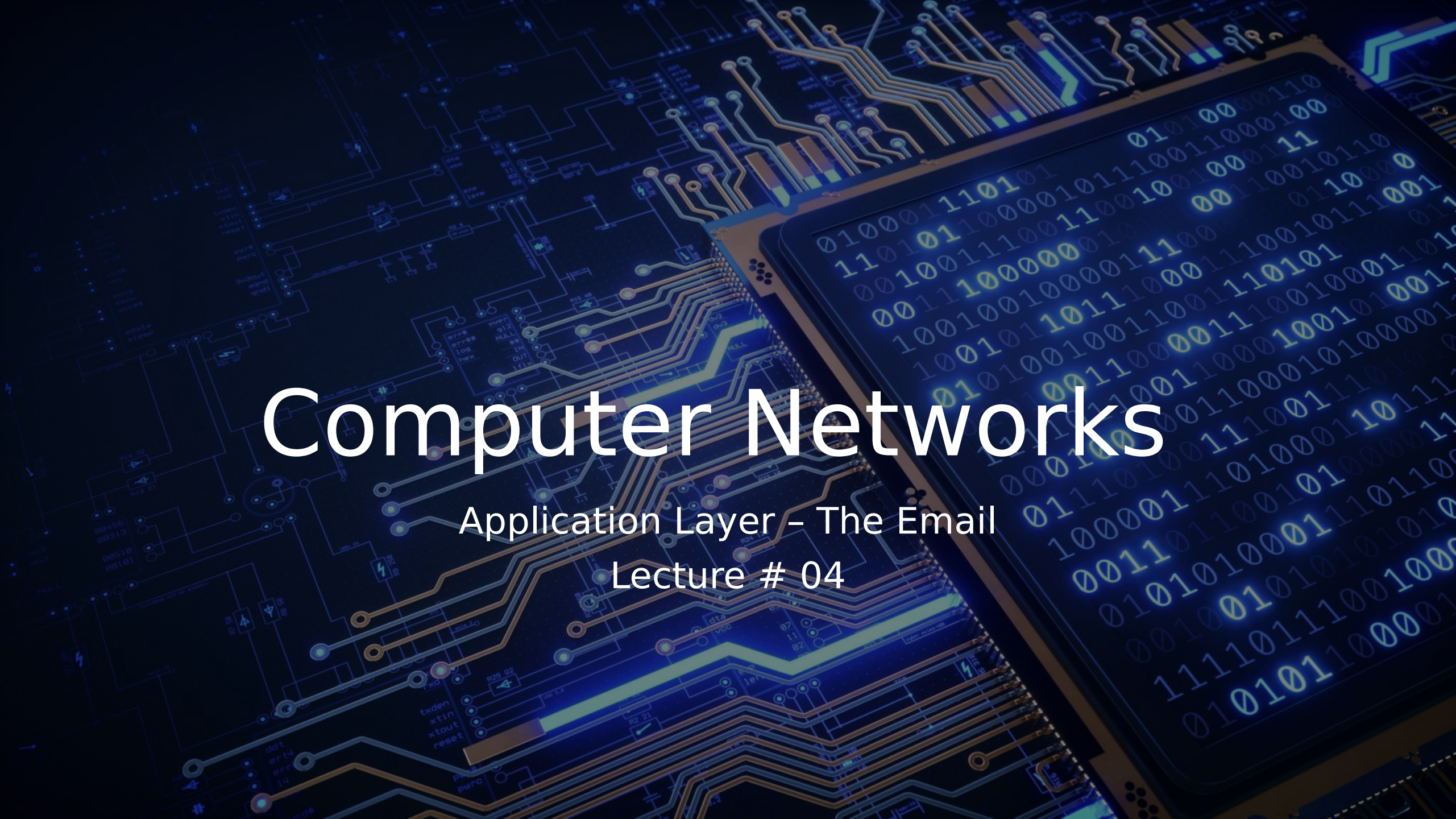


Computer Networks

Application Layer – The Email

Lecture # 04

Network Applications

Some important network applications are:

- The Web – HTTP
- file transfer - FTP
- electronic mail – SMTP, POP
- directory service - DNS
- P2P applications – Distributed file sharing and lookup service

Application Layer- Services & Ports

- **DNS** (Domain Name System)

  Resolves Internet names (URLs) to IP Addresses, port 53
- **Telnet, SSH** (Terminal emulation, Secure shell)

  access to servers and network devices, port 23, 22
- **SMTP** (Simple Mail Transfer Protocol)

  Transfer of mail messages and attachments (outgoing), port 25
- **POP3, POP3S** (Post Office Protocol)

  Transfer of mail messages and attachments (incoming), port 110, 995
- **IMAP**

  Internet Message Access Protocol, port 143
- **DHCP** (Dynamic Host Configuration Protocol)

  Assigns IP Addresses (IP, subnetmask) and other parameters (DNS, Gateway, …) to hosts, port 67, 68
- **HTTP(s)** (Hypertext Transfer Protocol)

  Transfer files that make up web pages, port 80, 443
- **FTP(S)** ((Secure) File Transfer Protocol)

  Interactive file transfer between systems, port control:21,data:21 and 3713, data:989,990

The Electronic Mail

- One of the Internet’s most important and utilized applications.
- 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.

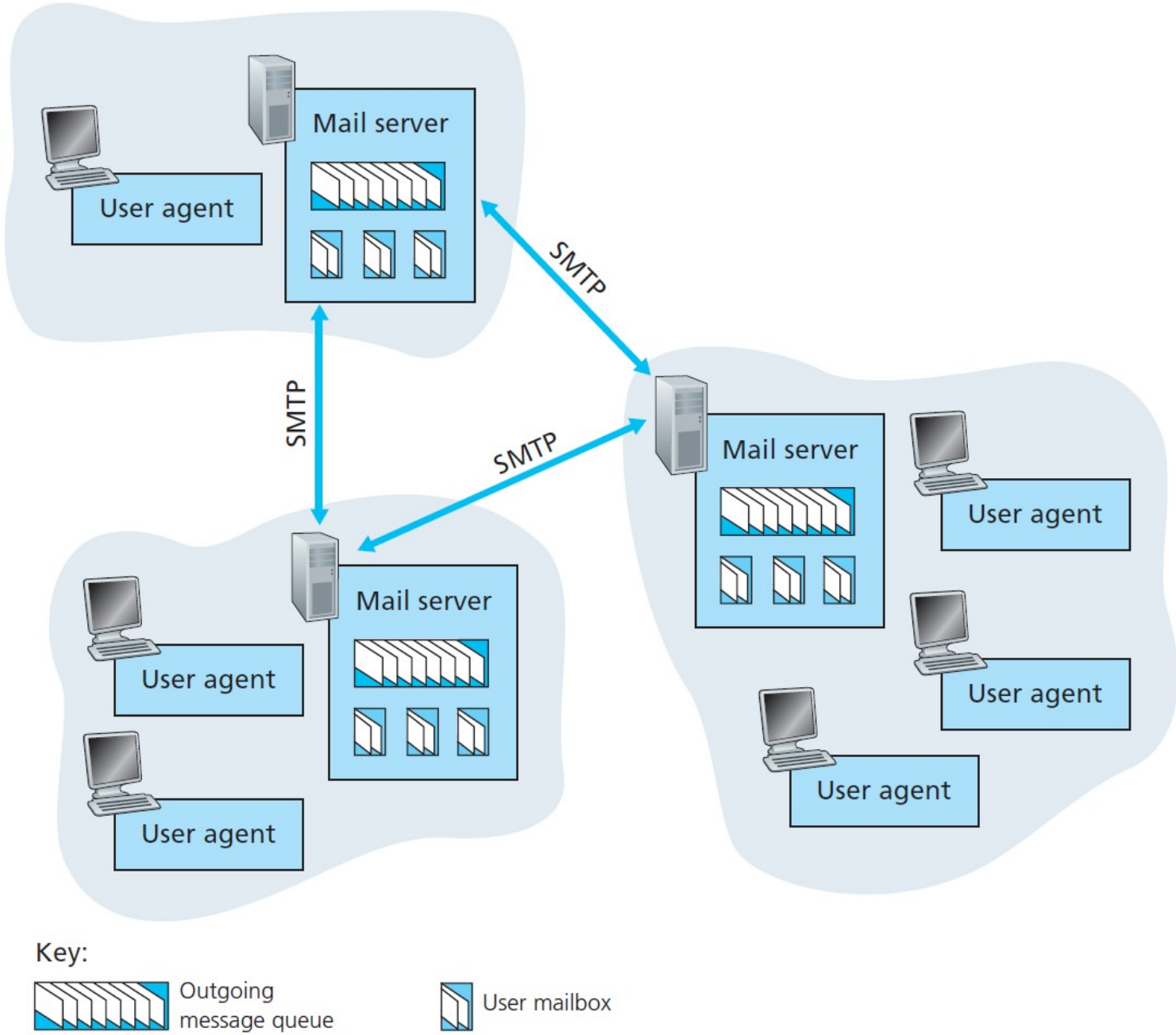


Figure 2.16 ♦ A high-level view of the Internet e-mail system

- User Agents:
  - Allow users to read, reply to, forward, save, and compose messages.
  - Retrieves the message from the mailbox in the mail server.
  - Microsoft Outlook, Gmail and Apple Mail are examples of user agents for e-mail.
- Mail Servers:
  - Keep messages stored
  - Resend(every 30 mins or so) messages if needed.
  - Maintain a mailbox for each user.
  - Authenticates the end users
- SMTP:
  - principal application-layer protocol for Internet electronic mail.
  - Both client and server sides.

CASE HISTORY

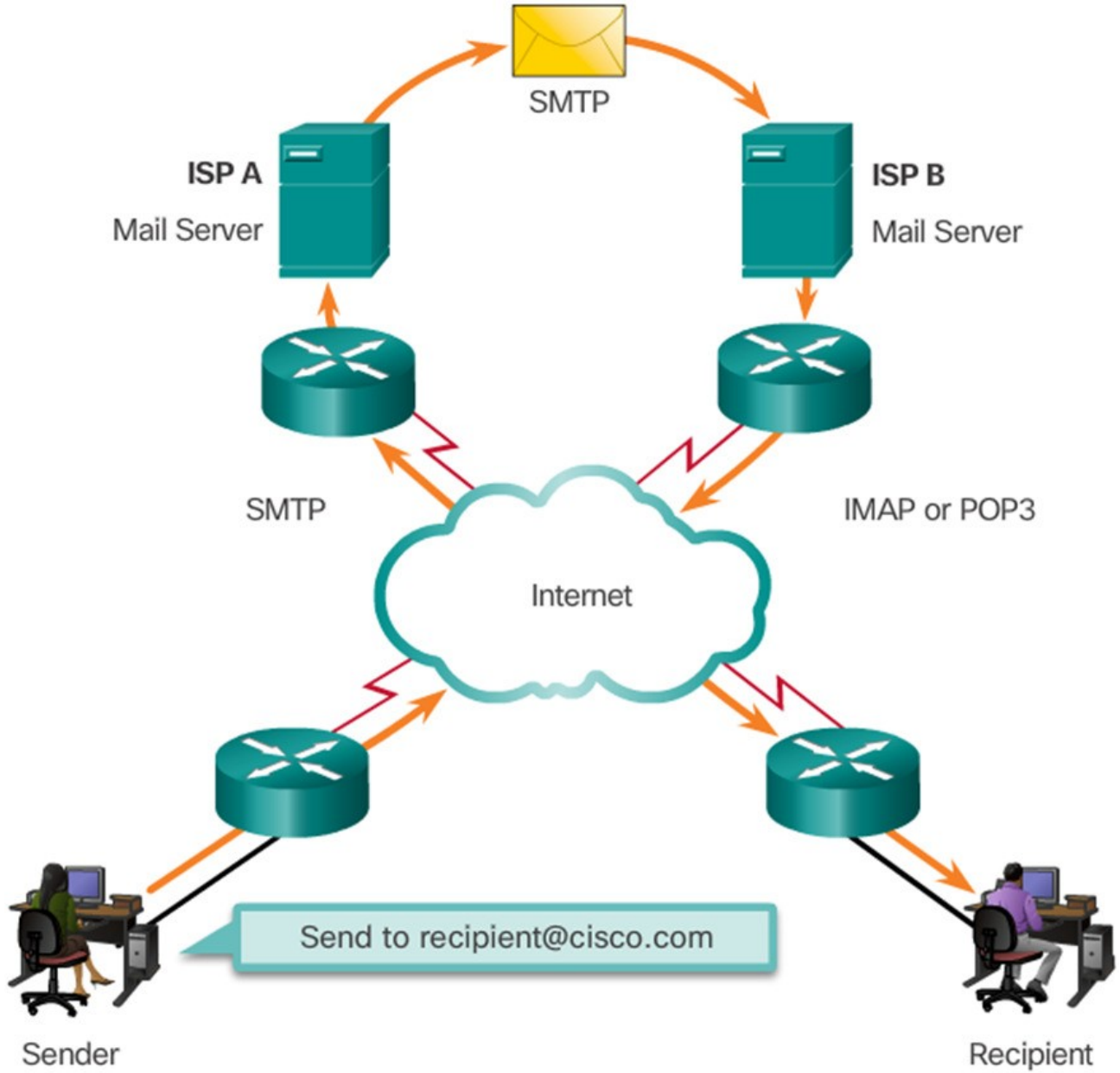
WEB E-MAIL

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.

Email Protocol

- Email is a store-and-forward method of sending, storing, and retrieving electronic messages.
- Email messages are stored in databases on mail servers.
- Email clients communicate with mail servers to send and receive email.
- Mail servers communicate with other mail servers to transport messages from one domain to another.
- Email clients do not communicate directly when sending email.
- Email relies on three separate protocols for operation: SMTP (sending),POP (retrieving), IMAP (retrieving).



The SMTP Protocol

Simple **M**ail **T**ransfer **P**rotocol

SMTP

- defined in RFC 5321.
- SMTP transfers messages from senders’ mail servers to the recipients’ mail servers.
- it restricts the body (not just the headers) of all mail messages to simple 7-bit ASCII.
- Uses persistent connection

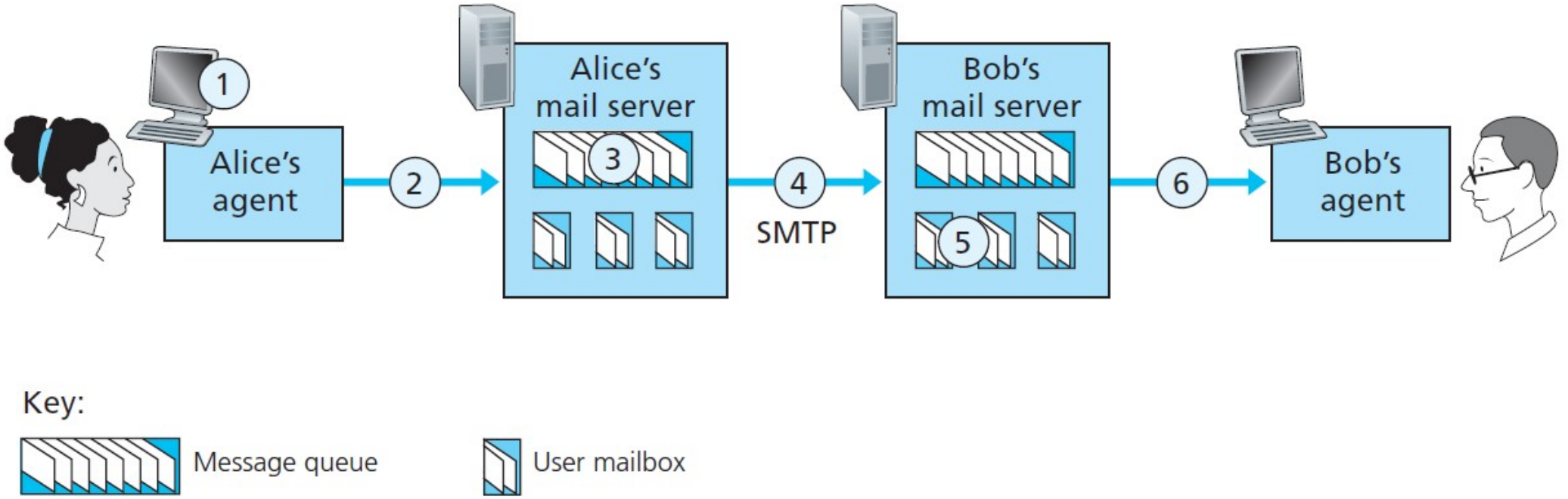


Figure 2.17 ♦ Alice sends a message to Bob

1. Alice invokes her user agent for e-mail, provides Bob’s e-mail address (for example, bob@someschool.edu), composes a message, and instructs the user agent to send the message.
2. Alice’s user agent sends the message to her mail server, where it is placed in a message queue.
3. The client side of SMTP, running on Alice’s mail server, sees the message in the message queue. It opens a TCP connection to an SMTP server, running on Bob’s mail server.
4. After some initial SMTP handshaking, the SMTP client sends Alice’s message into the TCP connection.
5. At Bob’s mail server, the server side of SMTP receives the message. Bob’s mail server then places the message in Bob’s mailbox.
6. Bob invokes his user agent to read the message at his convenience.

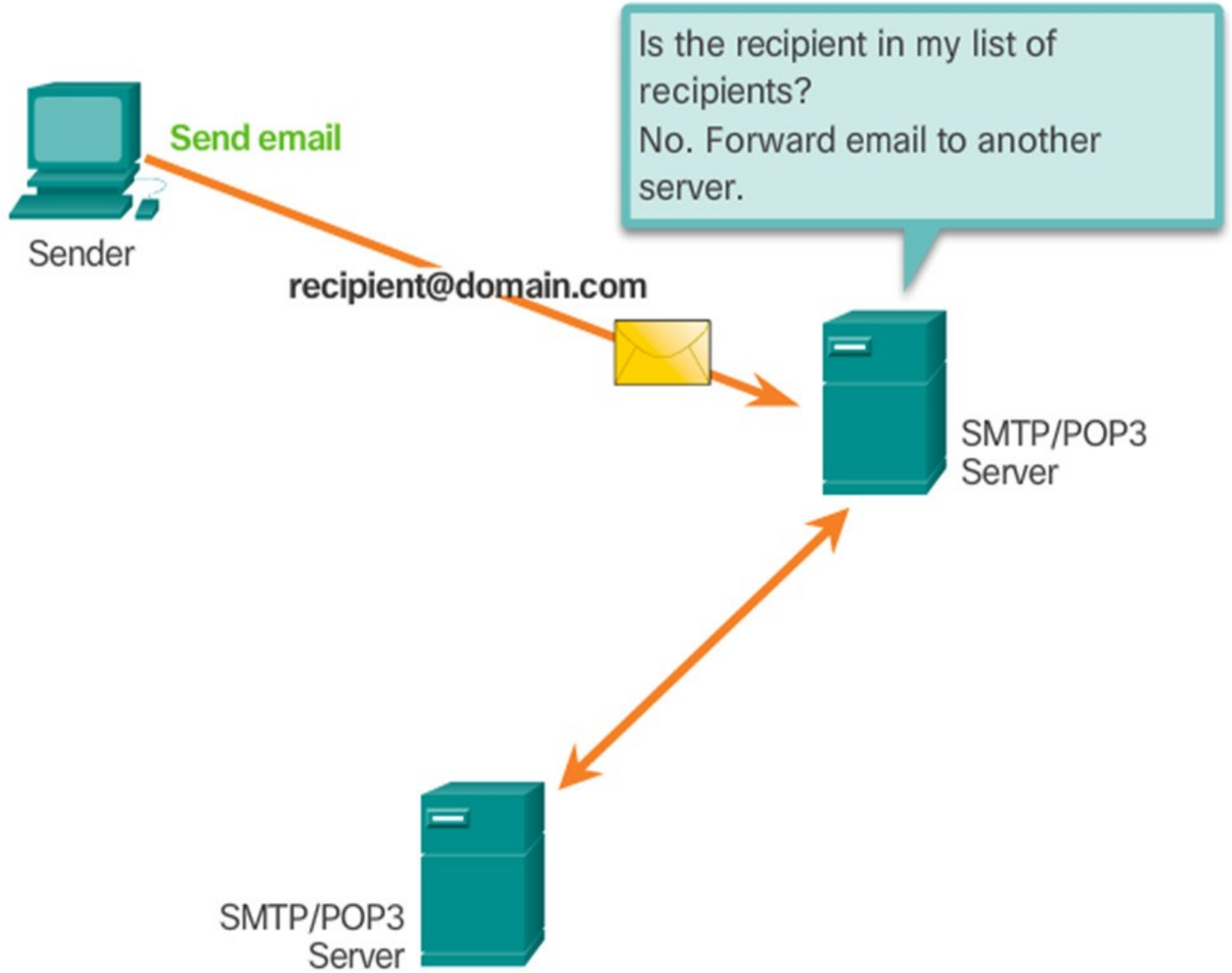
Note: SMTP does not normally use intermediate mail servers for sending mail, even when the two mail servers are located at opposite ends of the world.

- client SMTP (running on the sending mail server host) has TCP establish a connection to port 25 at the server SMTP (running on the receiving mail server host).
- Once this connection is established, the server and client perform some application-layer handshaking.
- During handshaking, the SMTP client indicates the e-mail address of the sender (the person who generated the message) and the e-mail address of the recipient.
- Once the SMTP client and server have introduced themselves to each other, the client sends the message.
- SMTP can count on the reliable data transfer service of TCP to get the message to the server without errors.
- The client then repeats this process over the same TCP connection if it has other messages to send to the server; otherwise, it instructs TCP to close the connection.

- S: 220 hamburger.edu
- C: HELO crepes.fr
- S: 250 Hello crepes.fr, pleased to meet you
- C: MAIL FROM: <alice@crepes.fr>
- S: 250 alice@crepes.fr ... Sender ok
- C: RCPT TO: <bob@hamburger.edu>
- S: 250 bob@hamburger.edu ... Recipient ok
- C: DATA
- S: 354 Enter mail, end with “.” on a line by itself
- C: Do you like ketchup?
- C: How about pickles?
- C: .
- S: 250 Message accepted for delivery
- C: QUIT
- S: 221 hamburger.edu closing connection

SMTP Operation

- SMTP message formats require a message header and body.
- The body can contain any amount of text.
- The header must have a properly formatted recipient email address and a sender address.
- An SMTP client sends an email by connecting to a SMTP server **on port 25**.
- The server receives the message and stores it message in a local mailbox or relays the message to another mail server.
- Users use email clients to retrieve messages stored on the server.
- IMAP and POP are two protocols commonly used by email clients to retrieve messages.



Reading Assignment

- Compare HTTP and SMTP
- Discuss MIME and S/MIME protocols

Mail Access Protocols

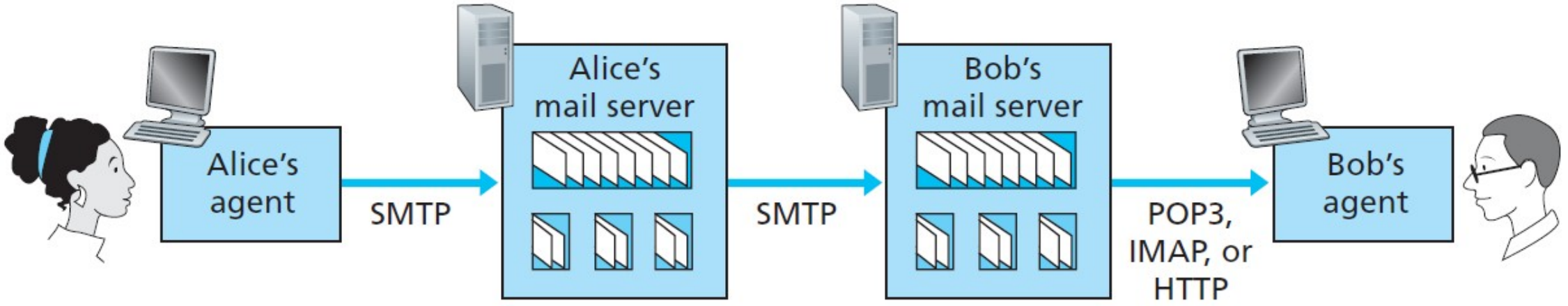


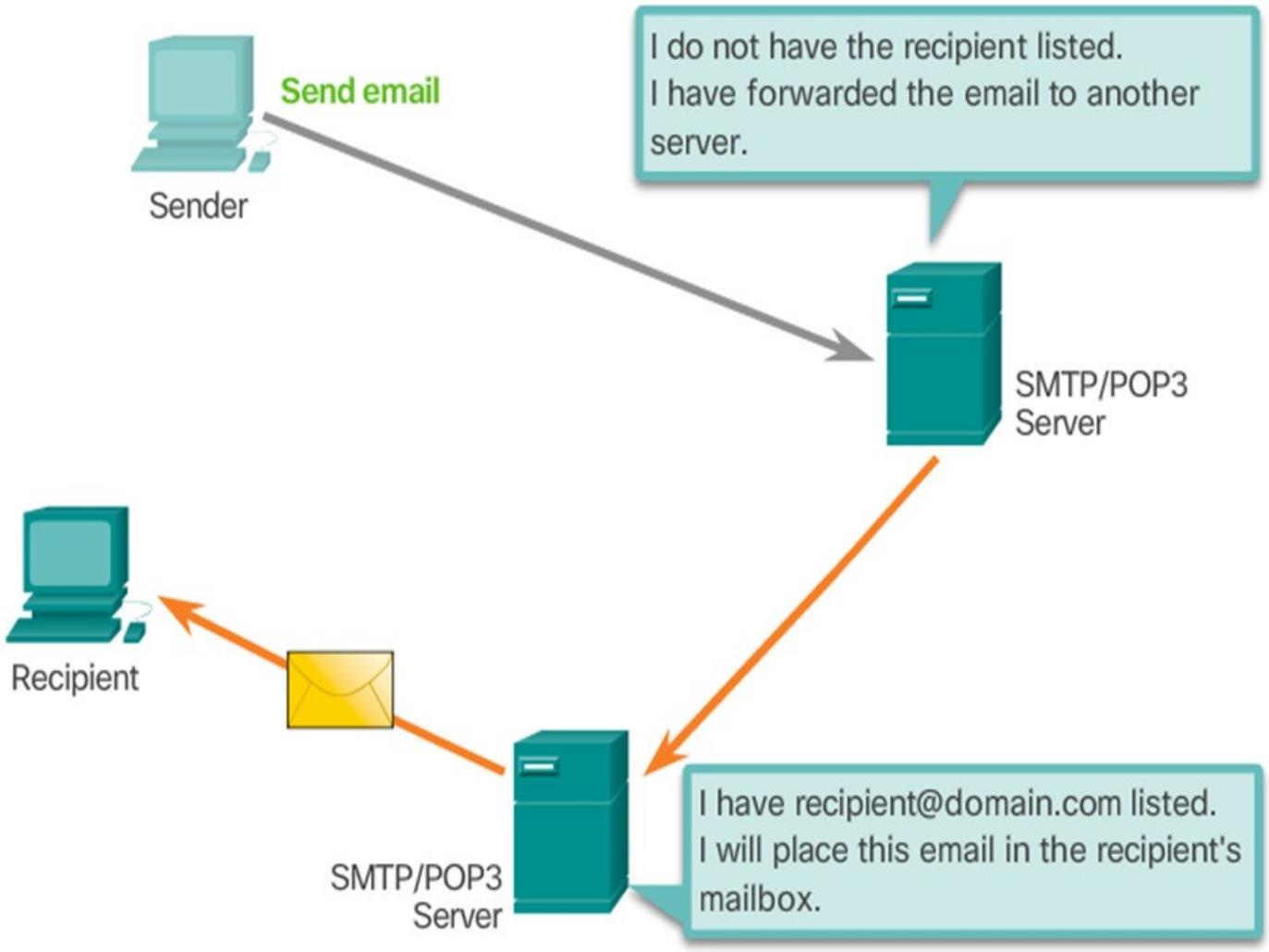
Figure 2.18 ♦ E-mail protocols and their communicating entities

Email Access Protocols

- There are currently a number of popular mail access protocols, including
  - Post Office Protocol—Version 3 (POP3),
  - Internet Mail Access Protocol (IMAP), and
  - HTTP.

POP3 Protocol

- Messages are downloaded from the server to the client.
- The server listens on **port 110 TCP** for client requests.
- Email clients direct their POP requests to mail servers on port TCP 110.
- The POP client and server exchange commands and responses until the connection is closed or aborted.
- POP allows for email messages to be downloaded to the client's device (computer or phone) and removed from the server.
- There is no centralized location where email messages are kept.
- A downloaded message resides on the device that triggered the download.



- POP3 is an extremely simple mail access protocol.
- It is defined in [RFC 1939]
- Because the protocol is so simple, its functionality is rather limited.
- POP3 begins when the user agent (the client) opens a TCP connection to the mail server (the server) on port 110.
- With the TCP connection established, POP3 progresses through three phases: authorization, transaction, and update.
- During the first phase, **authorization**, the user agent sends a username and a password (in the clear) to authenticate the user.
- During the second phase**, transaction**, the user agent retrieves messages; also during this phase, the user agent can mark messages for deletion, remove deletion marks, and obtain mail statistics.
- The third phase, **update**, occurs after the client has issued the quit command, ending the POP3 session; at this time, the mail server deletes the messages that were marked for deletion.

Client server communication in POP3

- In a POP3 transaction, the user agent issues commands, and the server responds to each command with a reply.
- There are two possible responses:
  - +OK (sometimes followed by server-to-client data), used by the server to indicate that the previous command was fine;
  - and -ERR, used by the server to indicate that something was wrong with the previous command.

Authentication

- The authorization phase has two principal commands: user <username> and pass <password>.

  telnet mailServer 110
  +OK POP3 server ready
  user bob
  +OK
  pass hungry
  +OK user successfully logged on

- If you misspell a command, the POP3 server will reply with an -ERR message.

Transaction

- A user agent using POP3 can often be configured (by the user) to “download and delete” or to “download and keep.”
- The sequence of commands issued by a POP3 user agent depends on which of these two modes the user agent is operating in.
- In the download-and-delete mode, the user agent will issue the *list, retr, and dele* commands.

- suppose the user has two messages in his or her mailbox. In the dialogue below, C: (standing for client) is the user agent and S: (standing for server) is the mail server.
- The transaction will look something like:

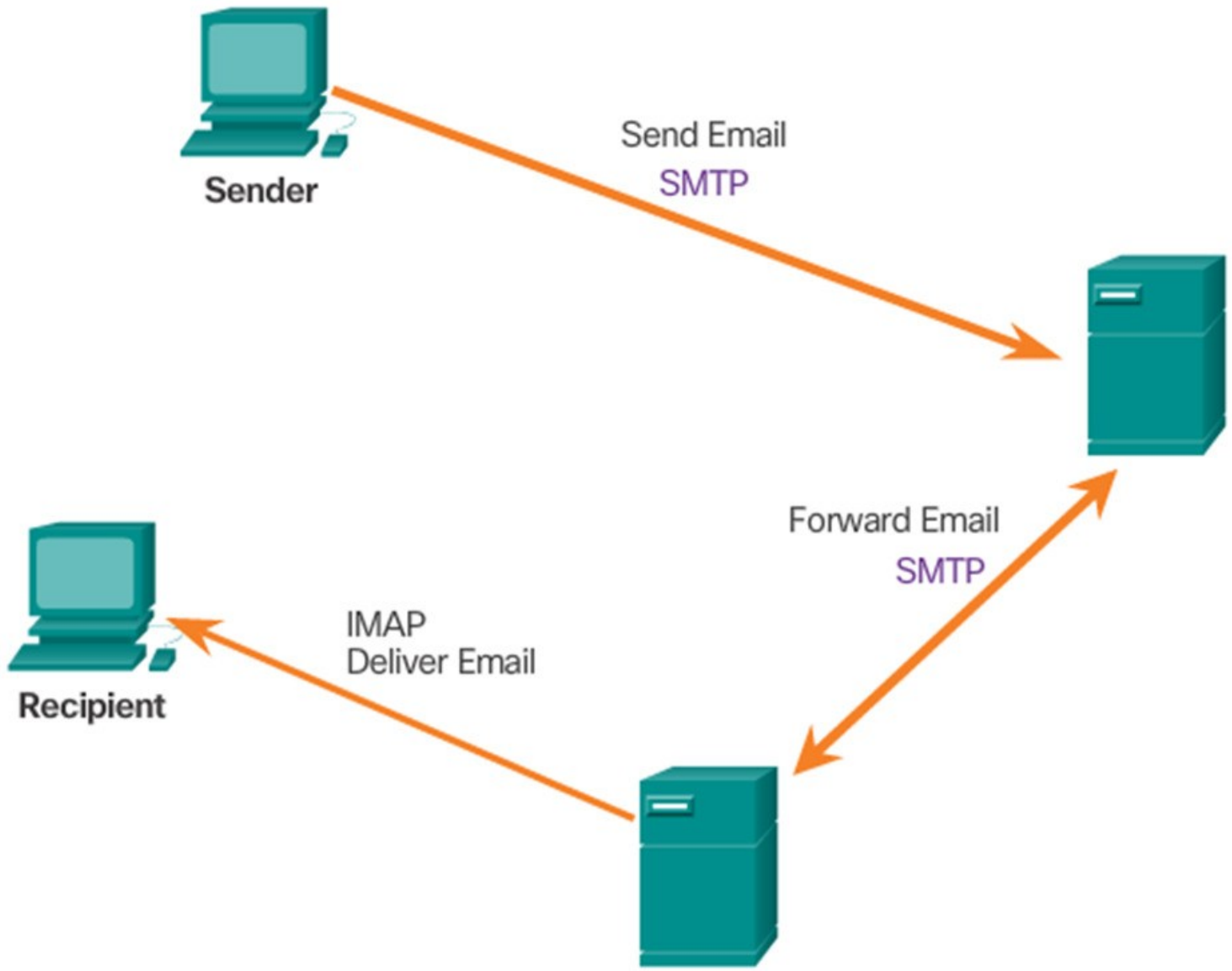
C: list
S: 1 498
S: 2 912
S: .
C: retr 1
S: (blah blah ...
S: .....
S: .....blah)
S: .
C: dele 1
C: retr 2
S: (blah blah ...
S: .....
S: .....blah)
S: .
C: dele 2
C: quit
S: +OK POP3 server signing off

IMAP

- Internet Message Access Ptotocol, defined in [RFC 3501]
- Defined to handle the need of multiple access to the mail server.
- An IMAP server will associate each message with a folder.
- When a message first arrives at the server, it is associated with the recipient's INBOX folder. The recipient can then move the message into a new, user-created folder, read the message, delete the message, and so on.
- The IMAP protocol provides commands to allow users to create folders and move messages from one folder to another. IMAP also provides commands that allow users to search remote folders for messages matching specific criteria.
- IMAP server maintains user state information across IMAP sessions. Another important feature of IMAP is that it has commands that permit a user agent to obtain components of messages.

IMAP Operation

- IMAP is another protocol used to retrieve email messages.
- Allows for messages to be displayed to the user rather than downloaded
- The original messages reside on the server until manually deleted by the user.
- Users view copies of the messages in their email client software.
- Users can create a folder hierarchy on the server to organize and store mail.
- That file structure is displayed on the email client.
- When a user decides to delete a message, the server synchronizes that action and deletes the message from the server.



Web-Based Email

- More and more users today are sending and accessing their e-mail through their Web browsers.
- With this service, the user agent is an ordinary Web browser, and the user communicates with its remote mailbox via HTTP.
- When a recipient, such as Bob, wants to access a message in his mailbox, the e-mail message is sent from Bob’s mail server to Bob’s browser using the HTTP protocol rather than the POP3 or IMAP protocol.
- When a sender, such as Alice, wants to send an e-mail message, the e-mail message is sent from her browser to her mail server over HTTP rather than over SMTP.
- Alice’s mail server, however, still sends messages to, and receives messages from, other mail servers using SMTP.