's MAC address

- From this point onwards, both MAC addresses are known and therefore frames can be transferred by the Data Link Layer
- This shows how new nodes joining a network gain membership through Address Resolution Protocol

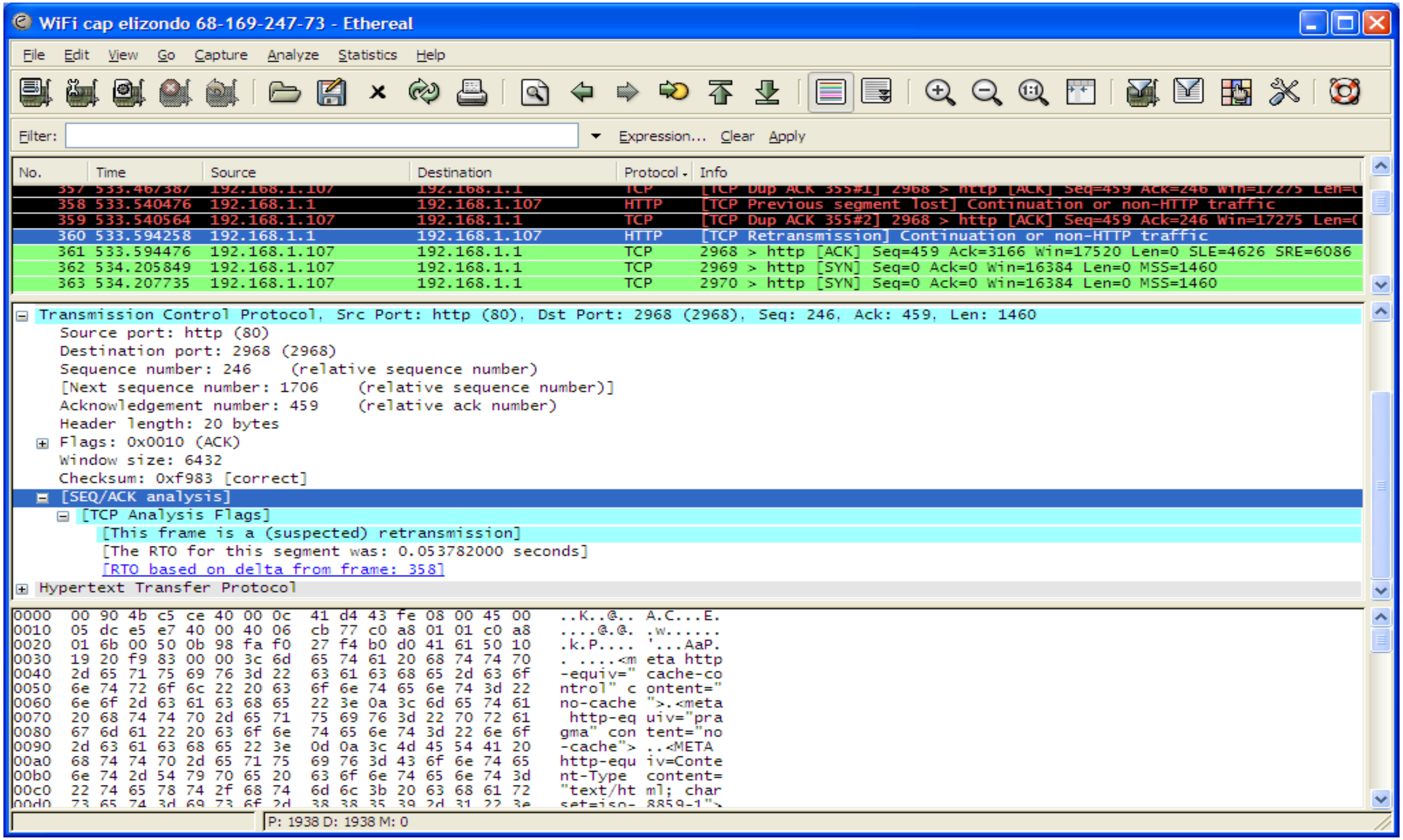
How Ethereal works

- Puts the Network Adapter into Promiscuous mode
- Forces interface not to drop any frames
- Thus it allows all frames to be captured…
- And viewed
- If this particular machine was on a simple switch then all traffic to / from other machines would also be visible…

Some more useful features

- Can capture traffic to a file for later analysis and filtering
- Useful when trying to debug or trace problems with networks or find malware
- Can filter traffic by IP and port number etc
- Can perform statistical analysis of captured frames

Example of WiFi traffic

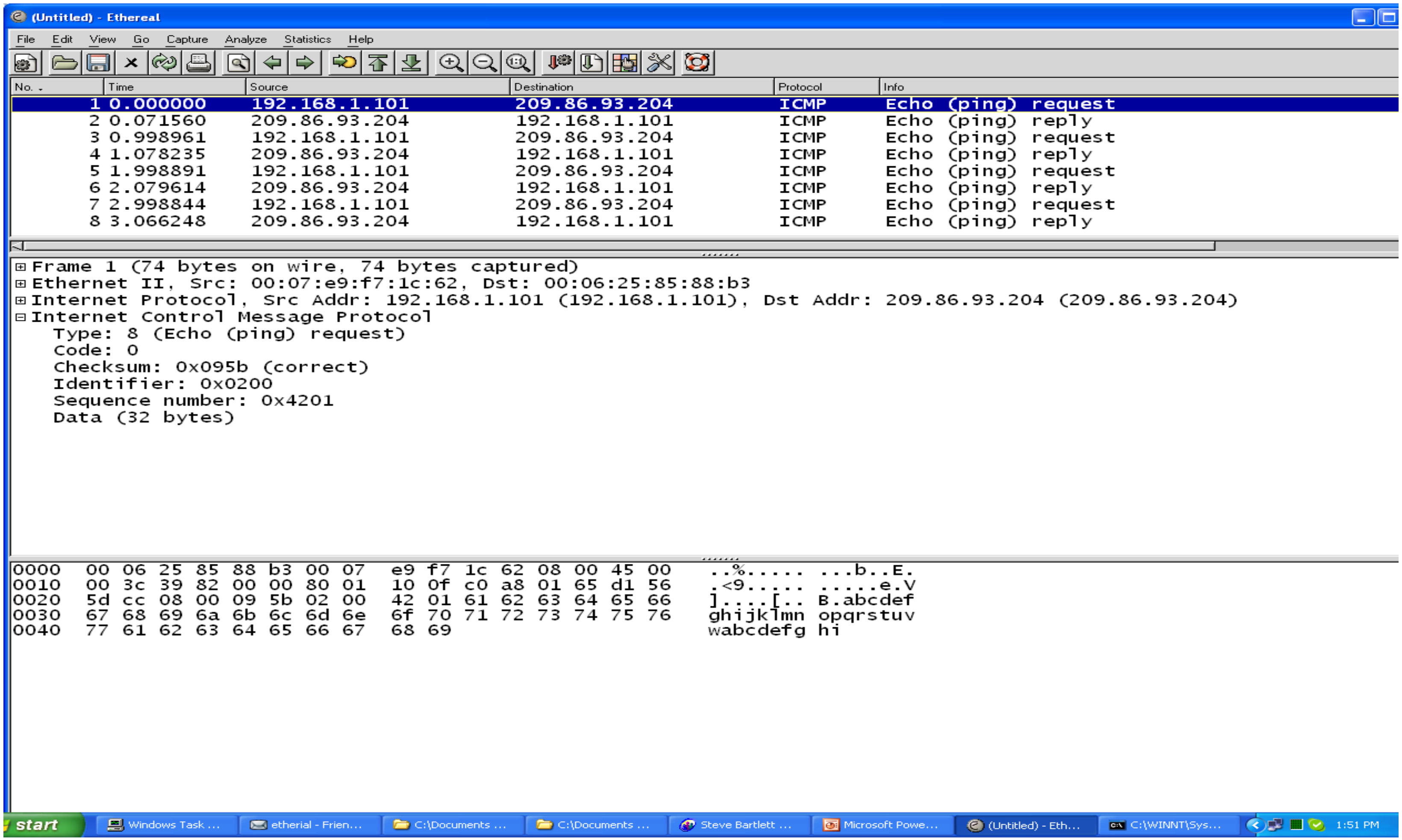


- The previous slide shows a suspected retransmission of a frame.
- This particular traffic was captured from a wireless LAN belonging to a neighbor that I am within range of.
- As the signal strength is rather low, the connection integrity is rather poor leading to data corruption errors – lots of retries.

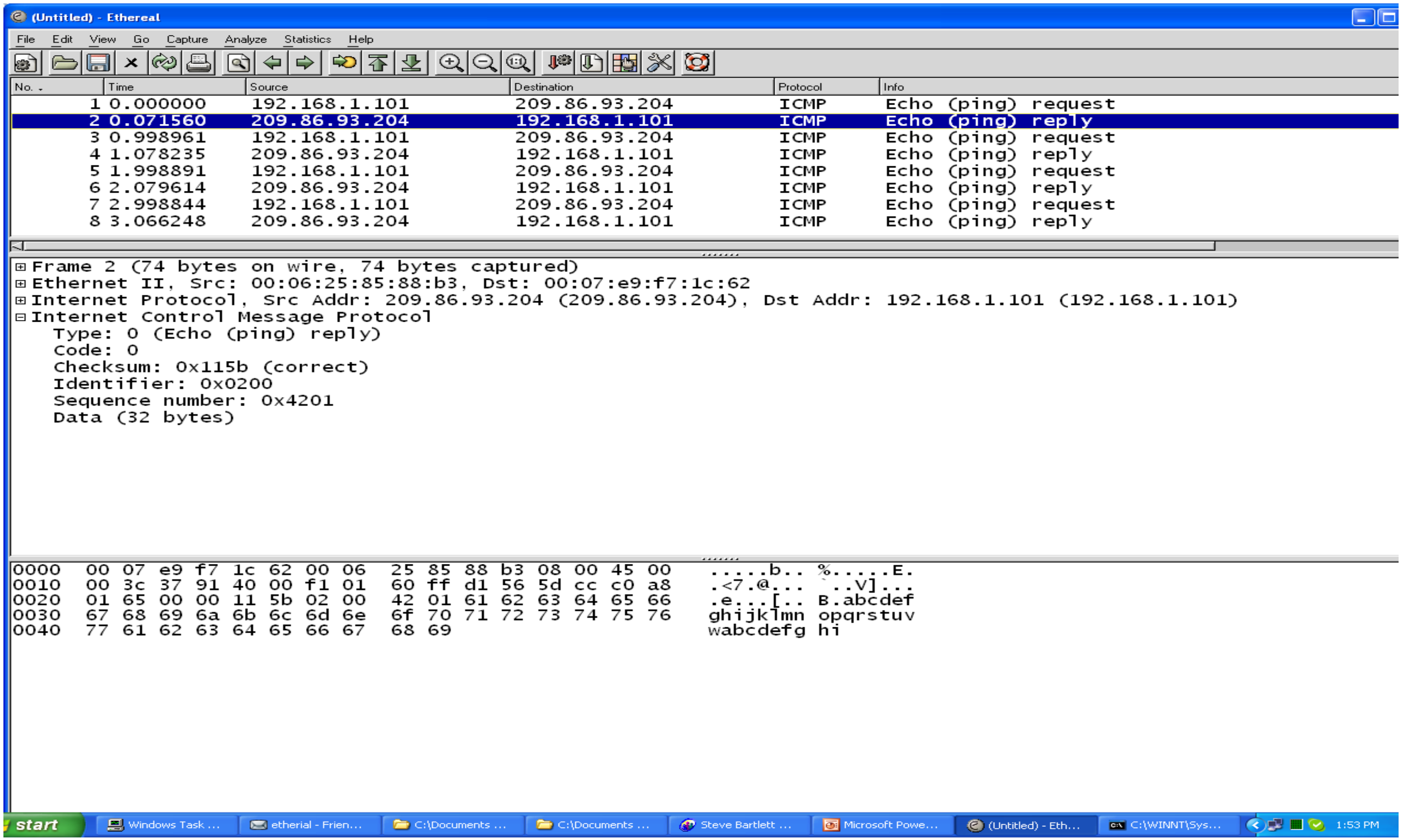
PING

- An example of Internet Control Message Protocol (ICMP)
- Used to find out if a host is ‘reachable’
- Run from CMD prompt on PC
- C:\> ping 209.86.93.204

Ping 209.86.93.204

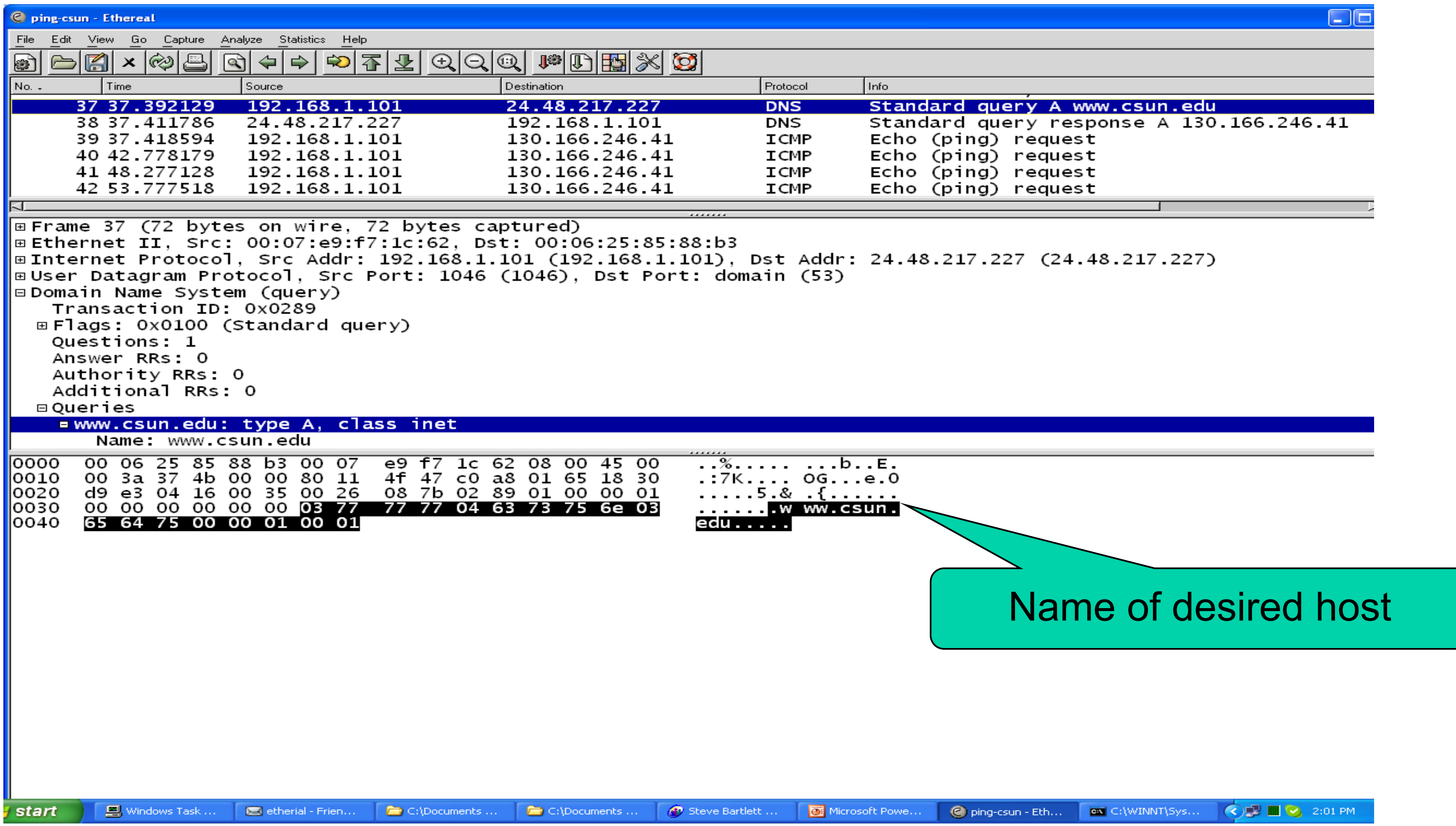


Ping reply


(Untitled) - Ethereal
File Edit View Go Capture Analyze Statistics Help
No. . Time Source Destination Protocol Info
1 0.000000 192.168.1.101 209.86.93.204 ICMP Echo (ping) request
2 0.071560 209.86.93.204 192.168.1.101 ICMP Echo (ping) reply
3 0.998961 192.168.1.101 209.86.93.204 ICMP Echo (ping) request
4 1.078235 209.86.93.204 192.168.1.101 ICMP Echo (ping) reply
5 1.998891 192.168.1.101 209.86.93.204 ICMP Echo (ping) request
6 2.079614 209.86.93.204 192.168.1.101 ICMP Echo (ping) reply
7 2.998844 192.168.1.101 209.86.93.204 ICMP Echo (ping) request
8 3.066248 209.86.93.204 192.168.1.101 ICMP Echo (ping) reply
Frame 2 (74 bytes on wire, 74 bytes captured)
Ethernet II, Src: 00:06:25:85:88:b3, Dst: 00:07:e9:f7:1c:62
Internet Protocol, Src Addr: 209.86.93.204 (209.86.93.204), Dst Addr: 192.168.1.101 (192.168.1.101)
Internet Control Message Protocol
Type: 0 (Echo (ping) reply)
Code: 0
Checksum: 0x115b (correct)
Identifier: 0x0200
Sequence number: 0x4201
Data (32 bytes)
0000 00 07 e9 f7 1c 62 00 06 25 85 88 b3 08 00 45 00 .....b.. %.....E.
0010 00 3c 37 91 40 00 f1 01 60 ff d1 56 5d cc c0 a8 .<7.@... `..V]...
0020 01 65 00 00 11 5b 02 00 42 01 61 62 63 64 65 66 .e...[.. B.abcdef
0030 67 68 69 6a 6b 6c 6d 6e 6f 70 71 72 73 74 75 76 ghijklmn opqrstuv
0040 77 61 62 63 64 65 66 67 68 69 wabcdefg hi
start Windows Task ... etherial - Frien... C:\Documents ... C:\Documents ... Steve Bartlett ... Microsoft Powe... (Untitled) - Eth... C:\WINNT\Sys... 1:53 PM

- First slide shows PING request
- Sends 32 bytes of data   abcdefghijkl…
- Recipient responds back with data
- Provides measurement of loopback time
- Can also be used to illustrate DNS operation – see next slide

PING www.csun.edu



- Slide shows that DNS is used to find the IP address of www.csun.edu
- Next frame is response from DNS with IP: 130.166.246.41
- Ping can now proceed as before

Use case..

- I found Ethereal after researching an unusually high traffic volume across my internet connection causing very slow page loads.
- Turns out that my machine was infected with a virus – a hidden server was running on my machine exchanging data with some remote host
- Examination of packets led to discovery of hidden server residing on my machine without my knowledge or consent!
- Ethereal is a very valuable tool to have

Where to get it:

- Visit   http://www.wireshark.org/
- Navigate to the ‘download’ section
- Select your particular machine type (Linux, Apple, Windows etc) and choose download.
- This will cause an installer executable file to download to your host.
- After completion, run the executable, follow the onscreen instructions and the installation of Ethereal tools will commence.