TCP/IP Applications

Objectives

- Describe common Transport layer protocols
- Explain the power of port numbers
- Define common TCP/IP applications such as HTTP, HTTPS, Telnet, e-mail (SMTP, POP3, and IMAP4), and FTP

Overview

Three Parts to this Area

- Transport Layer Protocols
- The Power of Port Numbers
- Common TCP/IP Applications

Transport Layer Protocols

How People Communicate

- **Connection-oriented**
  - Acknowledgement between two people beginning conversation
  - The conversation
  - Close of conversation

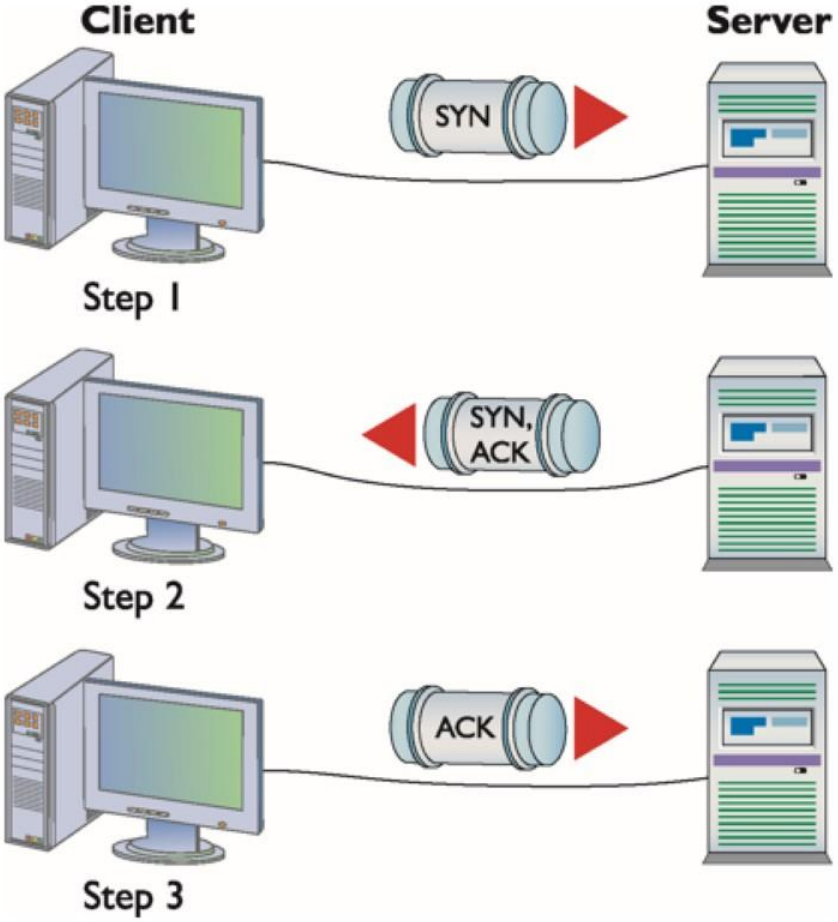


Figure 9.1 **A connection-oriented session starting**

- **Connectionless**
  - No opening acknowledge
  - Short message shouted across a room
  - No closing
- **Session**
  - Any single communication between computers
  - All session must begin and eventually end

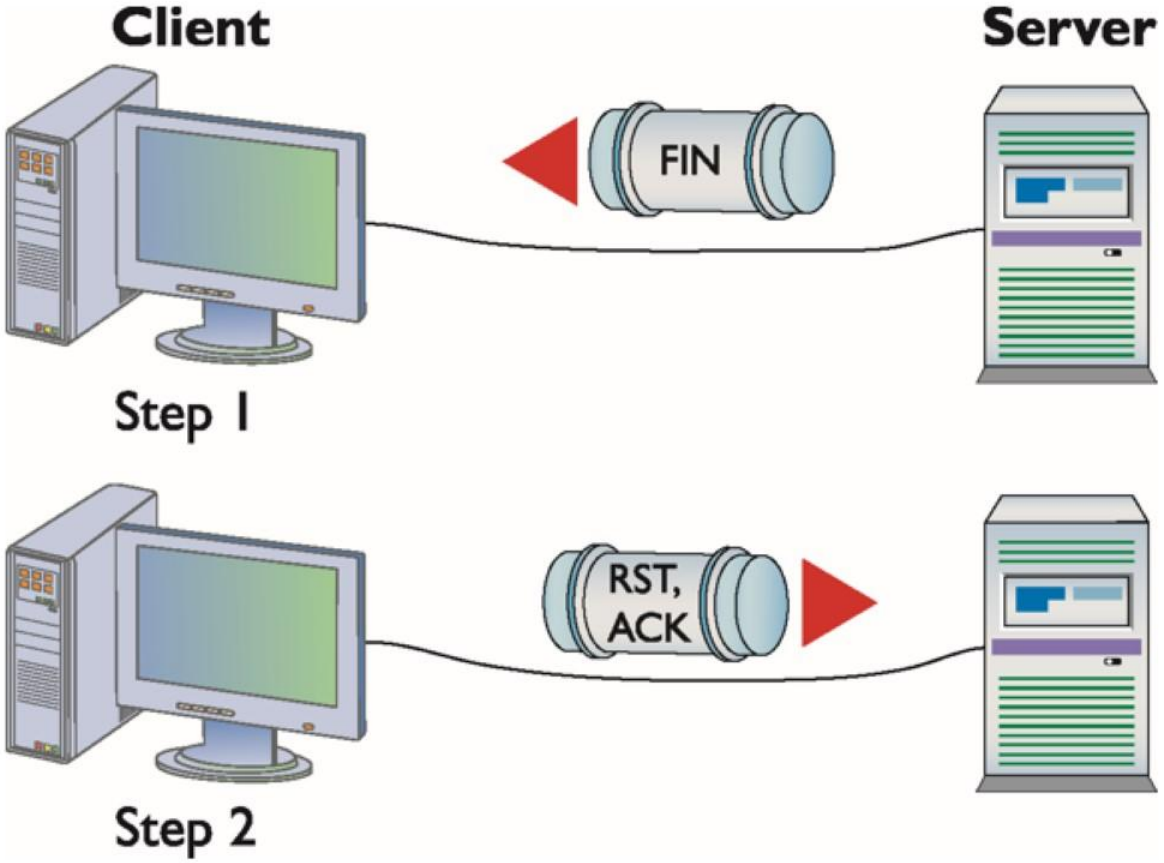


Figure 9.2 **A connection-oriented session ending**

- **Transmission Control Protocol (TCP)**
  - In charge of connection-oriented communication
  - Most common type of TCP/IP session

- **Connection-oriented session**
  - Browser sends an ACK packet
  - Server responds with a SYN, ACK packet
  - Client sends an ACK, requests Web page
  - Server sends Web page and a FIN packet
  - Client responds with RST, ACK

- **User Datagram Protocol (UDP)**
  - Used by very few applications
  - Requires much less overhead than TCP
  - No start, no acknowledgement, no end

- **DHCP uses UDP**
  - Client broadcasts discovery packet
  - Server responds with DHCP offer (sent directly to MAC address)
  - Client sends DHCP request directly to server MAC address
  - Server sends DHCP acknowledgement with IP configuration
  - Client responds with DHCP lease

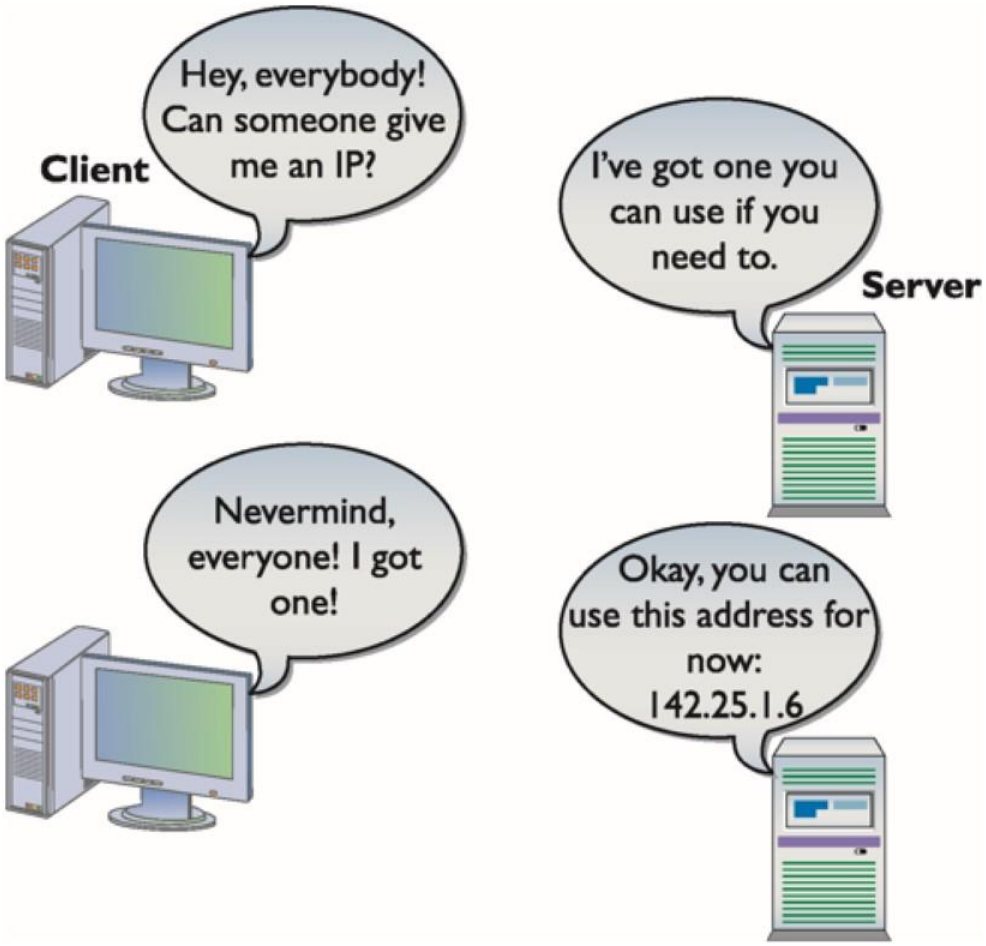


Figure 9.3 **DHCP steps**

- **Trivial File Transfer Protocol (TFTP)**
  - Uses UDP
  - Transfers files between computers
  - Does not have any data protection
  - Never use it over the Internet

- **Internet Control Message Protocol (ICMP)**
  - For connectionless communications that never need more than a single packet
  - Handles maintenance issues like disconnect (host unreachable)
  - Applications use ICMP to send status information to the other end of a session

- **PING**
  - **Sends a single ICMP packet**
    - Echo request
    - To an IP address
  - **All computers (unless blocked by a firewall) respond with echo reply**

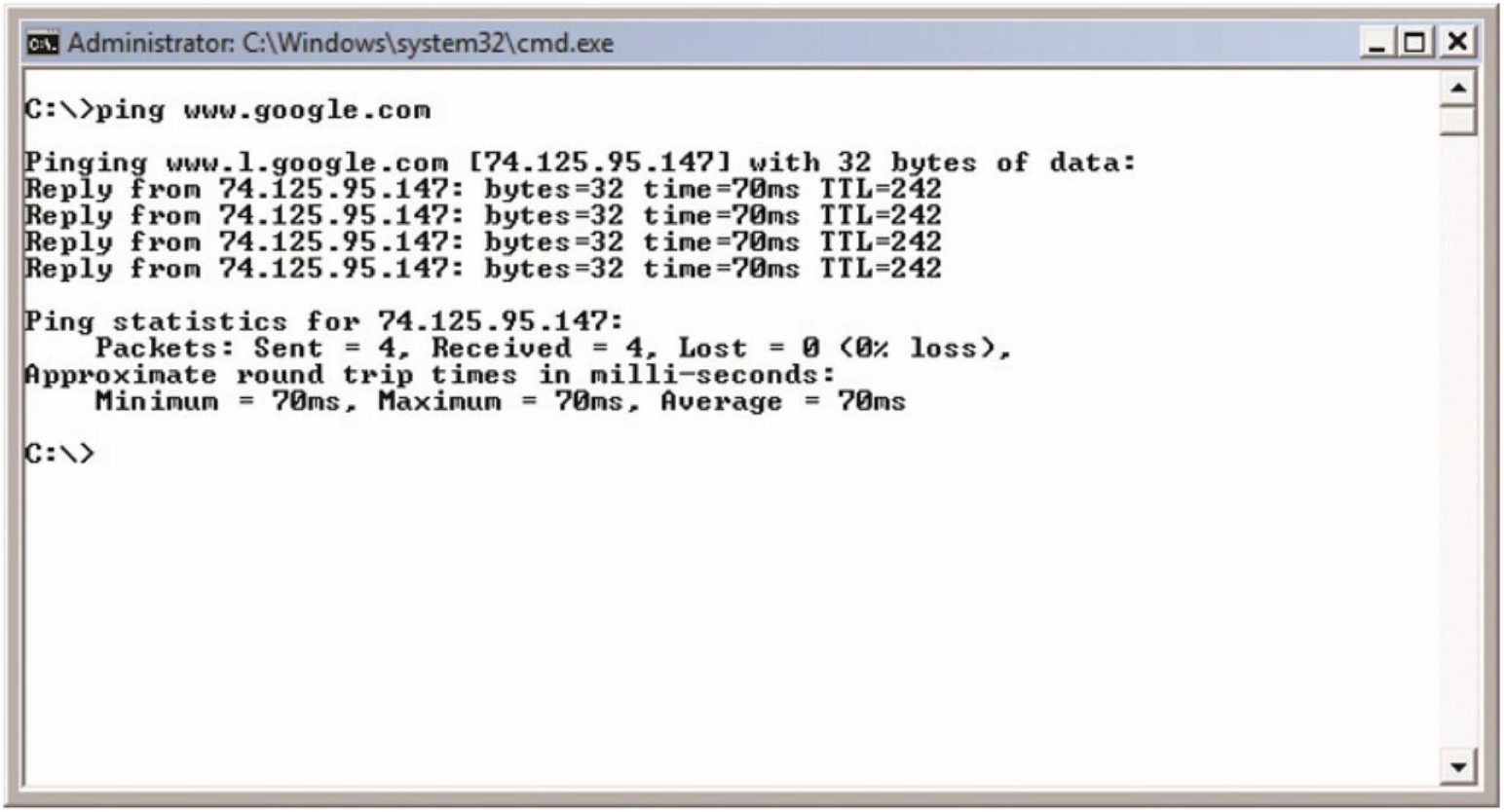


Figure 9.4 **PING in action**

- **Internet Group Management Protocol (IGMP)**
  - Used for multicasts
  - Routers use to determine a “group” membership
  - Class D IP addresses with network ID 224/8

- **More about multicast**
  - Does not assign IP addresses to hosts
  - A multicast is assigned a certain 224/8 address
  - Those who wish to receive this multicast must join the IGMP group
  - Upstream router will send multicasts

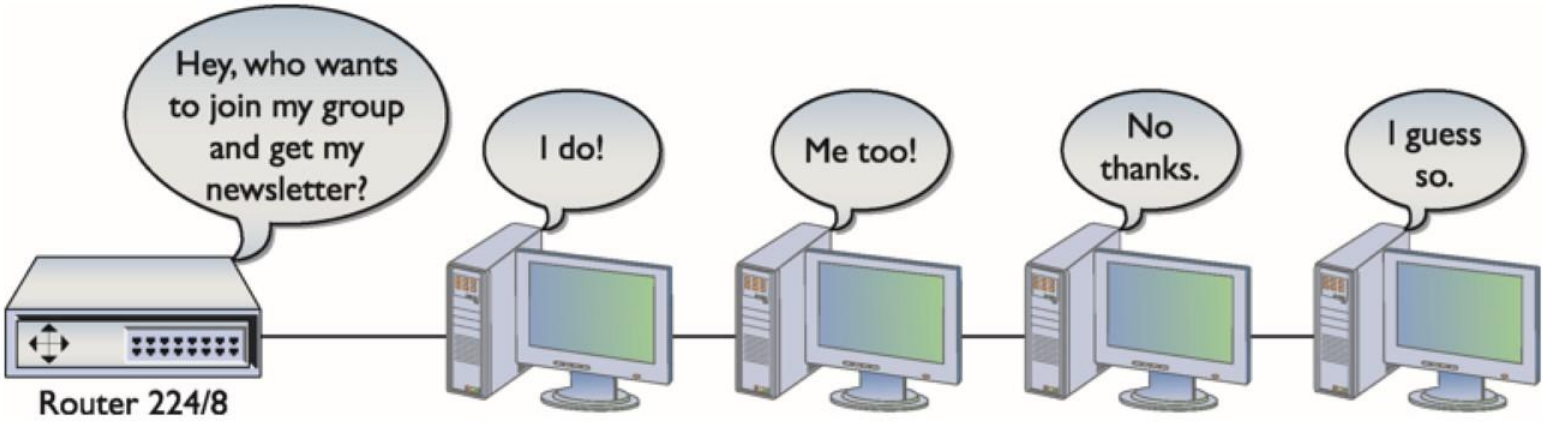


Figure 9.5 **IGMP in action**

- **More about multicast**
  - Does not assign IP addresses to hosts
  - A multicast is assigned a certain 224/8 address
  - Those who wish to receive this multicast must join the IGMP group
  - Upstream router will send multicasts

Transport Layer Protocols

- **Port numbers**
  - Memorize common port numbers
  - Every TCP/IP app requires a server and a client
  - Defined port number for popular (well-known) TCP/IP applications

- **By the (port) numbers**
  - 16-bit values (0 to 65,535)
  - **Well-known port numbers** (0-1023) for specific TCP/IP applications
  - Web servers use port number 80
  - Web client sends HTTP ACT to server (port 80)
  - Server replies using ephemeral port

Figure 9.6 **HTTP ACK packet**

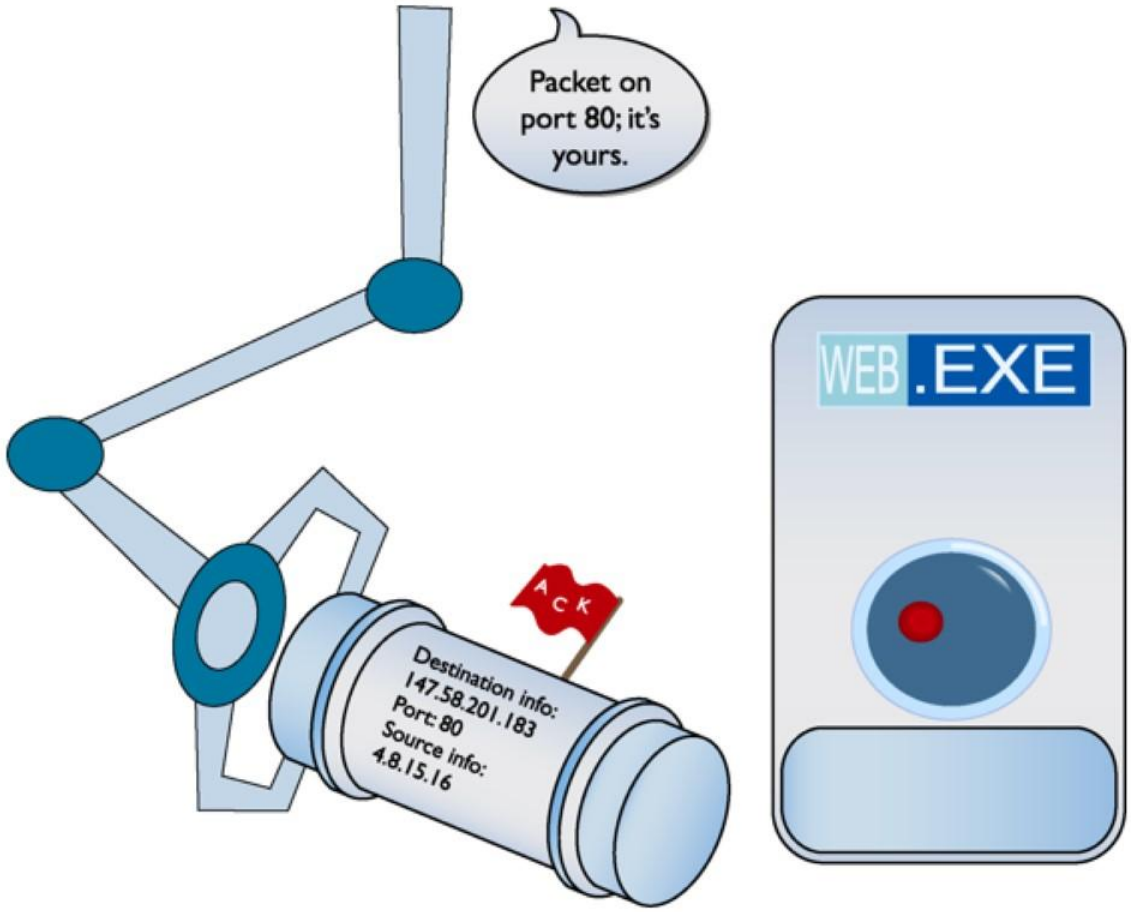


Figure 9.7 **Dealing with the incoming packet**

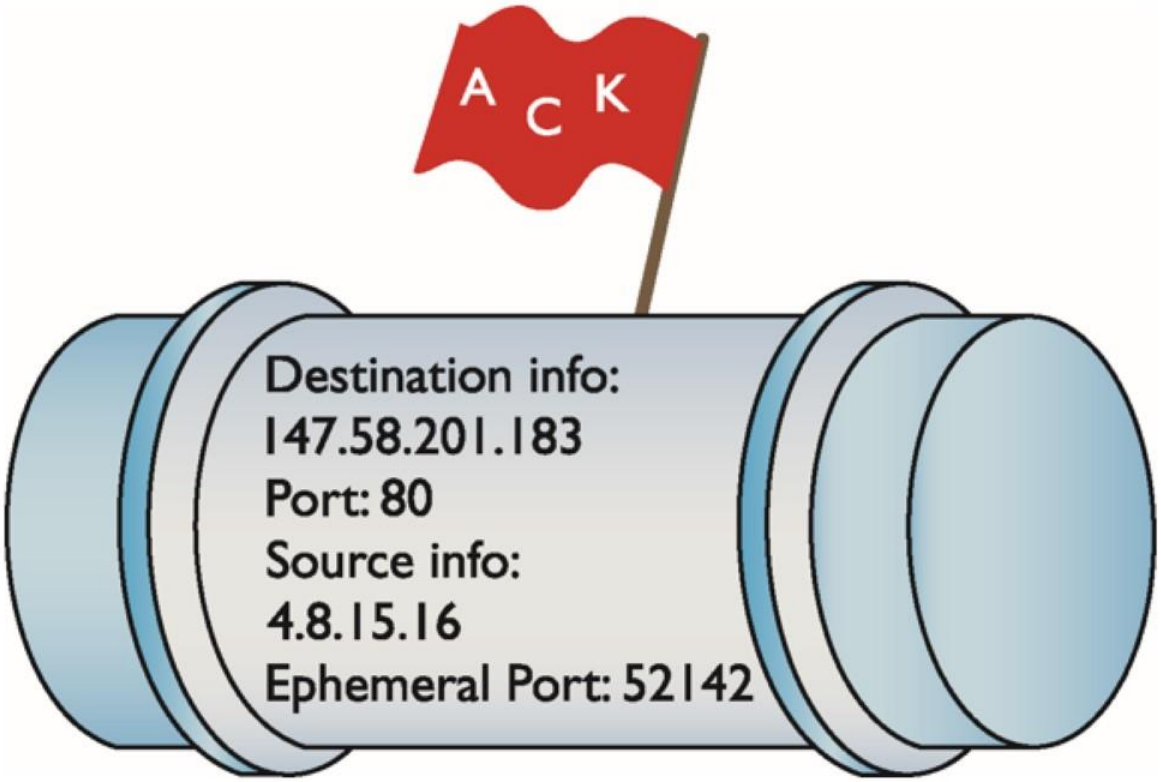


Figure 9.8 **A more complete IP packet**

- **Ephemeral ports**
  - Pseudo-randomly generated by Web client
  - Ephemeral port numbers 1024-5000
  - Dynamic or private port numbers 49152-65535
  - IANA recommends using only 49152-65535

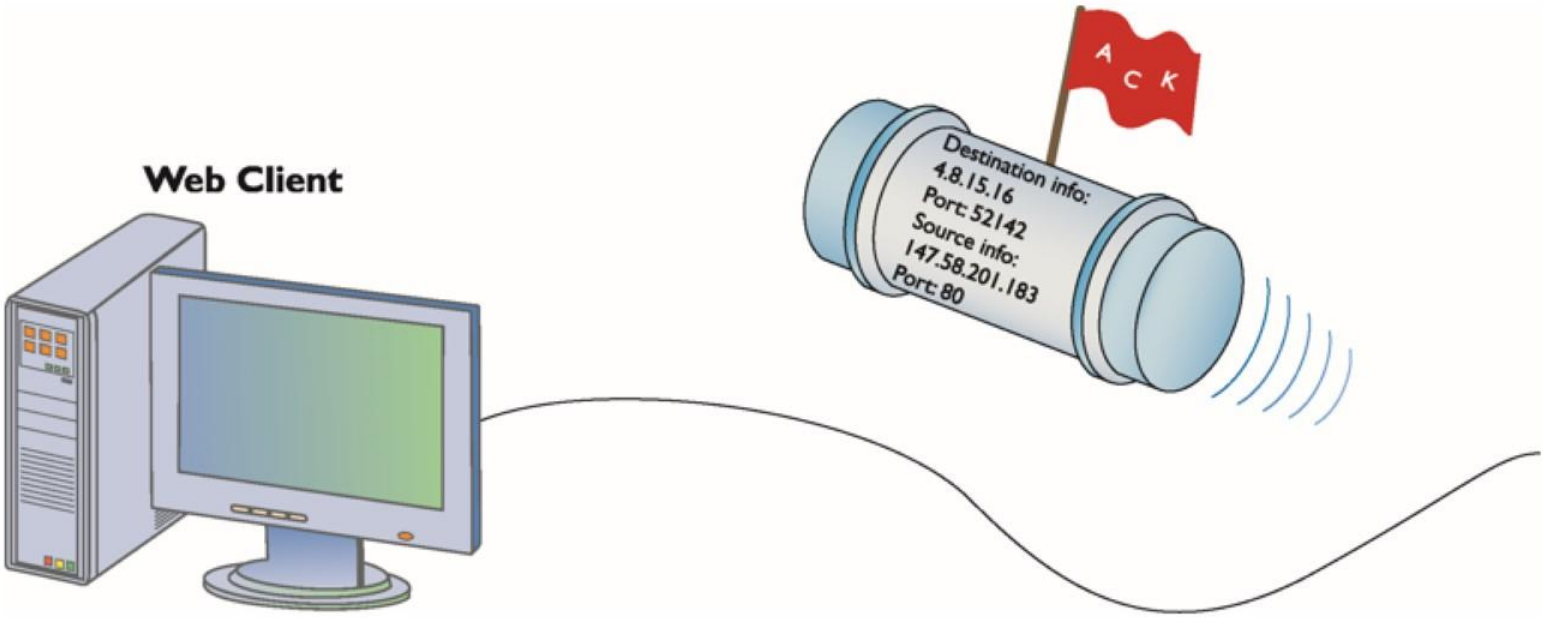


Figure 9.9 **Returning the packet**

- **Registered ports**
  - 1024-49151
  - Less-common TCP/IP applications register their ports with IANA
  - Most operating systems avoid registered port numbers and use dynamic/private ports

- **Summary of port numbers**
  - 0-1023 well-known ports
  - 1024-49151 registered ports
  - 49152-65535 dynamic or private ports

- **Using ports in a session**
  - **Both computers keep track of status**
    - Status info held in RAM
    - Socket or endpoint is one side's session information
    - Socket pairs or endpoints refer to data each computer stores about the connection
    - Session or connection refers to a connection in general

- **Endpoint information**
  - **Source and destination for one session**
  - **Many simultaneous sessions**
  - **Use `netstat -n` to see sessions**
    - Usually shows many connections
    - TCPView for Windows: dynamic
    - Net Activity Viewer for Linux

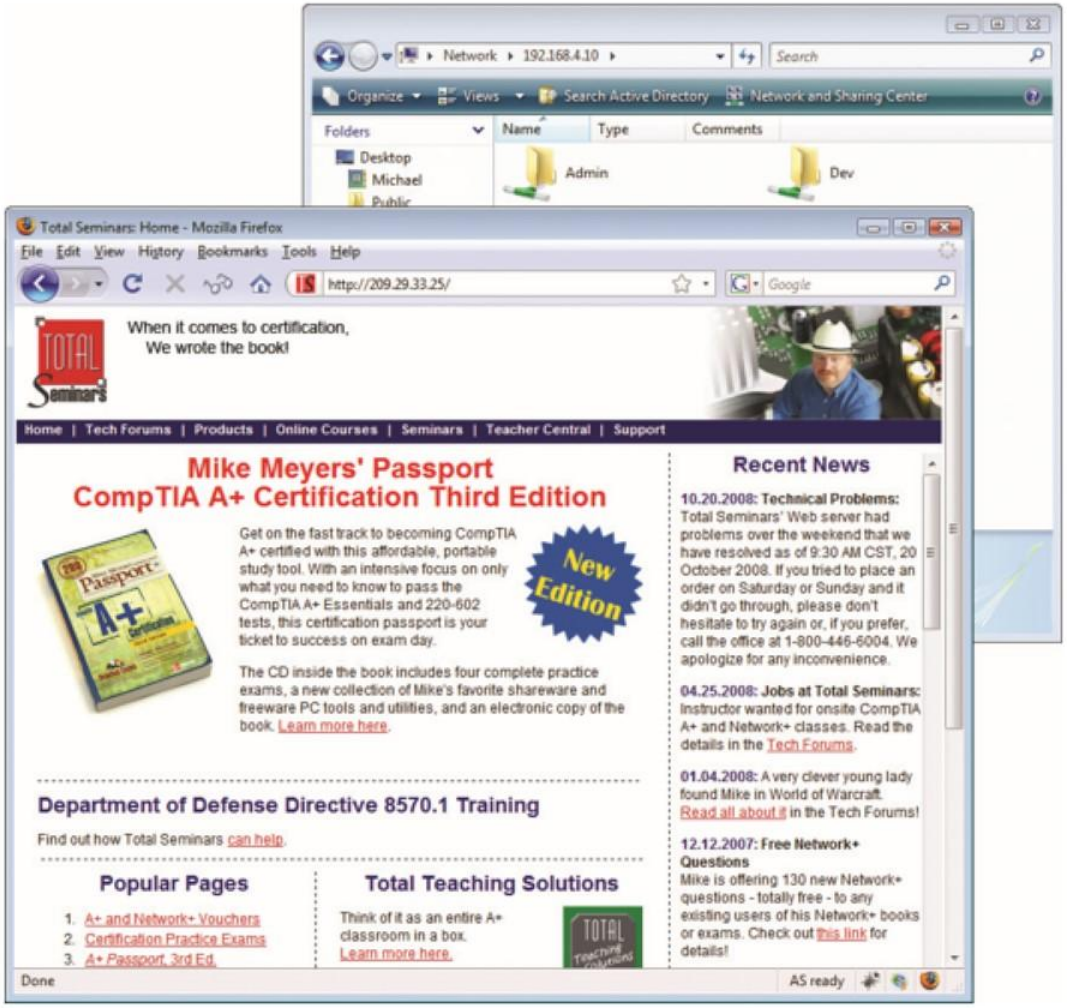


Figure 9.10 **Two open windows**

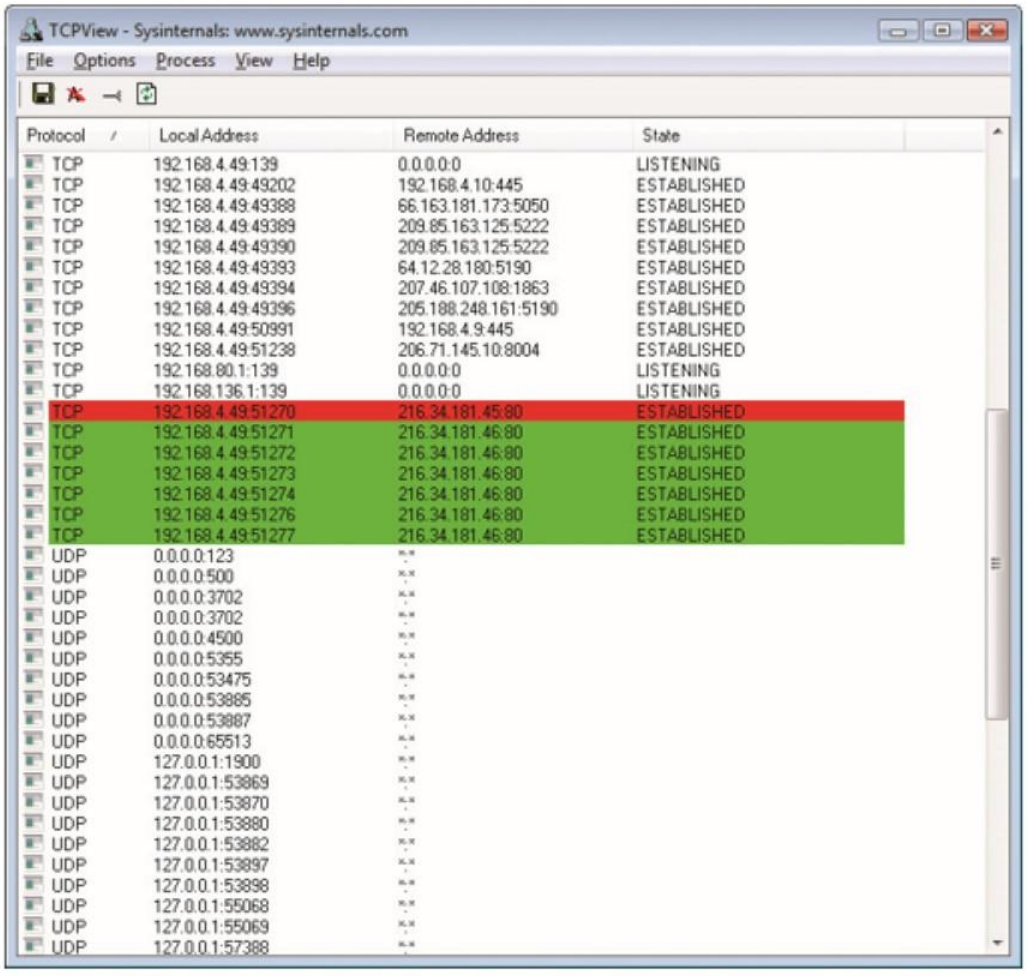
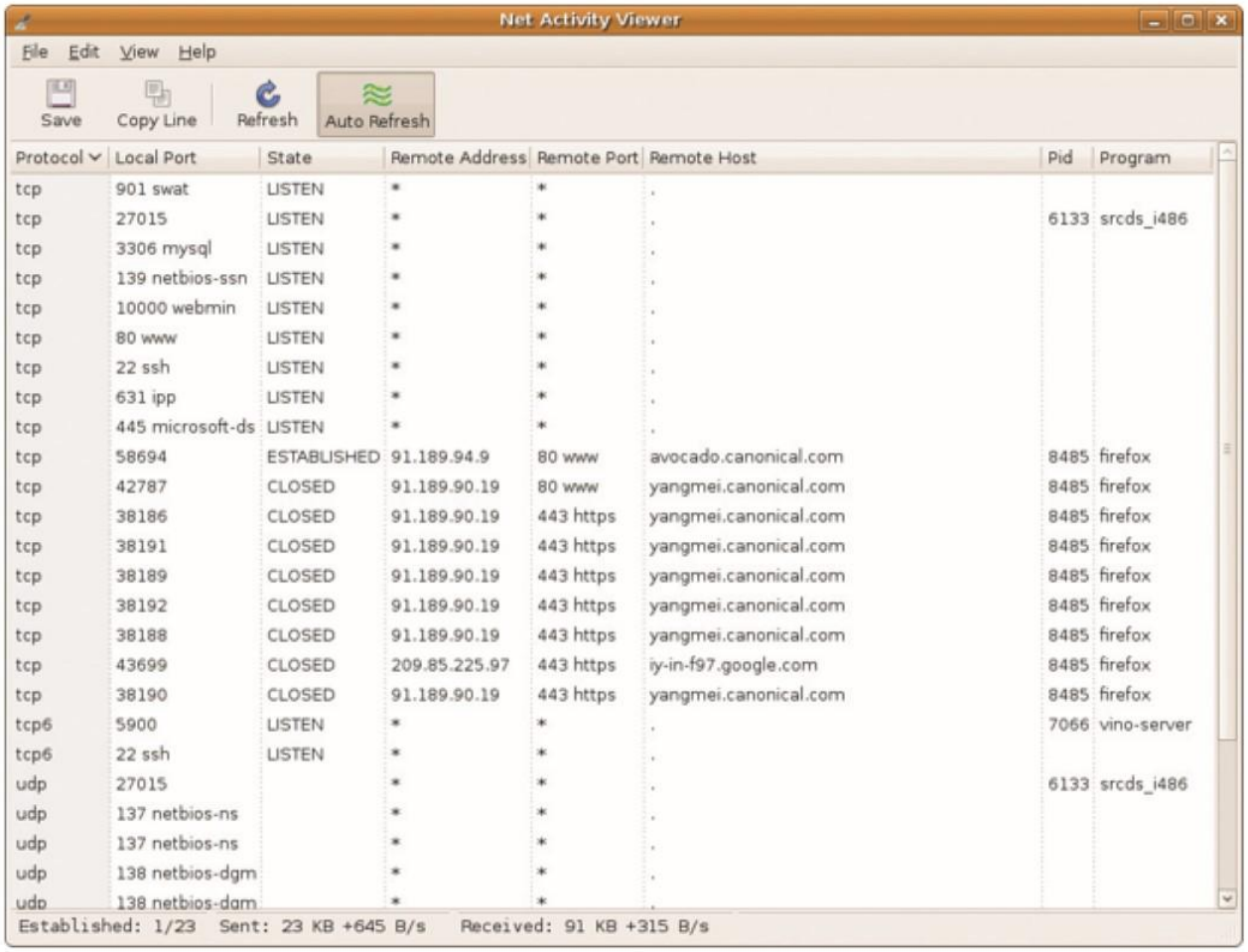


Figure 9.11 **TCPView in action**



Protocol	Local Port	State	Remote Address	Remote Port	Remote Host	Pid	Program
tcp	901 swat	LISTEN	*	*	.		
tcp	27015	LISTEN	*	*	.	6133	srcds_i486
tcp	3306 mysql	LISTEN	*	*	.		
tcp	139 netbios-ssn	LISTEN	*	*	.		
tcp	10000 webmin	LISTEN	*	*	.		
tcp	80 www	LISTEN	*	*	.		
tcp	22 ssh	LISTEN	*	*	.		
tcp	631 ipp	LISTEN	*	*	.		
tcp	445 microsoft-ds	LISTEN	*	*	.		
tcp	58694	ESTABLISHED	91.189.94.9	80 www	avocado.canonical.com	8485	firefox
tcp	42787	CLOSED	91.189.90.19	80 www	yangmei.canonical.com	8485	firefox
tcp	38186	CLOSED	91.189.90.19	443 https	yangmei.canonical.com	8485	firefox
tcp	38191	CLOSED	91.189.90.19	443 https	yangmei.canonical.com	8485	firefox
tcp	38189	CLOSED	91.189.90.19	443 https	yangmei.canonical.com	8485	firefox
tcp	38192	CLOSED	91.189.90.19	443 https	yangmei.canonical.com	8485	firefox
tcp	38188	CLOSED	91.189.90.19	443 https	yangmei.canonical.com	8485	firefox
tcp	43699	CLOSED	209.85.225.97	443 https	iy-in-f97.google.com	8485	firefox
tcp	38190	CLOSED	91.189.90.19	443 https	yangmei.canonical.com	8485	firefox
tcp6	5900	LISTEN	*	*	.	7066	vino-server
tcp6	22 ssh	LISTEN	*	*	.		
udp	27015		*	*	.	6133	srcds_i486
udp	137 netbios-ns		*	*	.		
udp	137 netbios-ns		*	*	.		
udp	138 netbios-dgm		*	*	.		
udp	138 netbios-dgm		*	*	.		

Figure 9.12 **Net Activity Viewer**

- **Connection Status**
  - State changes continually
  - Listening port or open port
  - ESTABLISHED ports are active, working endpoint pairs
  - CLOSE_WAIT indicates that a client is making a graceful closure
  - TIME_WAIT indicates a lost connection

- **Detecting local program in a connection**
  - `Netstat -ano` will show local process ID (PID) for each connection

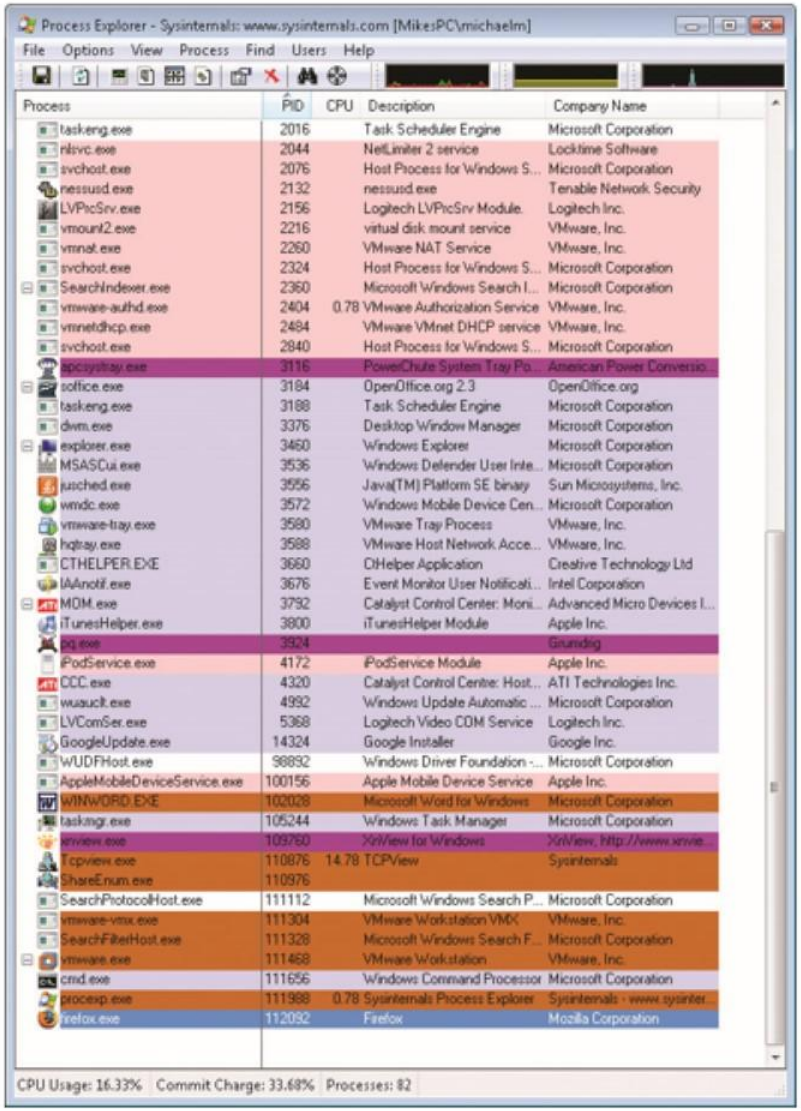


Figure 9.13 **Process Explorer**

- **Determining Good vs. Bad**
  - Memorize a bunch of common ports
  - Learn how to use NETSTAT
  - Learn the ports that normally run on your operating system
  - Research processes you don't recognize
  - Get rid of bad processes

Common TCP/IP Applications

- **Web Servers**
  - Store HTML documents
  - XHTML is an updated HTML with XML syntax

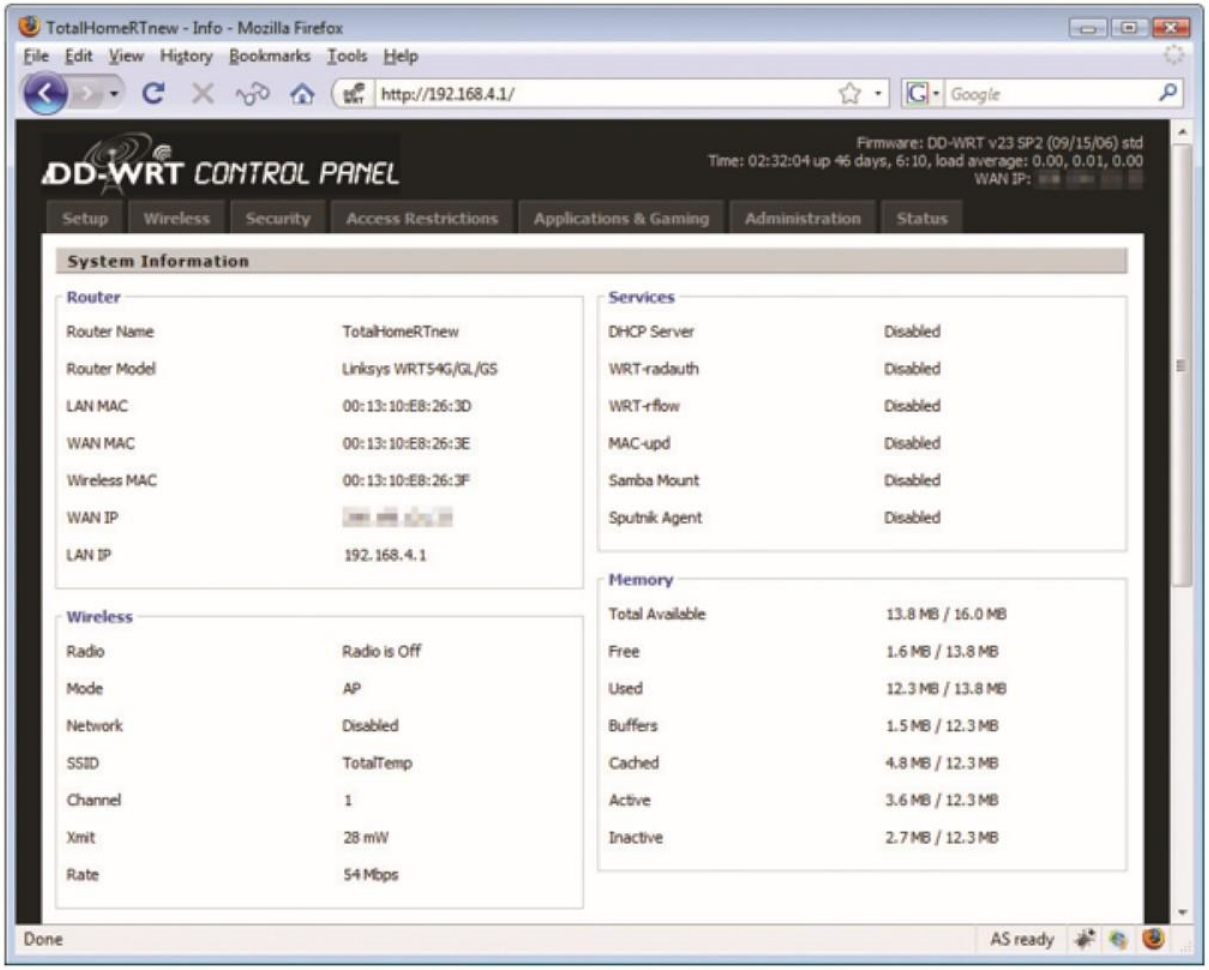


Figure 9.14 **My router's Web page**

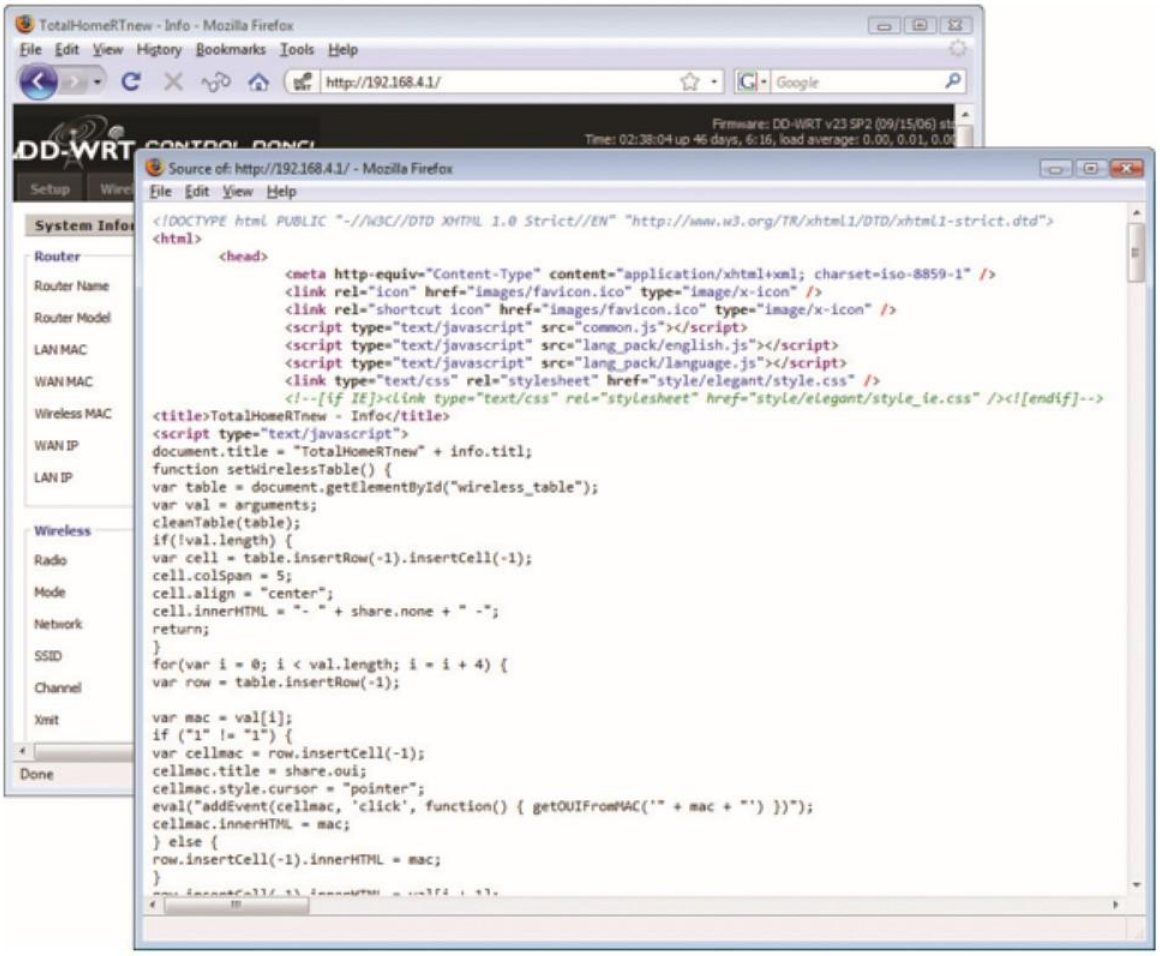


Figure 9.15 **XHTML source code**

- **Web browsers (client side)**
  - Request HTML pages from Web servers
  - Enter address into browser
  - All browsers have a default Web page
  - Web sites use text addresses using DNS

- **HTTP**
  - Stands for **Hypertext Transport Protocol**
  - Underlying protocol of the Web
  - Uses port 80 to transmit Web page data
  - http:// at beginning of Web server address

- **HTTP weakness**
  - **Relays commands without reference to any commands the user previously executed**
  - **Difficult to design complex and interactive Web pages**
  - **Other technologies enhance HTTP**
    - JavaScript/AJAX
    - Server-side scripting
    - Adobe Flash
    - Cookies

- **Publishing Web pages**
  - **Web server will "host" a HTML document**
  - **You can self-host**
    - Install Web server software
    - Acquire a public IP address
    - Time-consuming and challenging
  - **Host through your ISP**
  - **Use a Web hosting service company**
  - **Free Web hosting (nothing is free)**

- **Web Servers and Web Clients**
  - **Web server serves up Web pages**
  - **Listens on port 80**
  - **Fetches and sends requested HTML pages**
  - **To create a Web server**
    - Install Web server software
    - Connect computer to the Web

- **Web Server Software**
  - **Microsoft Internet Information Services (IIS)**
    - 20-connection limit on non-server versions of Windows
    - Only run IIS on Server versions of Windows
  - **Apache Server runs on UNIX/Linux/Windows**
    - On over 50% of Internet Web servers
    - Free
    - Non-GUI
    - Web admininstrators use an add-on GUI (Webmin)

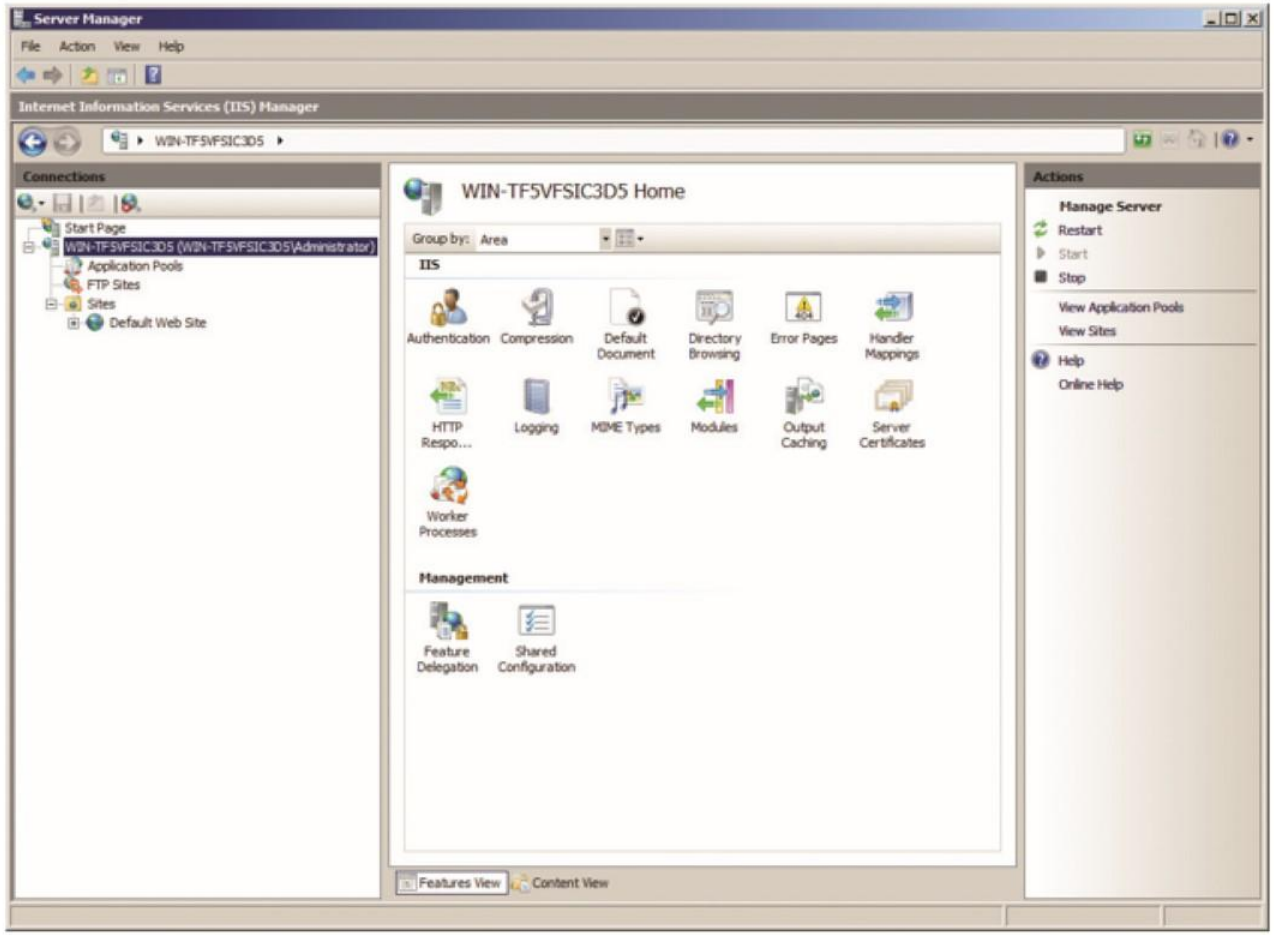


Figure 9.16 **IIS in action**

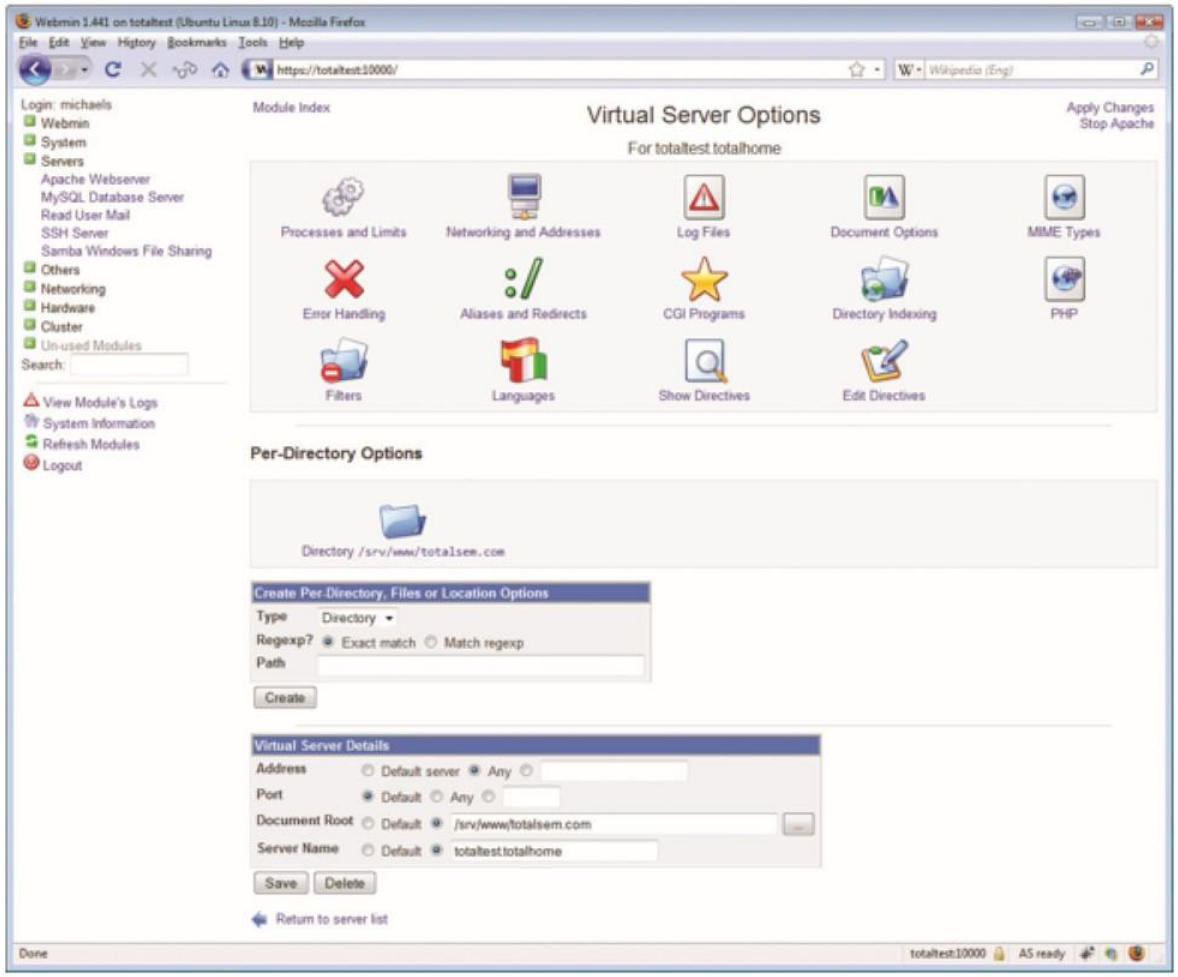


Figure 9.17 **Webmin Apache module**

- **Web Client Software (browsers)**
  - **Request and display Web pages**
  - **Many have multiple functions**
  - **Most popular**
    - MS Internet Explorer (IE)
    - Mozilla Firefox
    - Apple Safari
    - Opera
    - Google Chrome

- **Secure Sockets Layer and HTTPS**
  - **HTTP not secure**
  - **Requirements for secure Internet apps**
    - Authentication
    - Encryption
    - Nonrepudiation
  - **SSL and HTTPS offer security**

- **Secure Sockets Layer (SSL)**
  - Netscape-developed protocol
  - Encrypts data with a public key
  - Sends encrypted data over an SSL connection
  - Data decrypted on receiving end with private key
  - Supported by Web browsers and servers
  - Many Web sites use SSL for confidential data
  - Look for HTTPS or small lock in browser

- **HTTP over SSL**
  - Uses TCP port 443
  - Being replaced by Transport Layer Security (TLS)

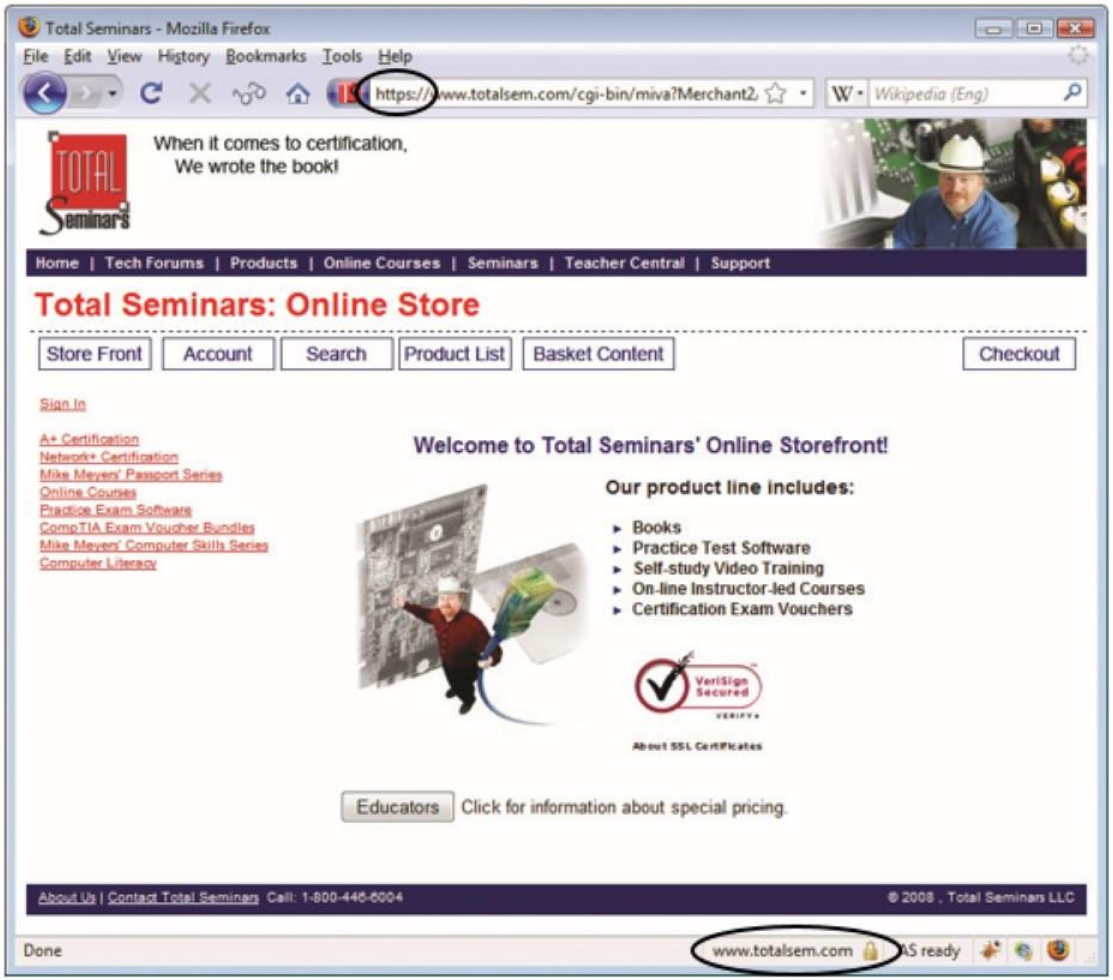


Figure 9.18 **Secure Web Page**

- **Telnet**
  - First networks were dumb terminals connected to more than one mainframe
  - Run commands as if sitting at the mainframe
  - Still exists as a way to connect remotely
  - Uses port 23
  - Used to administer servers
  - Requires long on with user name and password

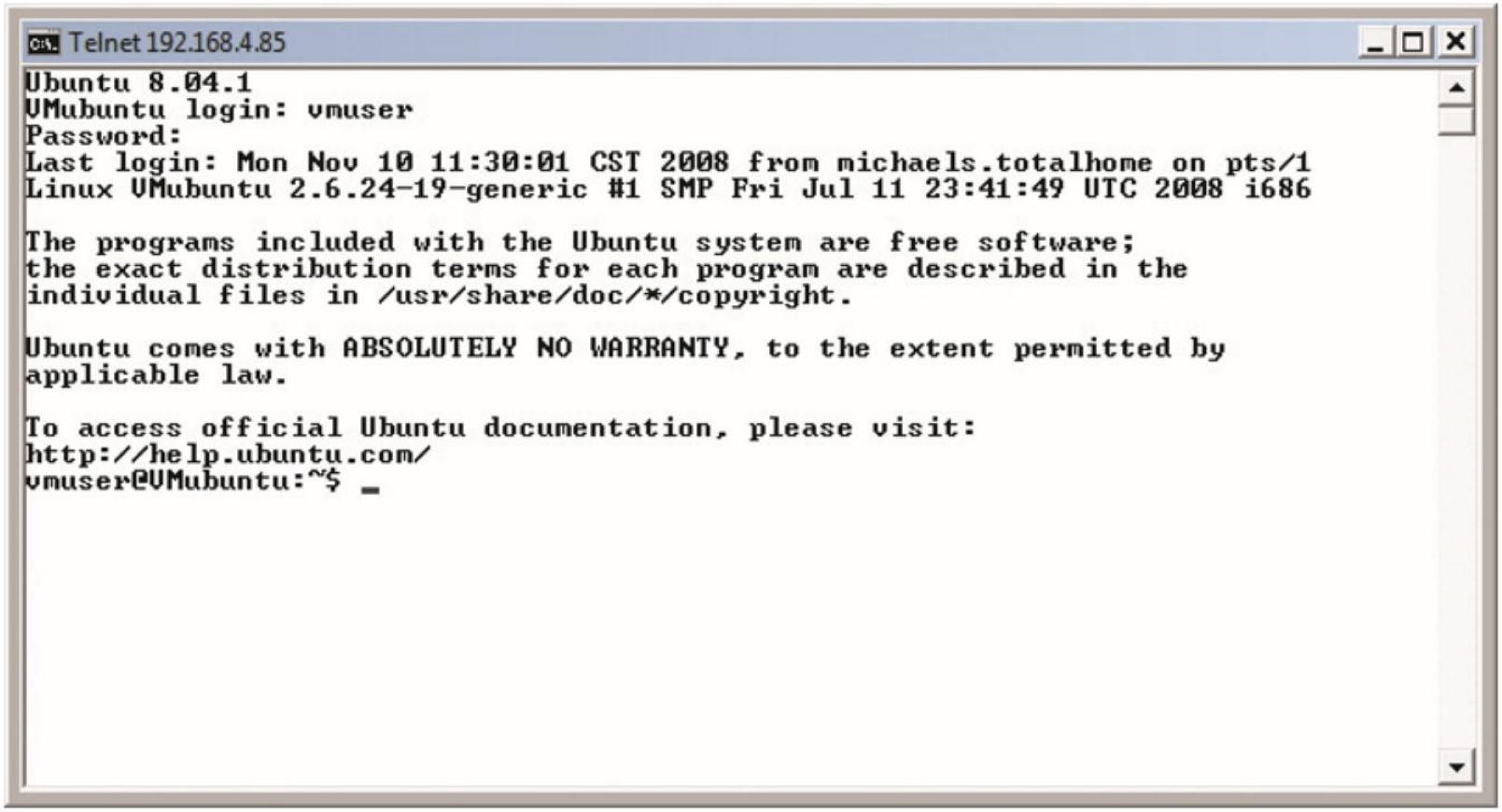


Figure 9.20 **Telnet client**

- **Telnet (cont.)**
  - Has no form of encryption
  - Rarely used on the Internet
  - Replaced by Secure Shell (SSH), which has encryption
  - Telnet still used on trusted networks
  - Most routers support Telnet (often turned off for security)

- **Telnet (cont.)**
  - Most OSs have built-in Telnet clients and servers
  - Most servers allow access using Telnet
  - Third-party clients and servers have more features

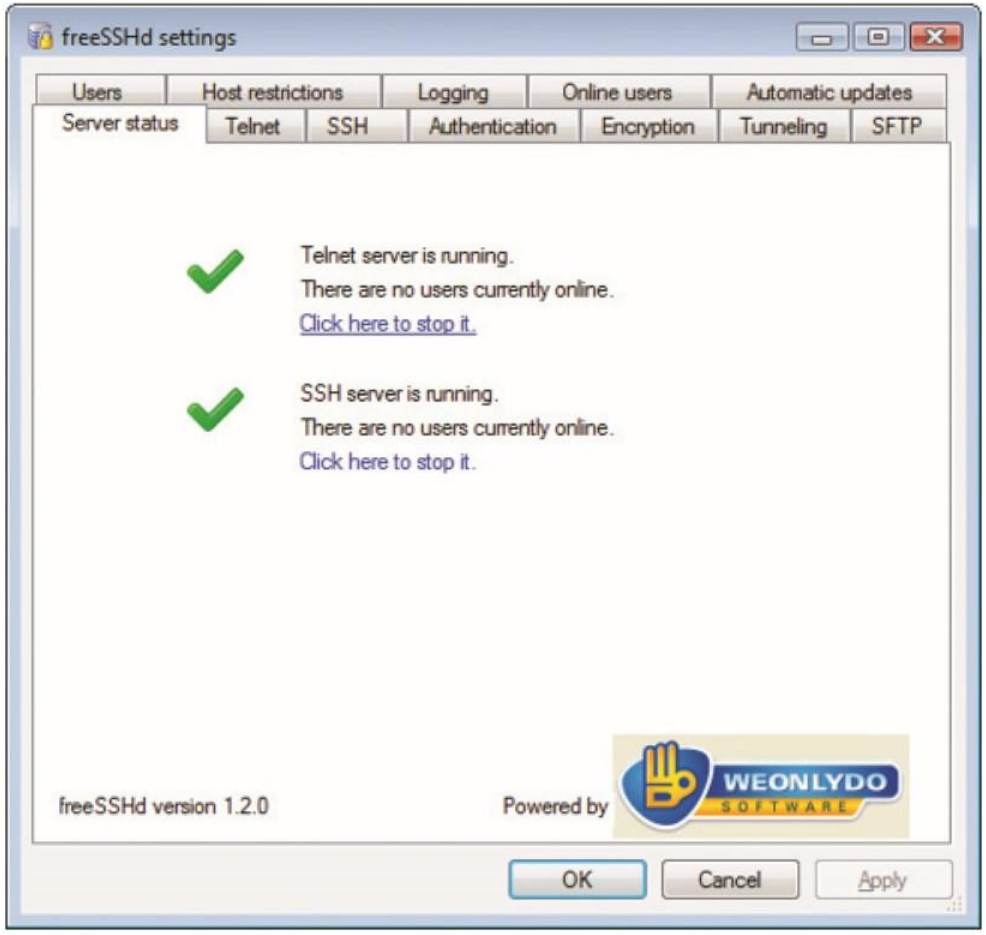


Figure 9.21 **freeSSHd**

- **Telnet (cont.)**
  - **Configuring a Telnet client**
    - Host name (name or IP address)
    - User login name
    - Password

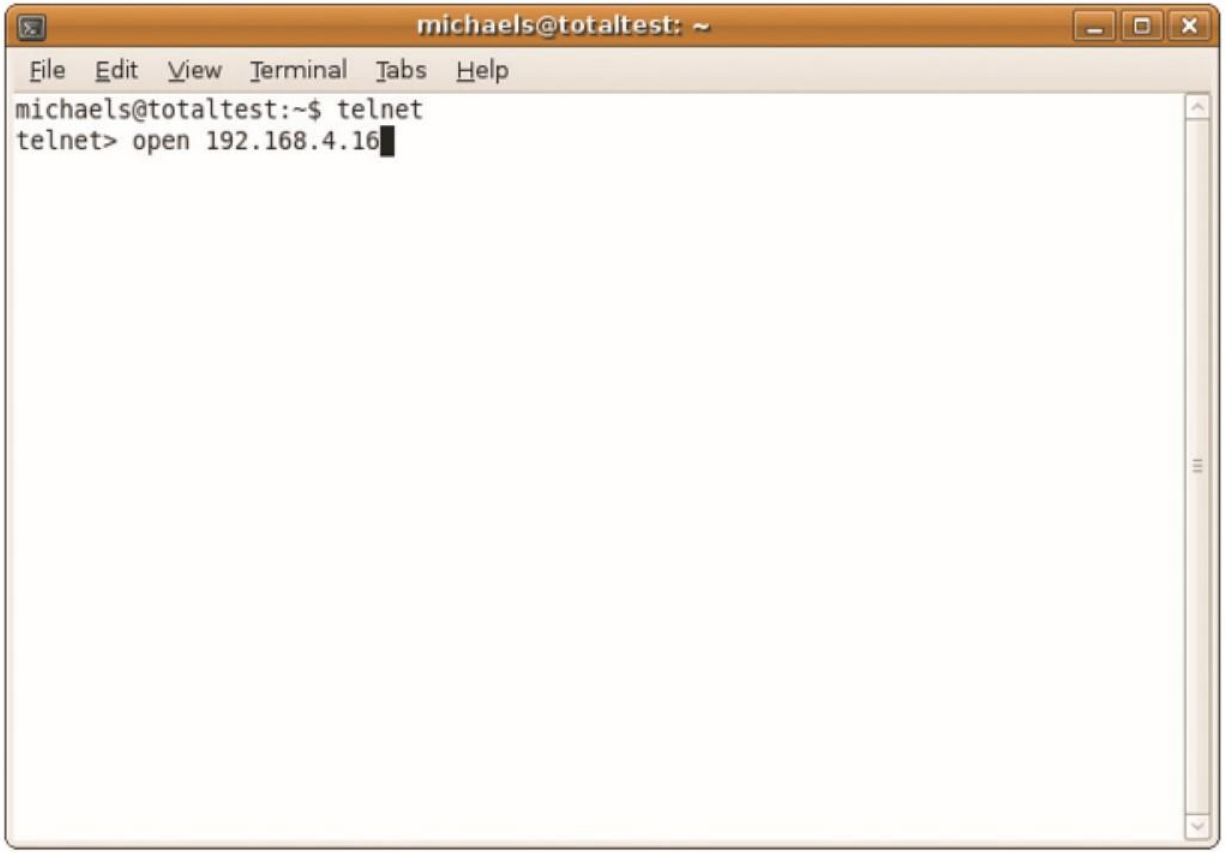


Figure 9.22 **Ubuntu Telnet**

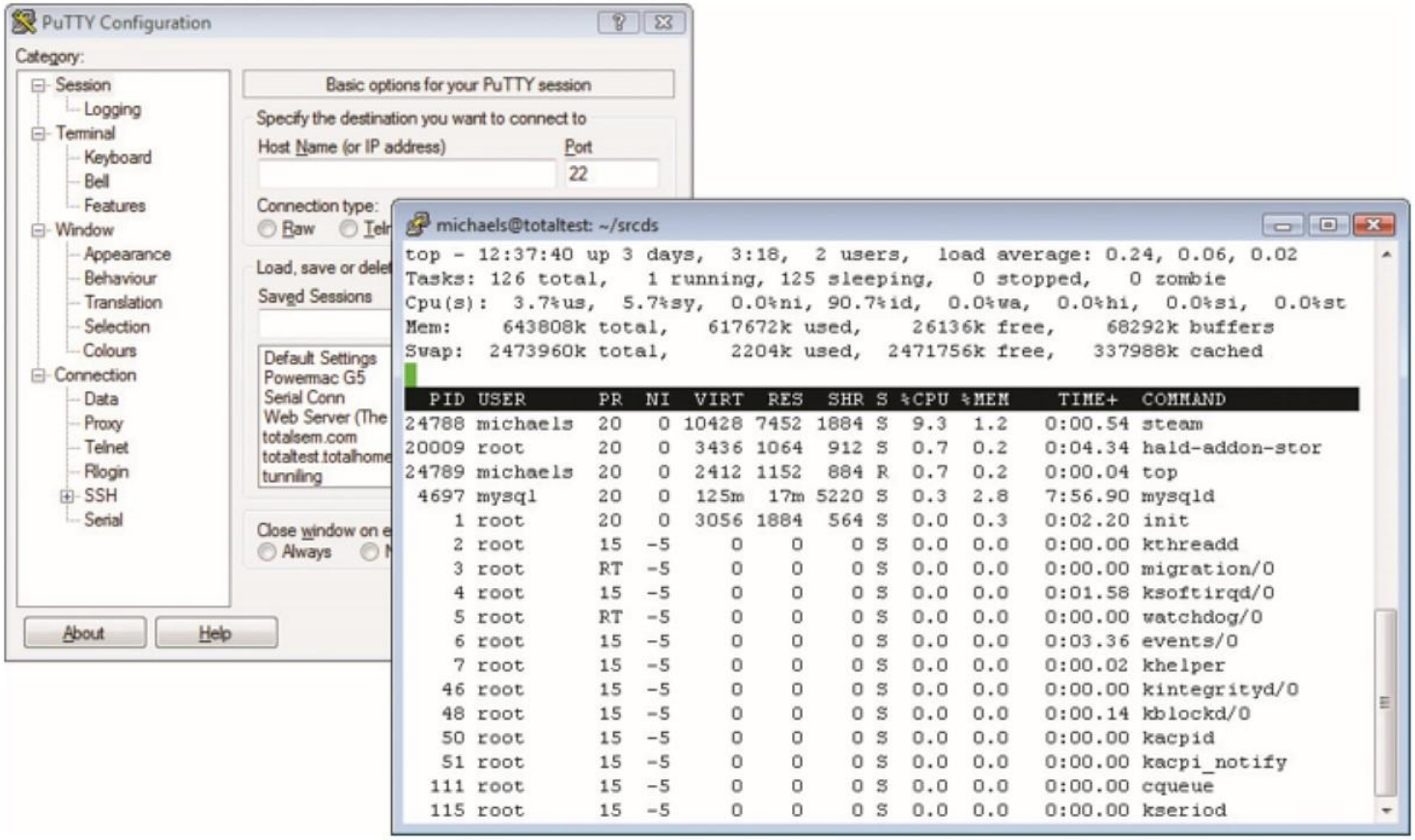


Figure 9.23 **PuTTY**

- **Rlogin, RSH, and RCP**
  - **Old UNIX remote programs**
  - **Remote access and control of servers**
  - **No encryption**
  - **Do not use across the Internet**
    - Rlogin – interactive, automatic login, TCP port 513
    - RSH – non-interactive, sends a single command to server, use in scripts, TCP port 514
    - RCP – copy files, use in scripts, shares TCP port 514 with RSH

- **SSH and the Death of Telnet**
  - Has replaced Telnet
  - Encrypts data
  - Creates a terminal connection to remote host
  - TCP port 22

- **Electronic mail (e-mail)**
  - Major contributor to Internet revolution
  - Streamlined junk mail industry
  - Provides quick way for people to communicate
  - Sends messages and attachments
  - Normally offered free by ISPs
  - Most e-mail clients have simple text editors

- **Electronic mail (e-mail)**
  - Messages stored on e-mail server
  - Most e-mail clients notify you when new message arrives or automatically download
  - You manage messages (forward, delete, etc.)
  - Most clients delete downloaded messages
  - E-mail programs use application-level protocols

- **Simple Mail Transfer Protocol (SMTP)**
  - Used by clients to send e-mail
  - TCP port 25

- **Post Office Protocol version 3 (POP3)**
  - Clients use to retrieve e-mail from SMTP servers
  - TCP port 110
  - Used by most e-mail clients

- **Internet Message Access Protocol version 4 (IMAP4)**
  - **Alternative to POP#**
  - **Retrieves e-mail from an e-mail server**
  - **TCP port 143**
  - **Supports features not supported by POP3**
    - Search messages by keyword
    - Select messages before download
    - Supports folders on IMAP4 servers

- **Alternatives to SMTP, POP3, and IMAP4**
  - **Web-based e-mail**
    - Access your e-mail from anywhere
    - Free
    - Handy for throw-away accounts
    - Do not confuse with Web-based e-mail services provided by traditional SMTP/POP/IMAP accounts
  - **Proprietary solutions**

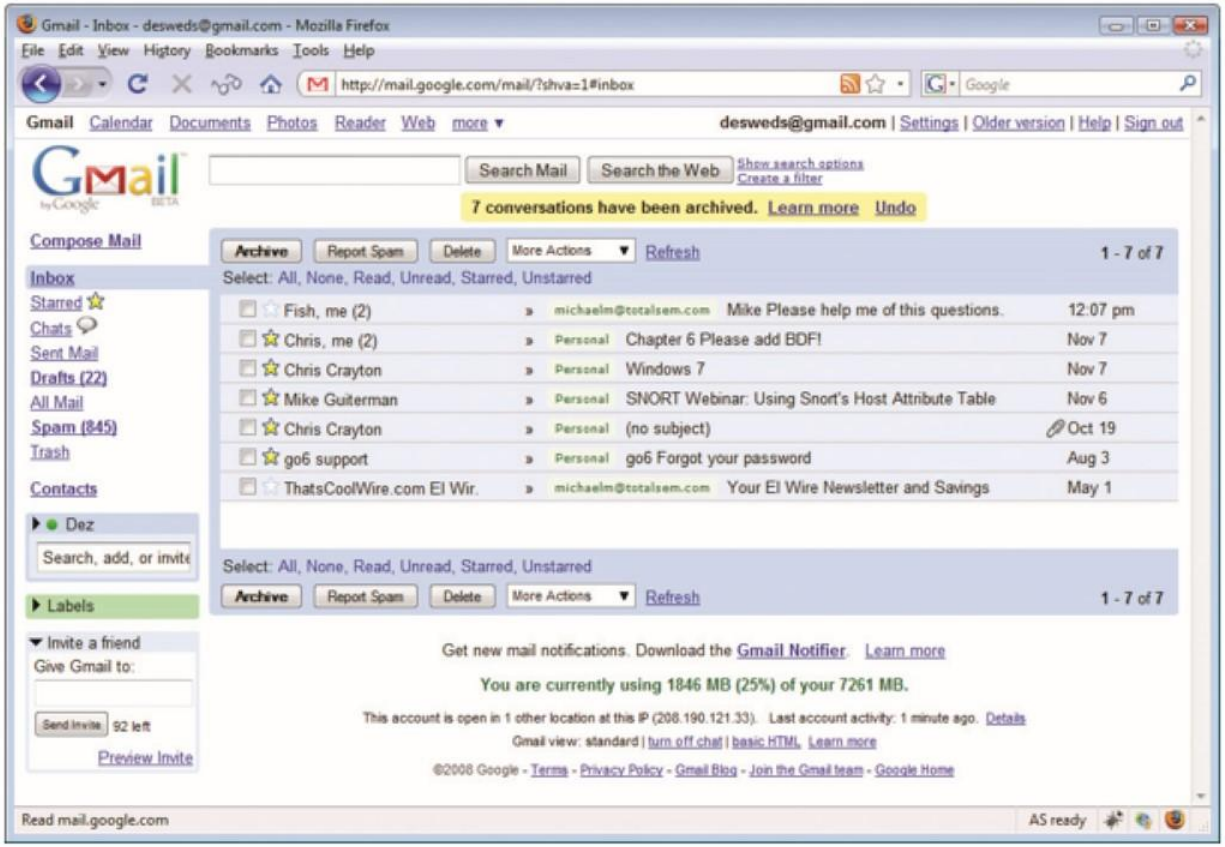


Figure 9.24 **Gmail in action**

- **E-mail Server software**
  - **E-mail server market fragmented**
  - **Sendmail for UNIX/Linux is leader (SMTP only)**
    - No GUI interface
    - Third-part interfaces (Webmin)
    - Controls about 20% of e-mail servers
    - Must use a POP3 or IMAP server program to support e-mail clients
  - **Eudora's Qpopper sends mail to POP3 e-mail clients**

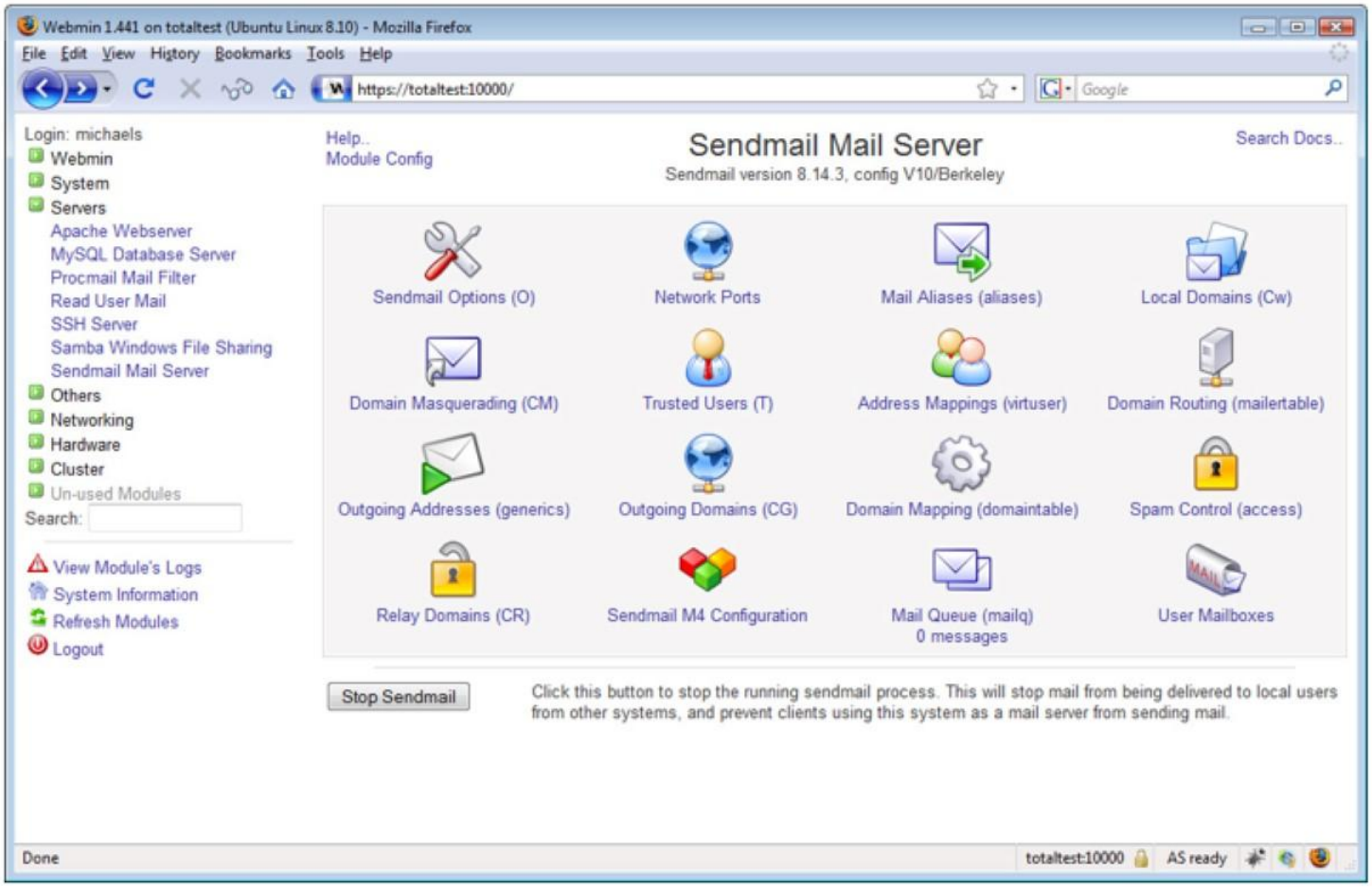


Figure 9.25 **Webmin with the sendmail module**

- **E-mail Server software (cont.)**
  - MS Exchange Server (both SMTP and POP3)
  - **Mailboxes** are holding areas on server for each user's messages
  - Server arranges incoming messages
  - Server returns messages with unknown recipient
  - Difficult to manage

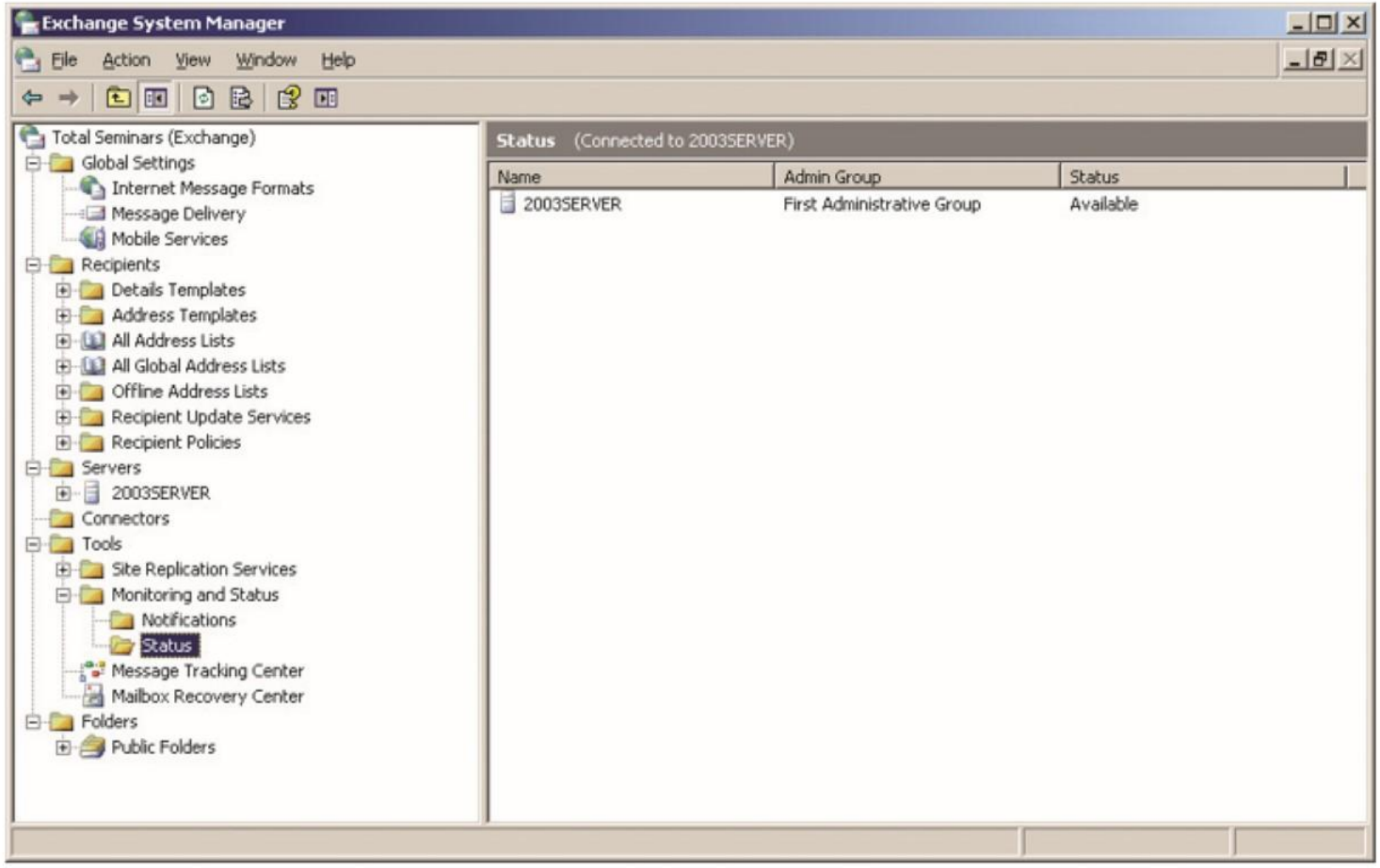


Figure 9.26 **Microsoft Exchange Server**

- **E-mail Client Software**
  - **Enables you to send, receive, and organize**
  - **Communicates with SMTP server to send**
  - **Communicates with IMAP or POP3 server to download messages**
  - **Hundreds of e-mail client programs**
    - Microsoft Windows Mail
    - Microsoft Outlook
    - Mozilla Thunderbird
    - Qualcomm Eudora

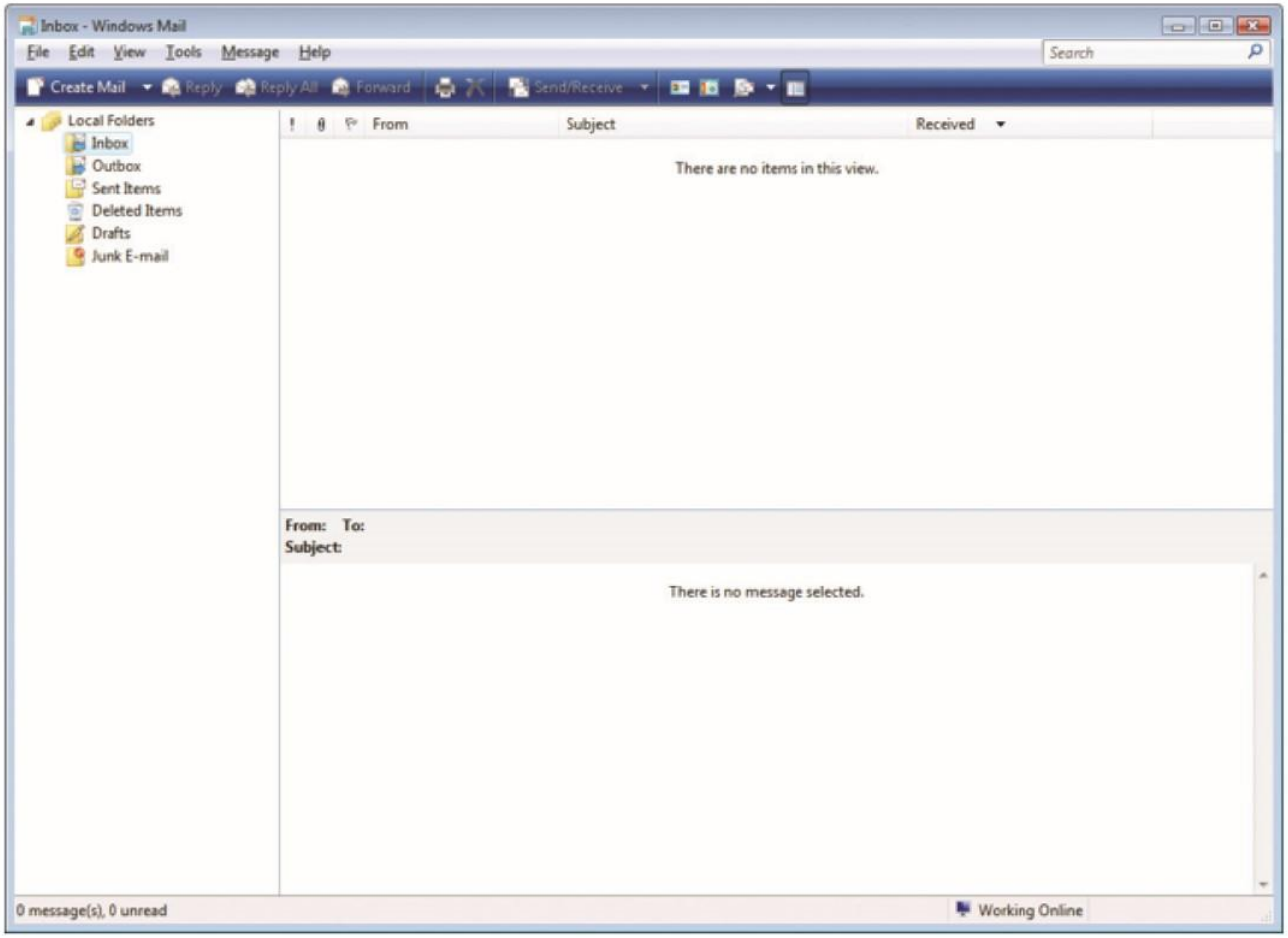


Figure 9.27 **Windows Mail**

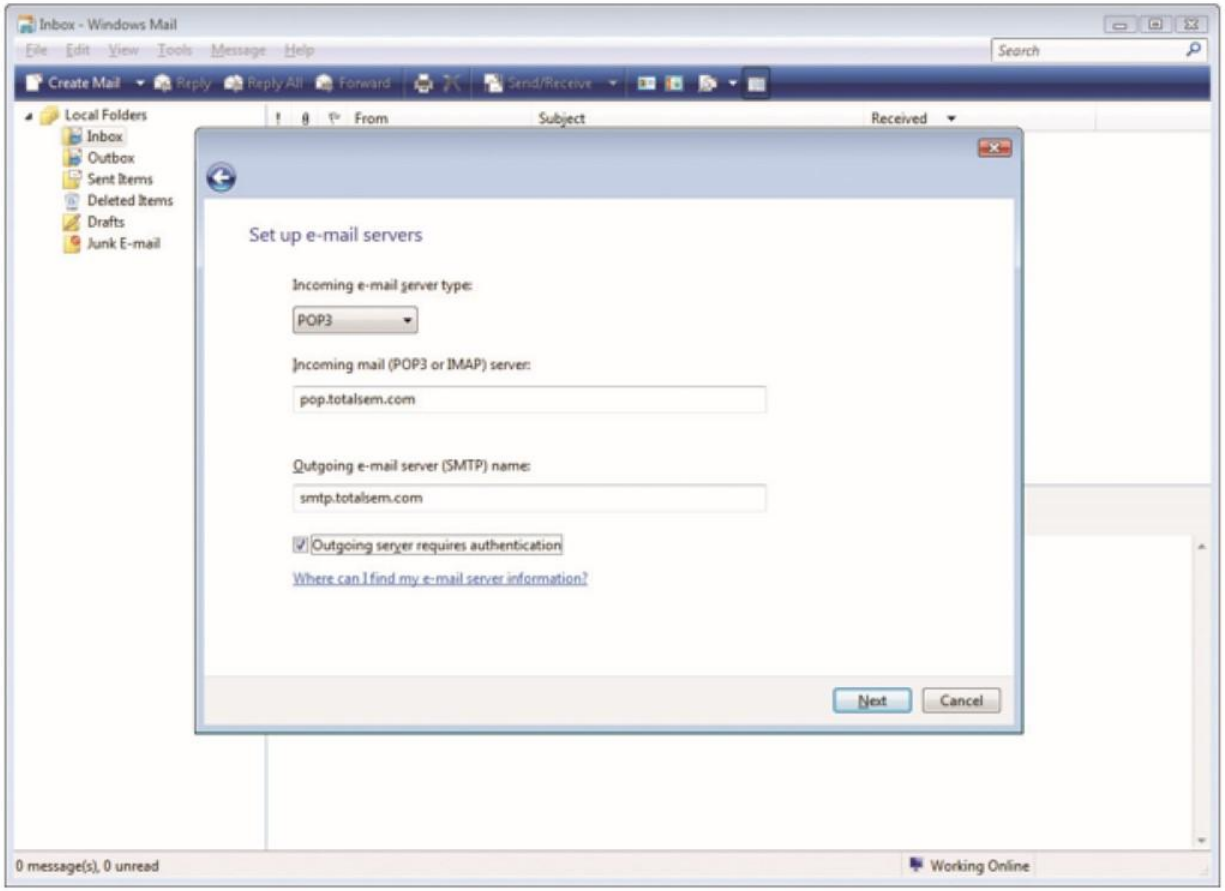


Figure 9.28 **Entering server information in Windows Mail**

- **Configuring E-mail Client Software**
  - Obtain server's address and your mailbox user name and password
  - Enter POP3 or IMAP4 server's IP address
  - Enter user name and password

- **File Transfer Protocol (FTP)**
  - Original Internet file transfer protocol
  - Faster and more reliable than HTTP
  - Includes security and data integrity
  - TCP ports 20 and 21
  - Anonymous or secured sites
  - Some are both

- **FTP Servers**
  - Store files
  - Accept incoming connections
  - Verify user names and passwords
  - Transfer files
  - Easy to set up an FTP server
  - UNIX/Linux have built-in FTP servers
  - Third-party servers better

- **FTP Clients**
  - **Access FTP servers many ways**
    - Web site
    - Command line
    - FTP client applications
  - **Most Web browsers support FTP, but lack features**
  - **Dedicated FTP clients work best**
    - FileZilla client
    - Mozilla FireFTP add-on to Firefox

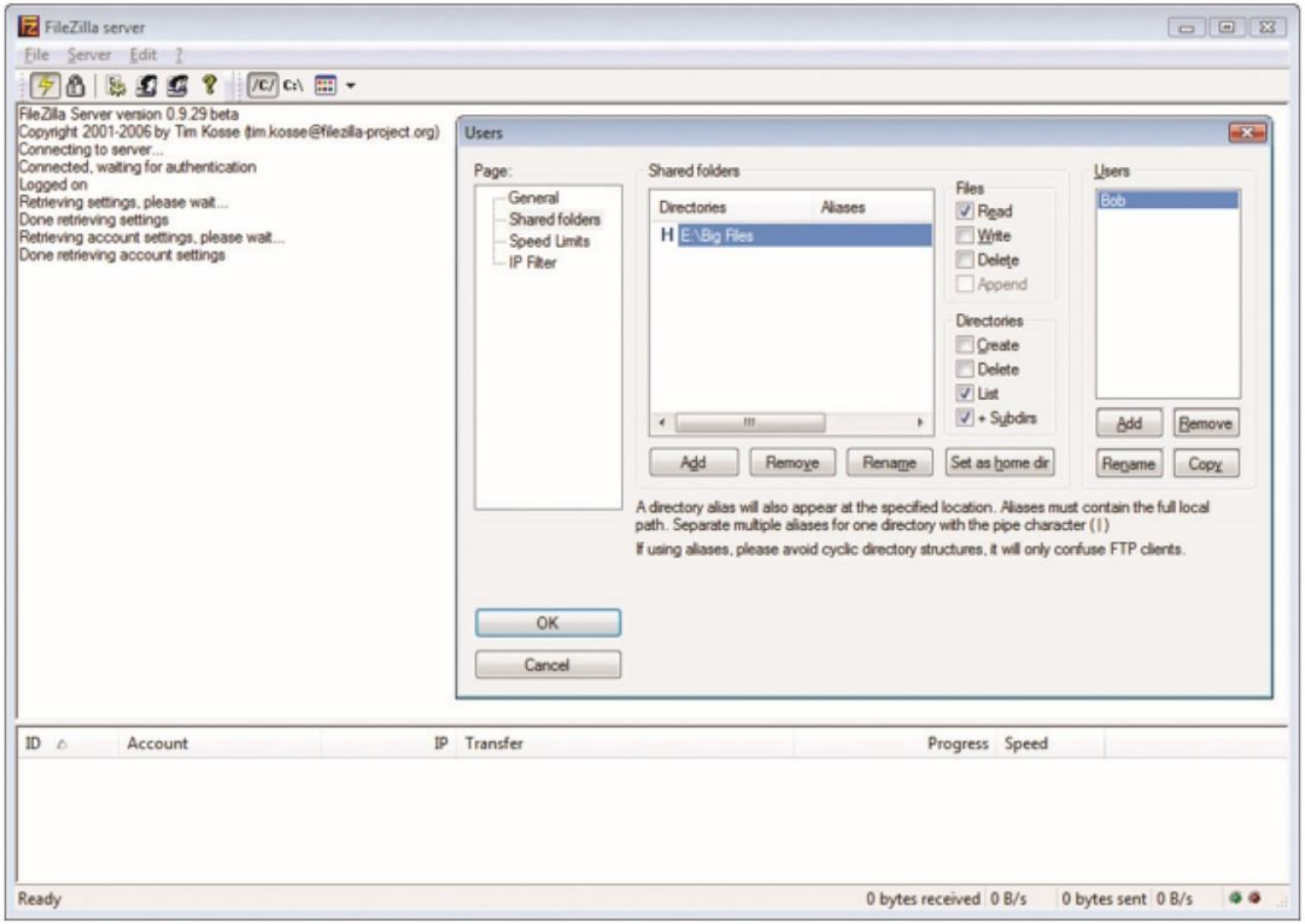


Figure 9.29 **FileZilla Server**

- **Passive vs. Active FTP**
  - **Traditional FTP uses active process**
    - Clients send FTP request on TCP port 21
    - Server responds on an ephemeral destination port with TCP port 20 as the source port
  - **Passive FTP server doesn't use port 20**
    - Works with NAT
    - Client must support passive FTP

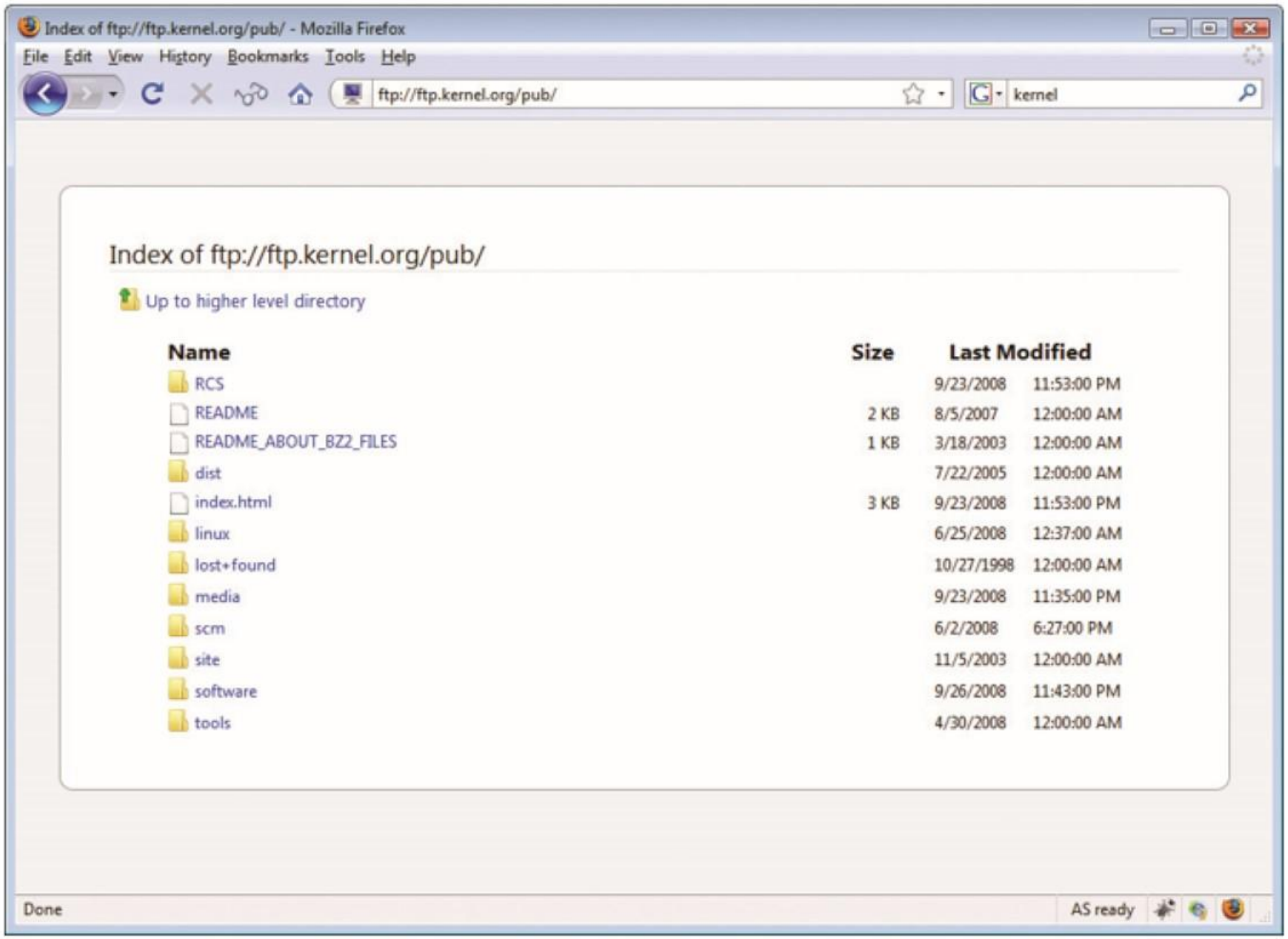


Figure 9.30 **FTP in Web browser**

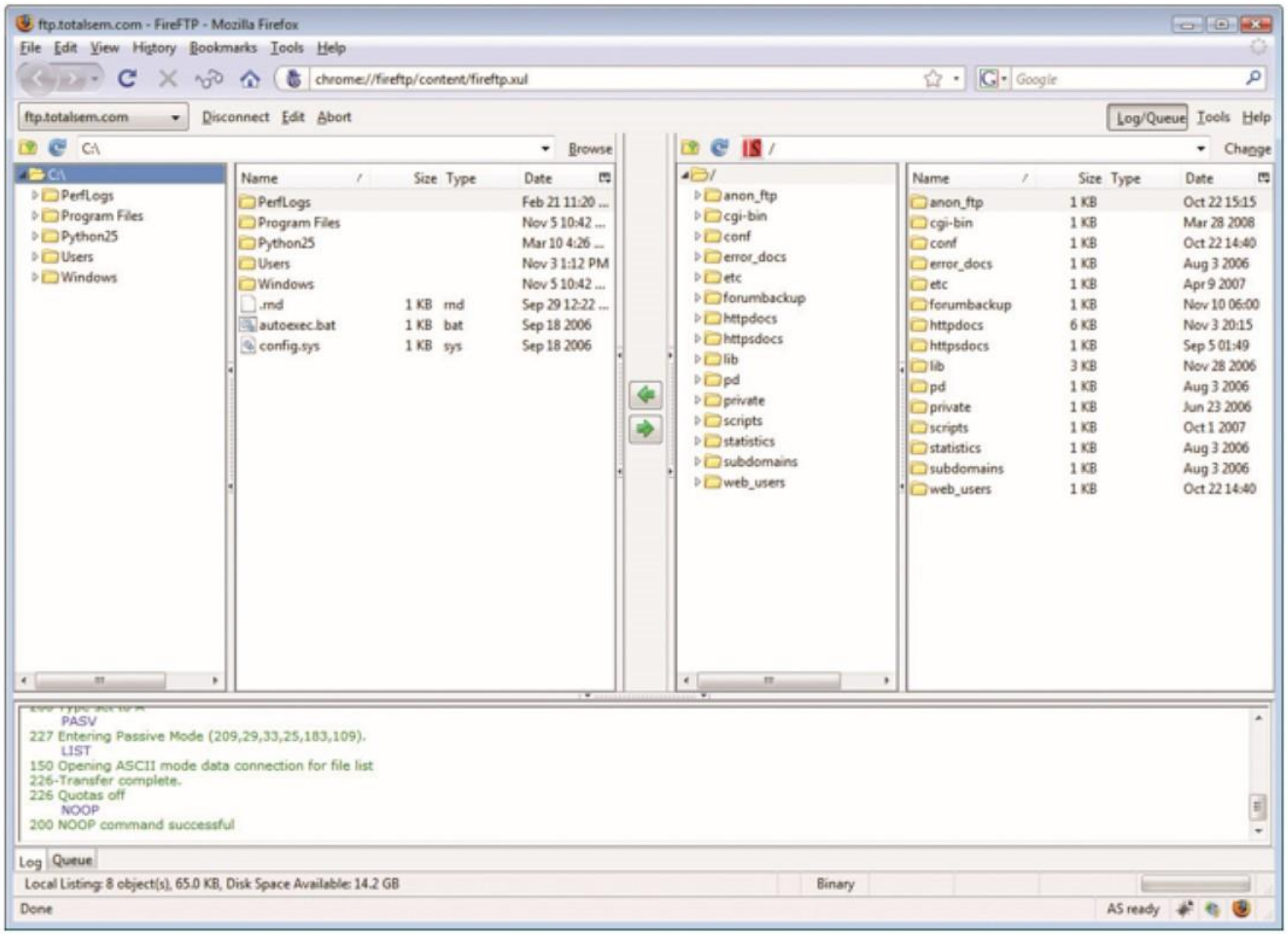


Figure 9.31 **Author's FireFTP hard at work**

Internet Application Port Usage

Application	TCP/UDP	Port	Notes
HTTP	TCP	80	The Web
HTTPS	TCP	443	The Web, securely
Telnet	TCP	23	Terminal emulation
SSH	TCP	22	Secure terminal emulation
SMTP	TCP	25	Sending e-mail
POP3	TCP	110	E-mail delivery
IMAP4	TCP	143	E-mail delivery
FTP	TCP	20/21	File transfer
TFTP	UDP	69	File transfer