

2.3.1 FTP Commands and Replies

We end this section with a brief discussion of some of the more common FTP commands and replies. The commands, from client to server, and replies, from server to client, are sent across the control connection in 7-bit ASCII format. Thus, like HTTP commands, FTP commands are readable by people. In order to delineate successive commands, a carriage return and line feed end each command. Each command consists of four uppercase ASCII characters, some with optional arguments. Some of the more common commands are given below:

- **USER username:** Used to send the user identification to the server.
- **PASS password:** Used to send the user password to the server.
- **LIST:** Used to ask the server to send back a list of all the files in the current remote directory. The list of files is sent over a (new and non-persistent) data connection rather than the control TCP connection.
- **RETR filename:** Used to retrieve (that is, get) a file from the current directory of the remote host. This command causes the remote host to initiate a data connection and to send the requested file over the data connection.
- **STOR filename:** Used to store (that is, put) a file into the current directory of the remote host.

There is typically a one-to-one correspondence between the command that the user issues and the FTP command sent across the control connection. Each command is followed by a reply, sent from server to client. The replies are three-digit numbers, with an optional message following the number. This is similar in structure to the status code and phrase in the status line of the HTTP response message. Some typical replies, along with their possible messages, are as follows:

- 331 Username OK, password required
- 125 Data connection already open; transfer starting
- 425 Can't open data connection
- 452 Error writing file

Readers who are interested in learning about the other FTP commands and replies are encouraged to read RFC 959.

2.4 Electronic Mail in the Internet

Electronic mail has been around since the beginning of the Internet. It was the most popular application when the Internet was in its infancy [Segaller 1998], and has

become more and more elaborate and powerful over the years. It remains one of the Internet's most important and utilized applications.

As with ordinary postal mail, e-mail is an asynchronous communication medium—people send and read messages when it is convenient for them, without having to coordinate with other people's schedules. In contrast with postal mail, electronic mail is fast, easy to distribute, and inexpensive. Modern e-mail has many powerful features, including messages with attachments, hyperlinks, HTML-formatted text, and embedded photos.

In this section, we examine the application-layer protocols that are at the heart of Internet e-mail. But before we jump into an in-depth discussion of these protocols, let's take a high-level view of the Internet mail system and its key components.

Figure 2.16 presents a high-level view of the Internet mail system. We see from this diagram that it has three major components: **user agents**, **mail servers**, and the

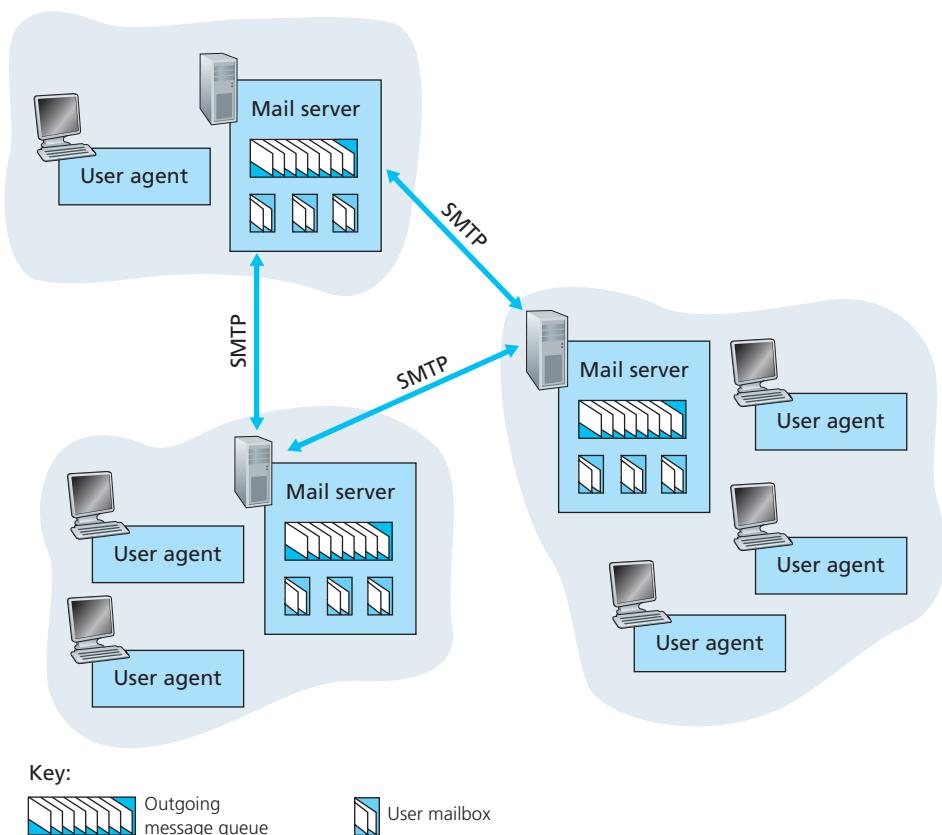


Figure 2.16 ♦ A high-level view of the Internet e-mail system

Simple Mail Transfer Protocol (SMTP). We now describe each of these components in the context of a sender, Alice, sending an e-mail message to a recipient, Bob. User agents allow users to read, reply to, forward, save, and compose messages. Microsoft Outlook and Apple Mail are examples of user agents for e-mail. When Alice is finished composing her message, her user agent sends the message to her mail server, where the message is placed in the mail server's outgoing message queue. When Bob wants to read a message, his user agent retrieves the message from his mailbox in his mail server.

Mail servers form the core of the e-mail infrastructure. Each recipient, such as Bob, has a **mailbox** located in one of the mail servers. Bob's mailbox manages and maintains the messages that have been sent to him. A typical message starts its journey in the sender's user agent, travels to the sender's mail server, and travels to the recipient's mail server, where it is deposited in the recipient's mailbox.

CASE HISTORY

WEB E-MAIL

In December 1995, just a few years after the Web was "invented," Sabeer Bhatia and Jack Smith visited the Internet venture capitalist Draper Fisher Jurvetson and proposed developing a free Web-based e-mail system. The idea was to give a free e-mail account to anyone who wanted one, and to make the accounts accessible from the Web. In exchange for 15 percent of the company, Draper Fisher Jurvetson financed Bhatia and Smith, who formed a company called Hotmail. With three full-time people and 14 part-time people who worked for stock options, they were able to develop and launch the service in July 1996. Within a month after launch, they had 100,000 subscribers. In December 1997, less than 18 months after launching the service, Hotmail had over 12 million subscribers and was acquired by Microsoft, reportedly for \$400 million. The success of Hotmail is often attributed to its "first-mover advantage" and to the intrinsic "viral marketing" of e-mail. (Perhaps some of the students reading this book will be among the new entrepreneurs who conceive and develop first-mover Internet services with inherent viral marketing.)

Web e-mail continues to thrive, becoming more sophisticated and powerful every year. One of the most popular services today is Google's gmail, which offers gigabytes of free storage, advanced spam filtering and virus detection, e-mail encryption (using SSL), mail fetching from third-party e-mail services, and a search-oriented interface. Asynchronous messaging within social networks, such as Facebook, has also become popular in recent years.