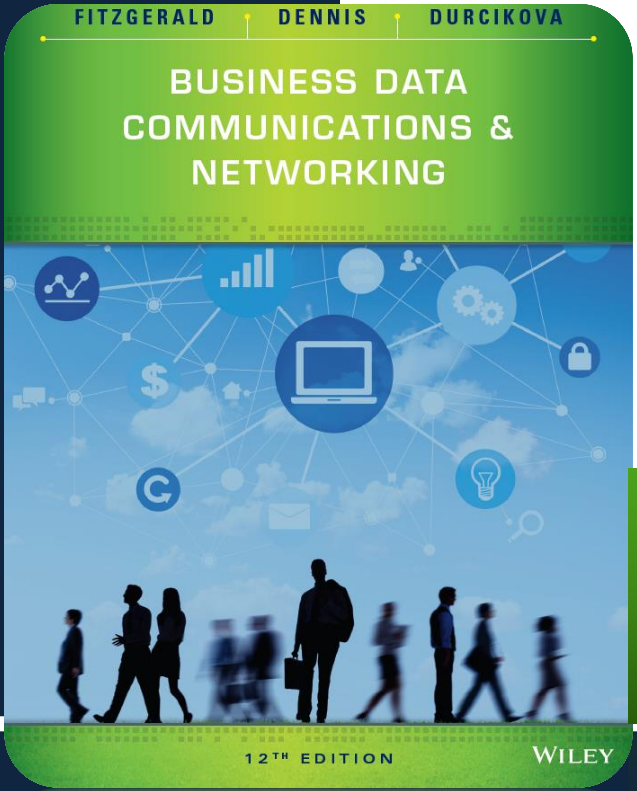
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Business Data Communications & Networking

Chapter 2
Application Layer

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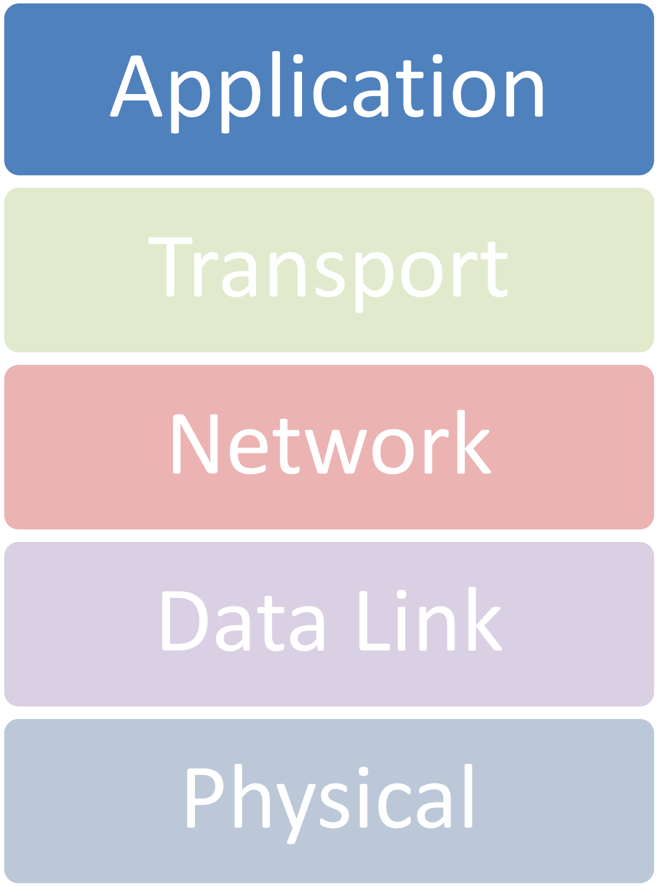
Outline

- Application Architectures
- The Web
- Email
- Other Application-Layer Protocols
- Implications for Management

Application Layer

- Layer 5 in the Internet model
- The software that enables users to interact with the network and accomplish tasks



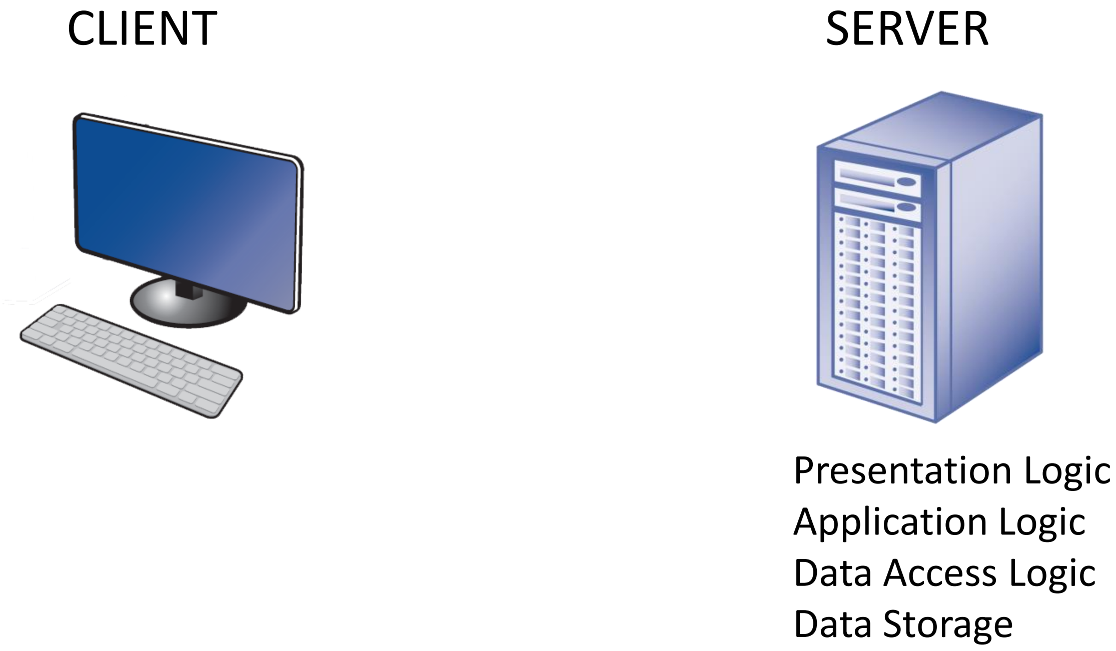
Internet Model

Application Architecture

- The way the functions of the application layer are spread out across the client and server
- Four components of applications:
  1. Presentation logic
  2. Application logic
  3. Data access logic
  4. Data Storage

Host-Based Architecture

- Server contains all components (“server-based”)
- Common in the 1960s with mainframes and terminals



CLIENT

SERVER

Presentation Logic
Application Logic
Data Access Logic
Data Storage

Host-Based Architecture

- Advantages
  - Very simple
  - Single point of control
- Disadvantages
  - Host (server) can become a bottleneck
  - Upgrades typically expensive

Client-Based Architecture

- Client contains presentation, application, and data access logic
- Most common in the 1980s

CLIENT

SERVER

Presentation Logic
Application Logic
Data Access Logic

Data Storage

Client-Based Architecture

- Advantages
  - Hardware and applications less expensive
  - Simple architecture
- Disadvantages
  - Data must travel back and forth between server and client

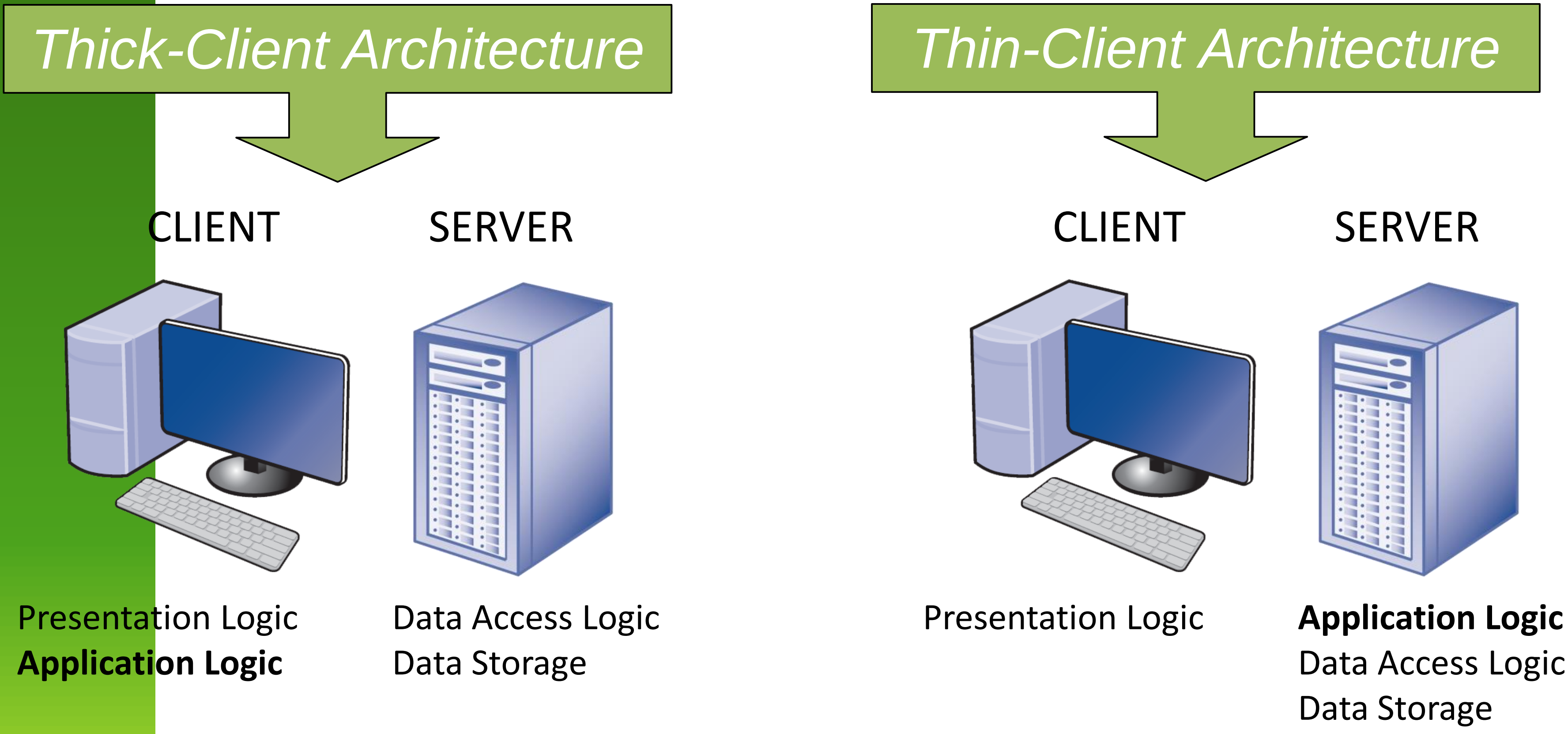
Client-Server Architecture

- Most common architecture today

OR

Client-Server Architecture

- Thin clients are easier to manage, thick clients have more functionality



Thick-Client Architecture

CLIENT

Presentation Logic
Application Logic

SERVER

Data Access Logic
Data Storage

Thin-Client Architecture

CLIENT

Presentation Logic

SERVER

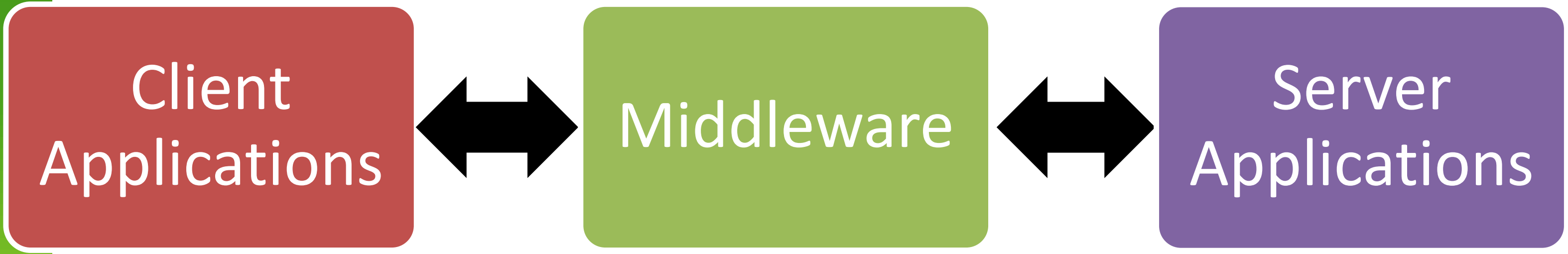
Application Logic
Data Access Logic
Data Storage

Client-Server Architecture

- Advantages
  - More efficient because of distributed processing
  - Allows hardware/software from different vendors to be used together
  - Less bandwidth required
- Disadvantages
  - May be challenges in configuring hardware/software from different vendors to work together
  - In many cases, **middleware** is required

Client-Server Architecture

- **Middleware** is software acts as an intermediary by “sitting between” client and server applications
- Provides a standard way of translating between software from different vendors
- Manages message transfers
- Insulates network changes from the clients (e.g., adding a new server)



Client-Server Architecture

- Example of **two-tier** **three-tier** architecture

CLIENT

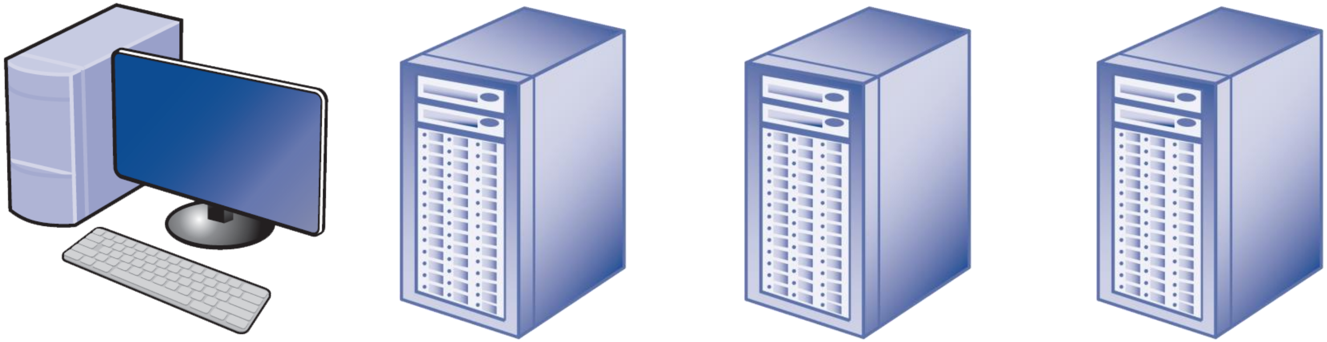
Application SERVER

Web SERVER

Application SERVER

Database SERVER

Database SERVER



Presentation Logic

Application Logic
Data Access Logic
Data Storage

Application Logic

Data Access Logic
Data Storage

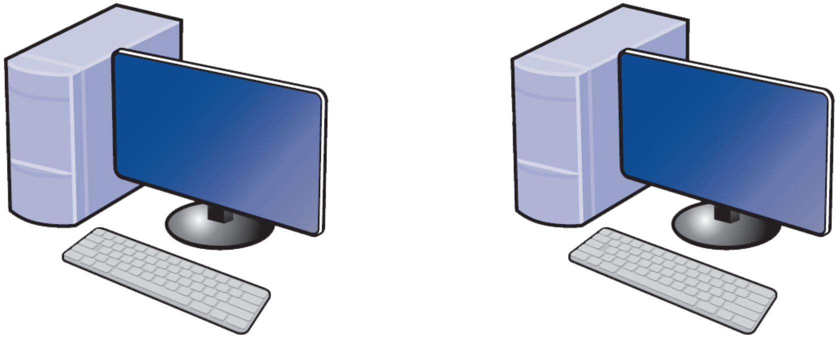
Data Access Logic
Data Storage

Tiered Client-Server Architecture

- Advantages
  - Load balancing
  - More scalable
- Disadvantages
  - Each tier increases network load
  - More complex and difficult to develop applications

Peer-to-Peer Architecture

- An older architecture that became popular again with Napster, BitTorrent, etc.
- All devices can act as client and server



CLIENT/SERVER

Presentation Logic
Application Logic
Data Access Logic
Data Storage

CLIENT/SERVER

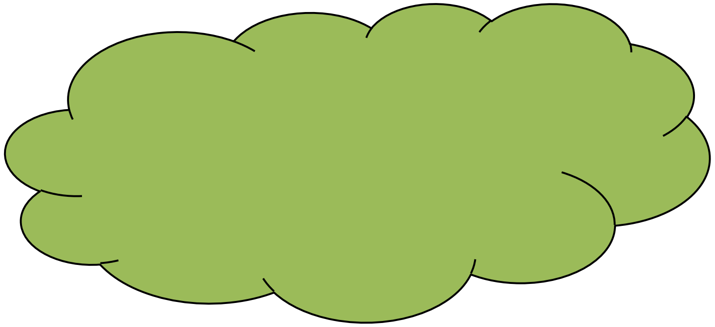
Presentation Logic
Application Logic
Data Access Logic
Data Storage

Peer-to-Peer Architecture

- Advantages
  - Resilient to failure
  - Data can be stored anywhere on network
  - Distributes bandwidth requirements
- Disadvantages
  - Finding the stored data
  - Security

Cloud Computing

- **Cloud Computing** is the general term for enabling access to computing services over the network (most commonly the Internet)
- Models of cloud computing define who manages each application function and associated hardware/software



Cloud Computing

- Cloud Computing Models
  - **Software as a Service (SaaS)**
    - All application components and associated hardware/software outsourced
    - Based on multitenancy
    - e.g. Salesforce.com
  - **Platform as a Service (PaaS)**
    - Application logic and data are managed internally
    - e.g., Microsoft Azure
  - **Infrastructure as a Service (IaaS)**
    - All hardware is outsourced

Cloud Computing

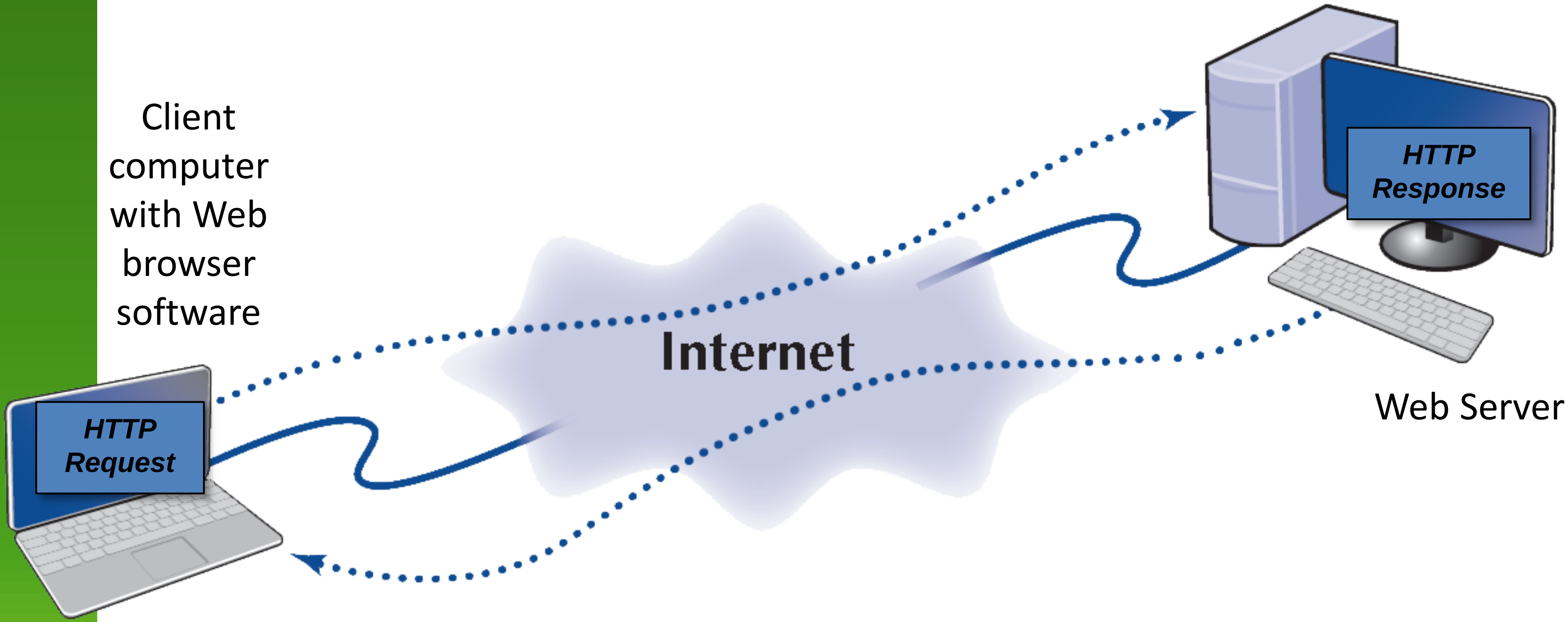
	Traditional Thin-Client Client-Server		Infrastructure as a Service (IaaS)		Platform as a Service (Paas)		Software as a Service (SaaS)	
	Internal	Outsourced	Internal	Outsourced	Internal	Outsourced	Internal	Outsourced
Application Logic	X		X		X			X
Data Storage	X		X		X			X
Data Access Logic	X		X			X		X
Operating System	X		X			X		X
Virtualization Software	X		X			X		X
Server Hardware	X			X		X		X
Storage Hardware	X			X		X		X
Network Hardware	X			X		X		X

Criteria for Choosing Architecture

- Infrastructure
  - Cost of servers, clients, and circuits
  - Reliability
- Development Costs
  - Software; cheaper on host-based architectures
- Scalability
  - Ability to increase (or decrease) in computing capacity as network demand changes
  - Easier in client-server architectures

The Web

- Hypertext Transfer Protocol (HTTP)
- HTTP Request and Response

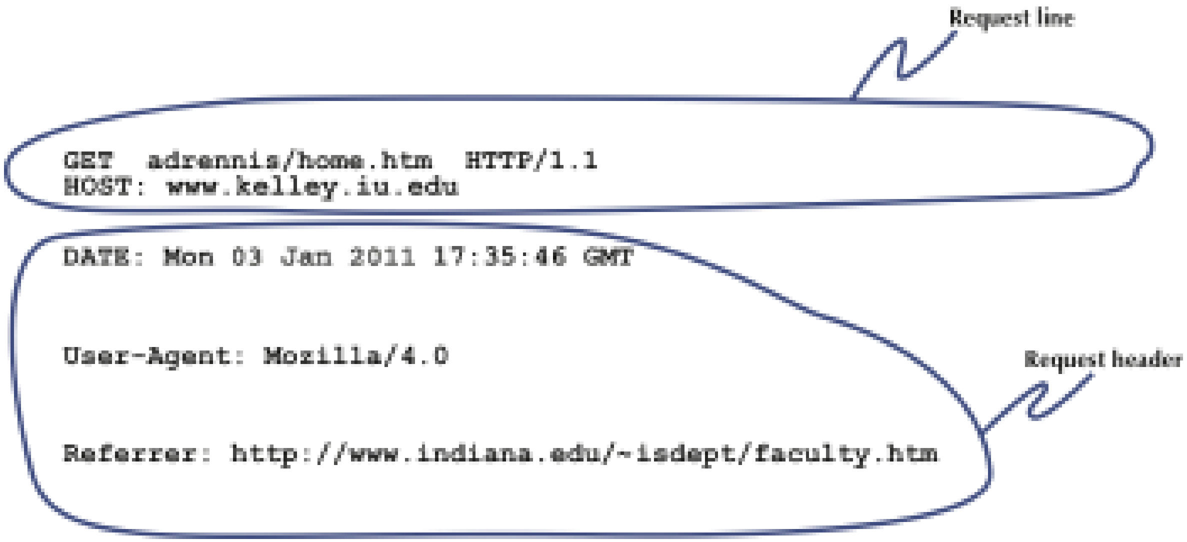


The Web

- HTTP Request

FIGURE 2-11

An example of a request from a Web browser to a Web server using the HTTP (Hypertext Transfer Protocol) standard



Request line
Request header

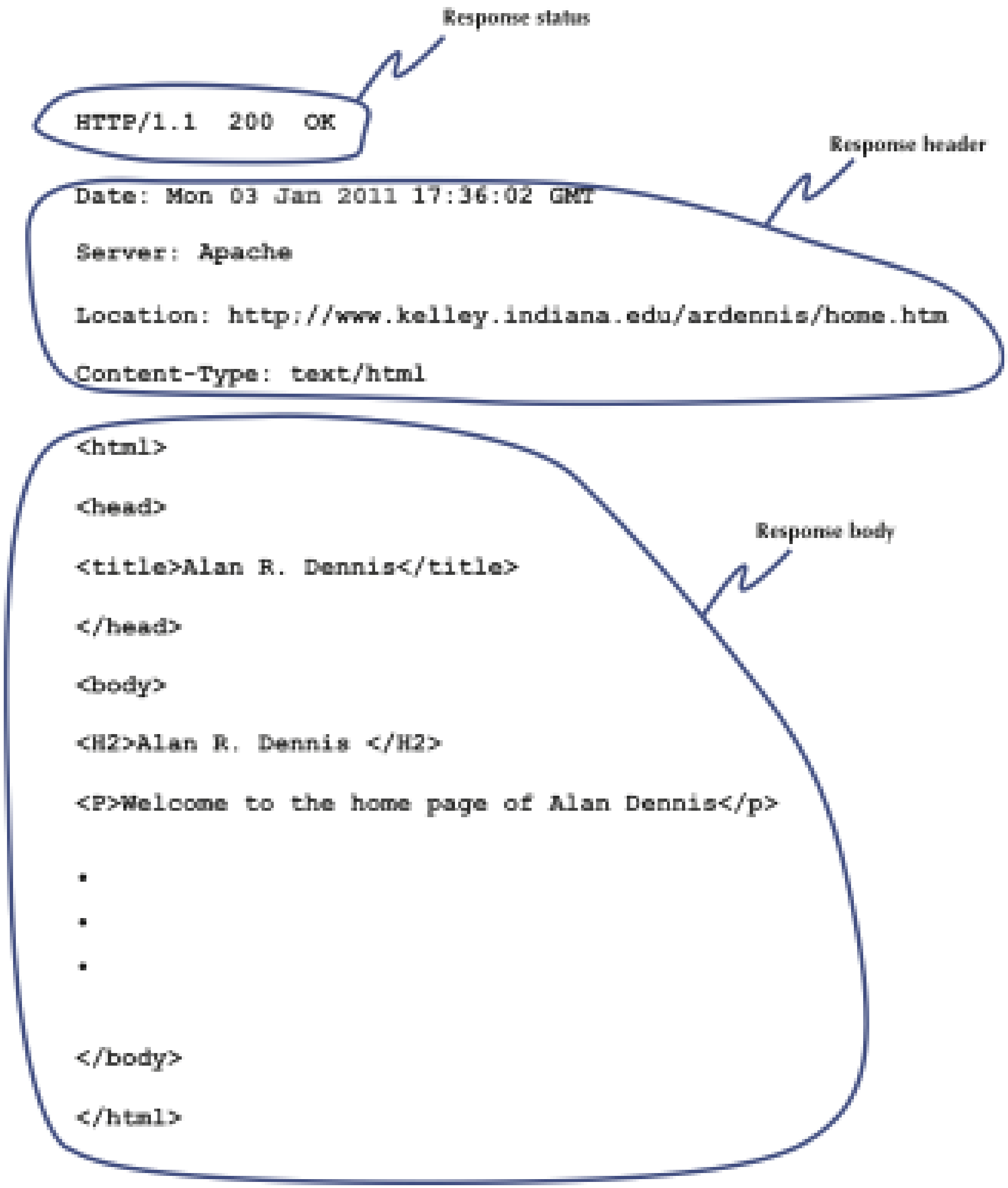
```
GET  adrennis/home.htm  HTTP/1.1
HOST: www.kelley.iu.edu
DATE: Mon 03 Jan 2011 17:35:46 GMT

User-Agent: Mozilla/4.0

Referrer: http://www.indiana.edu/~isdept/faculty.htm
```

The Web

- HTTP Response

FIGURE 2-12

An example of a response from a Web server to a Web browser using the HTTP standard



Response status
Response header
Response body

```
HTTP/1.1  200  OK

Date: Mon 03 Jan 2011 17:36:02 GMT
Server: Apache
Location: http://www.kelley.indiana.edu/ardennis/home.htm
Content-Type: text/html

<html>
<head>
<title>Alan R. Dennis</title>
</head>
<body>
<H2>Alan R. Dennis </H2>
<P>Welcome to the home page of Alan Dennis</p>
.
.
.

</body>
</html>
```

Email

- **Mail Transfer Agent (MTA)**
  - Formal name for mail server software
  - e.g., Sendmail, Postfix,
- **Mail User Agent (MUA)**
  - Formal name for mail client software
  - e.g., Outlook, Apple Mail, Thunderbird
- **Simple Mail Transfer Protocol (SMTP)**
  - Protocol used to send a message to a MTA
  - Originally only handled text files
- **Internet Message Access Protocol (IMAP)** or **Post Office Protocol (POP)**
  - Protocols used by a MUA to retrieve messages from an MTA
- **American Standard Code for Information Interchange (ASCII)**
  - A standard for encoding text characters (a-z, A-Z, 0-9, a few symbols)

Email

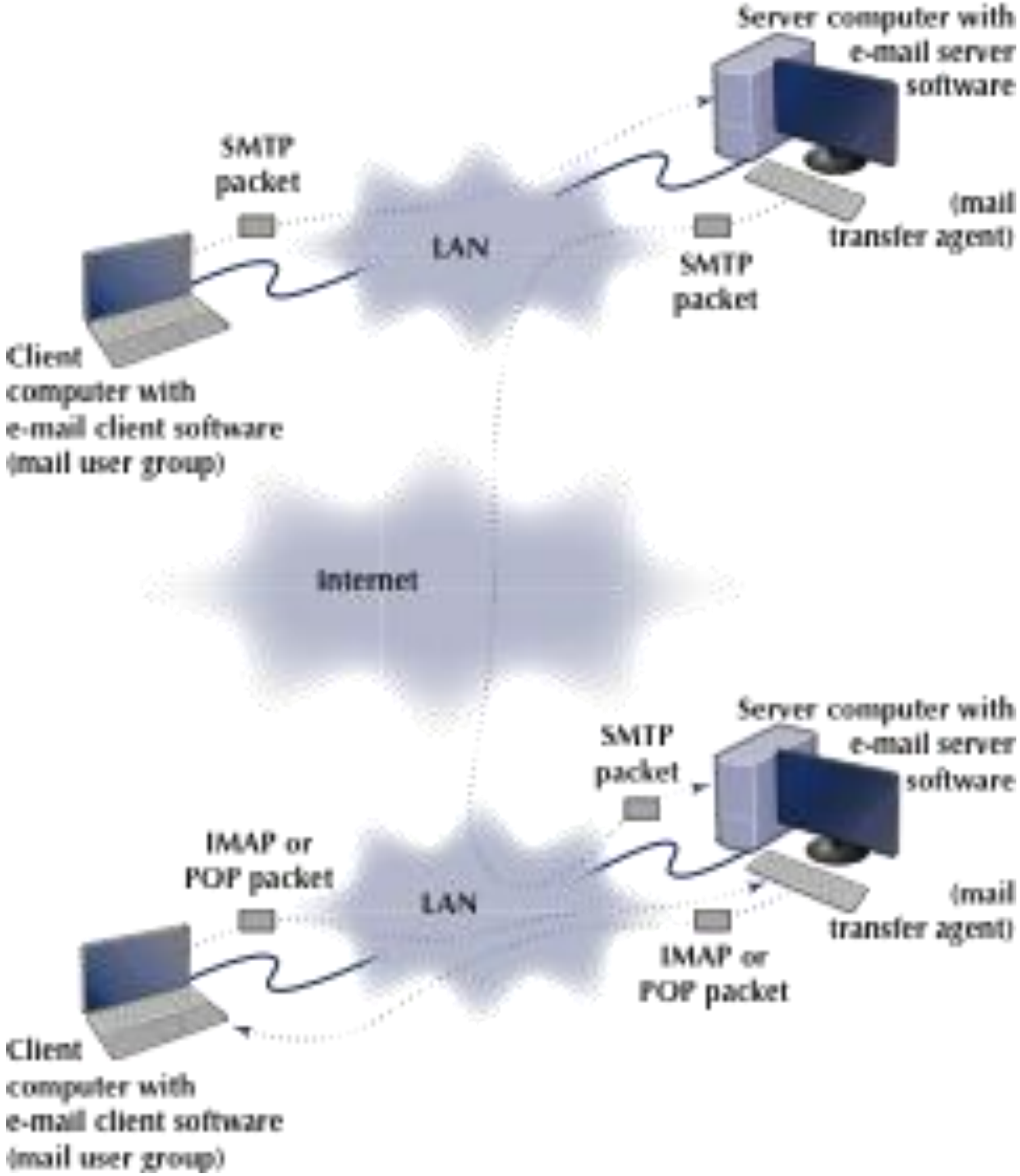
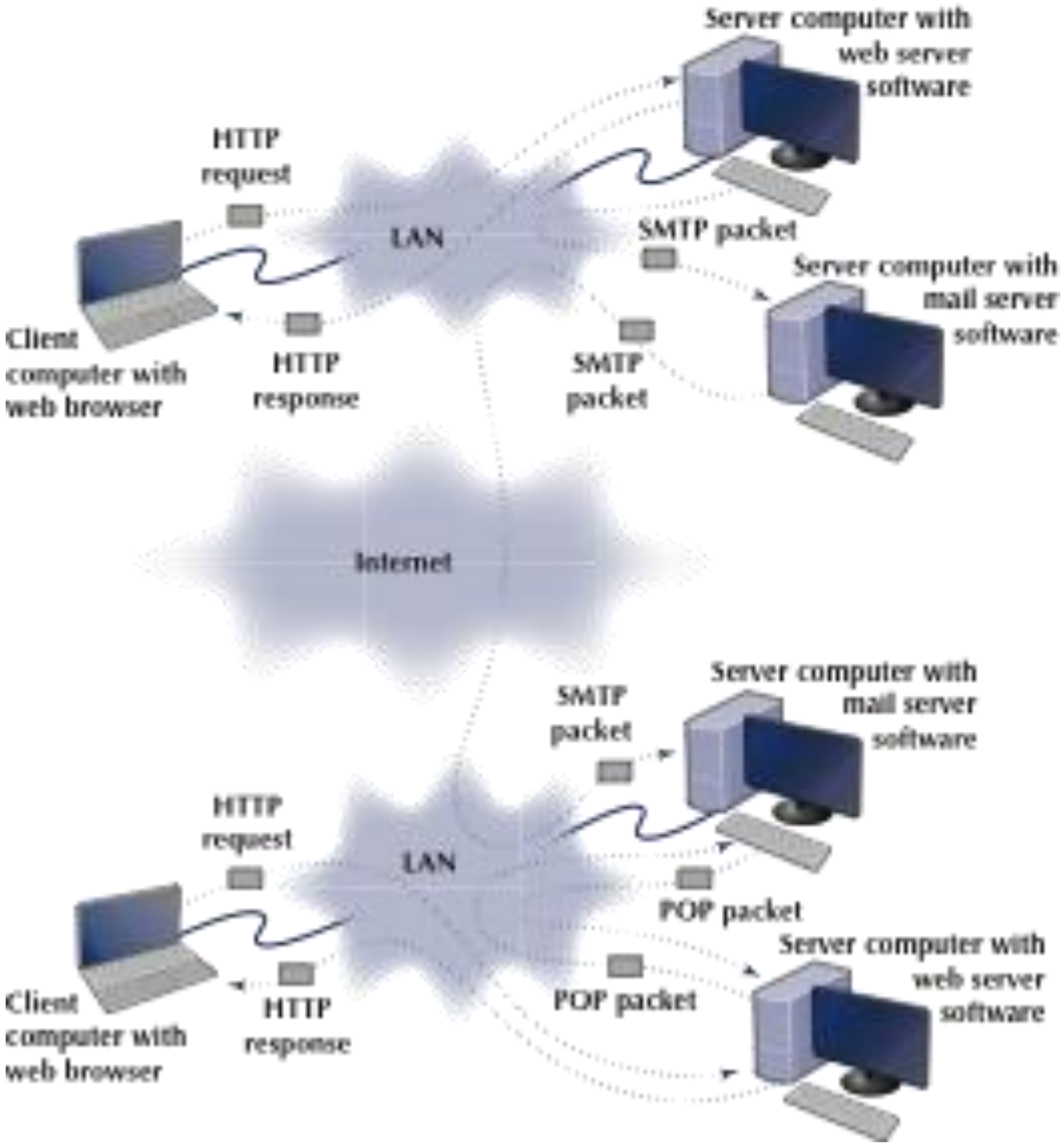

Server computer with e-mail server software
SMTP packet
LAN
(mail transfer agent)
SMTP packet
Client computer with e-mail client software (mail user group)
Internet
Server computer with e-mail server software
SMTP packet
IMAP or POP packet
LAN
(mail transfer agent)
IMAP or POP packet
Client computer with e-mail client software (mail user group)

FIGURE 2-13
How SMTP (Simple Mail Transfer Protocol) email works. IMAP = Internet Message Access Protocol; LAN = local area network

Email

- How a message is sent (2-tier, thick client)
- Sending Client → Sender’s Mail Server (SMTP)
- Sender’s Mail Server → Receiver’s Mail Server (SMTP)
- Message waits on Receiver’s Mail Server in “mailbox”
- Receiving Client → Receiver’s Mail Server (IMAP or POP)
- Receiver’s Mail Server → Receiving Client (IMAP or POP)

Email



Server computer with web server software
HTTP request
LAN
SMTP packet
Server computer with mail server software
Client computer with web browser
HTTP response
SMTP packet
Internet
SMTP packet
Server computer with mail server software
HTTP request
LAN
POP packet
Server computer with web server software
POP packet
Client computer with web browser
HTTP response

FIGURE 2-14

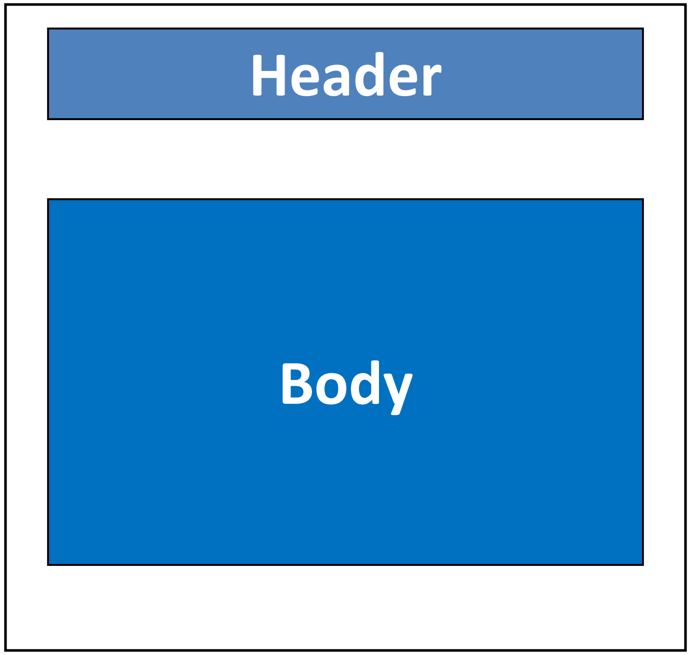
Inside the Web. HTTP = Hypertext Transfer Protocol; IMAP = Internet Message Access Protocol; LAN = local area network; SMTP = Simple Mail Transfer Protocol

Email

- How a message is sent via webmail (3-tier, thin client)
  1. Sending Client → Sender's Web Server (**HTTP**)
  2. Sender's Web Server → Sender's Mail Server (**SMTP**)
  3. Sender's Mail Server → Receiver's Mail Server (**SMTP**)
  4. Mail waits on Receiver's Mail Server in "mailbox"
  5. Receiving Client → Receiver's Web Server (**HTTP**)
  6. Receiver's Web Server → Receiver's Mail Server (**IMAP or POP**)
  7. Receiver's Mail Server → Receiver's Web Server (**IMAP or POP**)
  8. Receiver's Web Server → Receiving Client (**HTTP**)

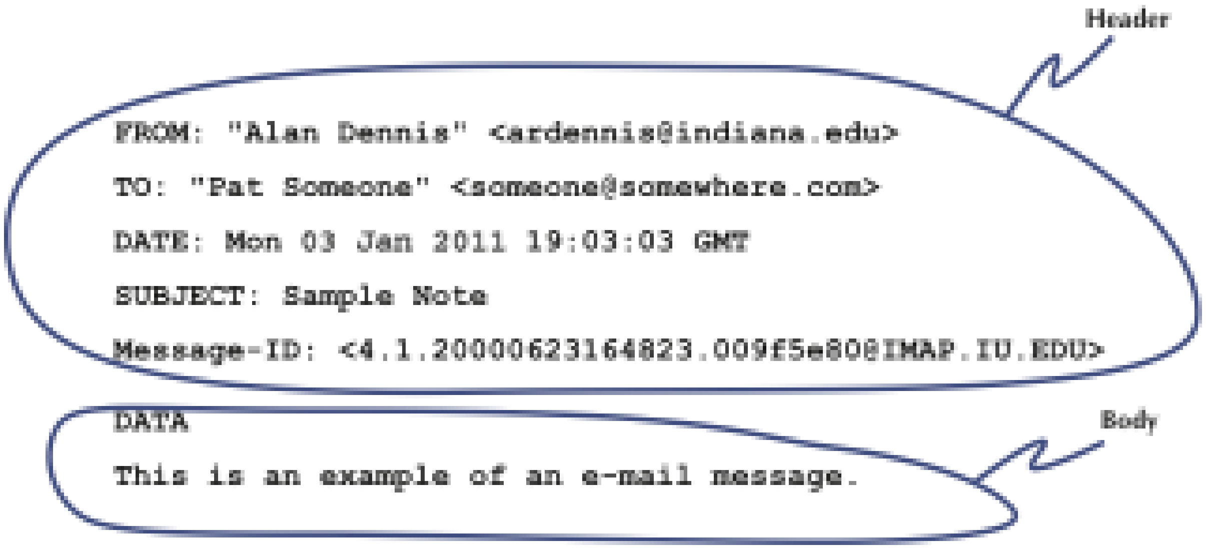
Email

- SMTP Message Format
  - RFC 822: Standard for text message format
- Header lines
  - Contain information about the message such as To, From, and Subject
- Body section
  - Contains the “content of the message
  - Begins with the “DATA” keyword
  - Only uses ASCII characters



Email

- Inside an SMTP packet
  - **Header:** source, destination, date, subject, etc.
  - **Body:** keyword “DATA”, then email message



```
FROM: "Alan Dennis" <ardennis@indiana.edu>
TO: "Pat Someone" <someone@somewhere.com>
DATE: Mon 03 Jan 2011 19:03:03 GMT
SUBJECT: Sample Note
Message-ID: <4.1.20000623164823.009f5e80@IMAP.IU.EDU>
DATA
This is an example of an e-mail message.
```

Header
Body

FIGURE 2-15
An example of an email message using the SMTP (Simple Mail Transfer Protocol) standard

Email

- SMTP is a simple protocol to send plain text
- Not designed to send images or attachments
- **Multipurpose Internet Mail Extension (MIME)**
  - A standard to extend support for attachments and non-ASCII characters in email
  - Used by sender to convert (encode) any non-ASCII content into ASCII
  - Receivers then convert (decode) the ASCII back to its original format

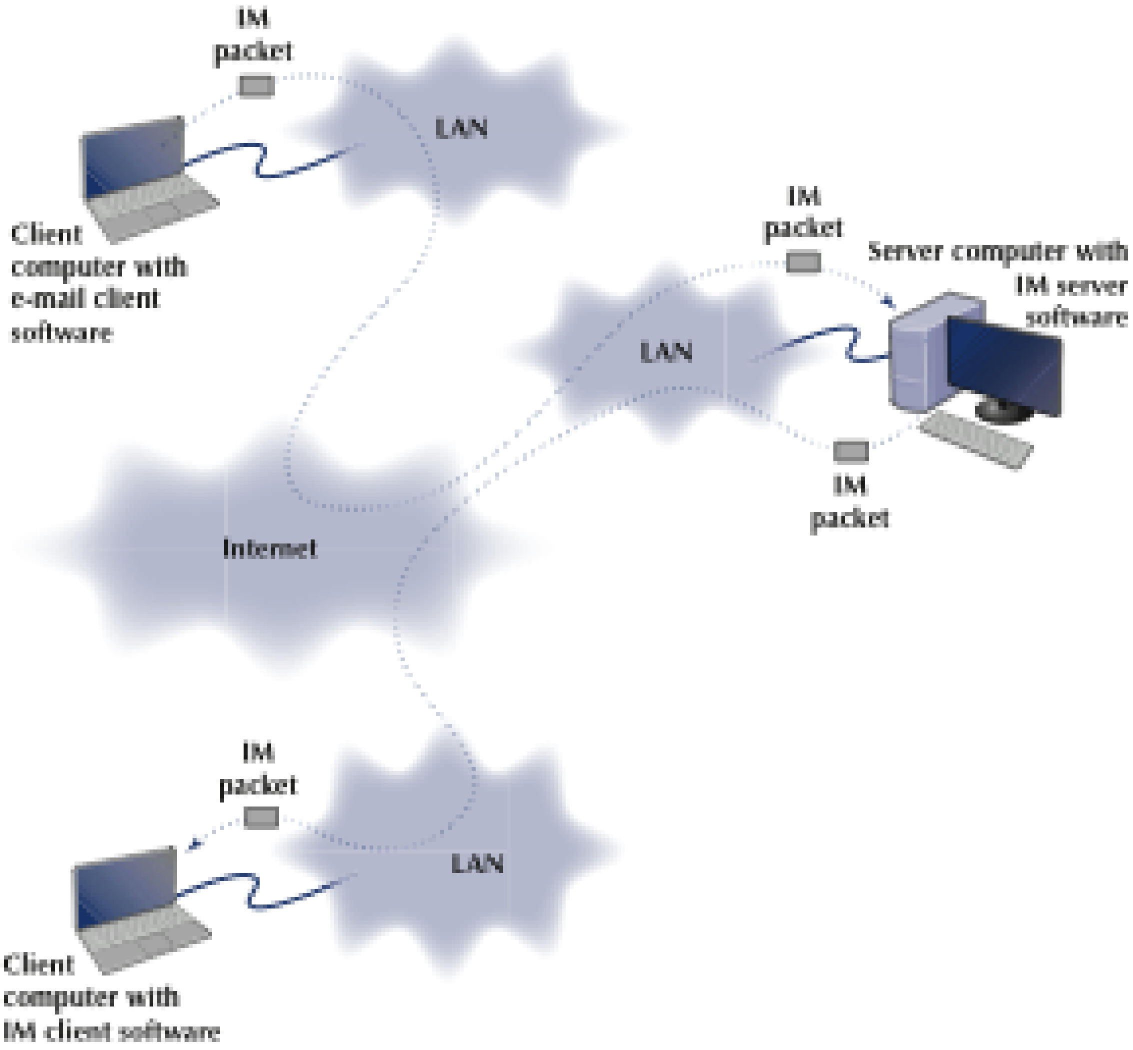
Other Application-Layer Protocols

- **File Transfer Protocol (FTP) -** for moving files between clients and servers
- **Telnet, Secure Shell (SSH) -** for executing commands on a remote system
- **Internet Relay Chat (IRC), Extensible Messaging and Presence Protocol (XMPP) -** for real-time text chat (instant messaging)
- **Domain Name System (DNS) -** for mapping domain names to IP addresses

Instant Messaging

FIGURE 2-16

How instant messaging (IM) works. LAN = local area network

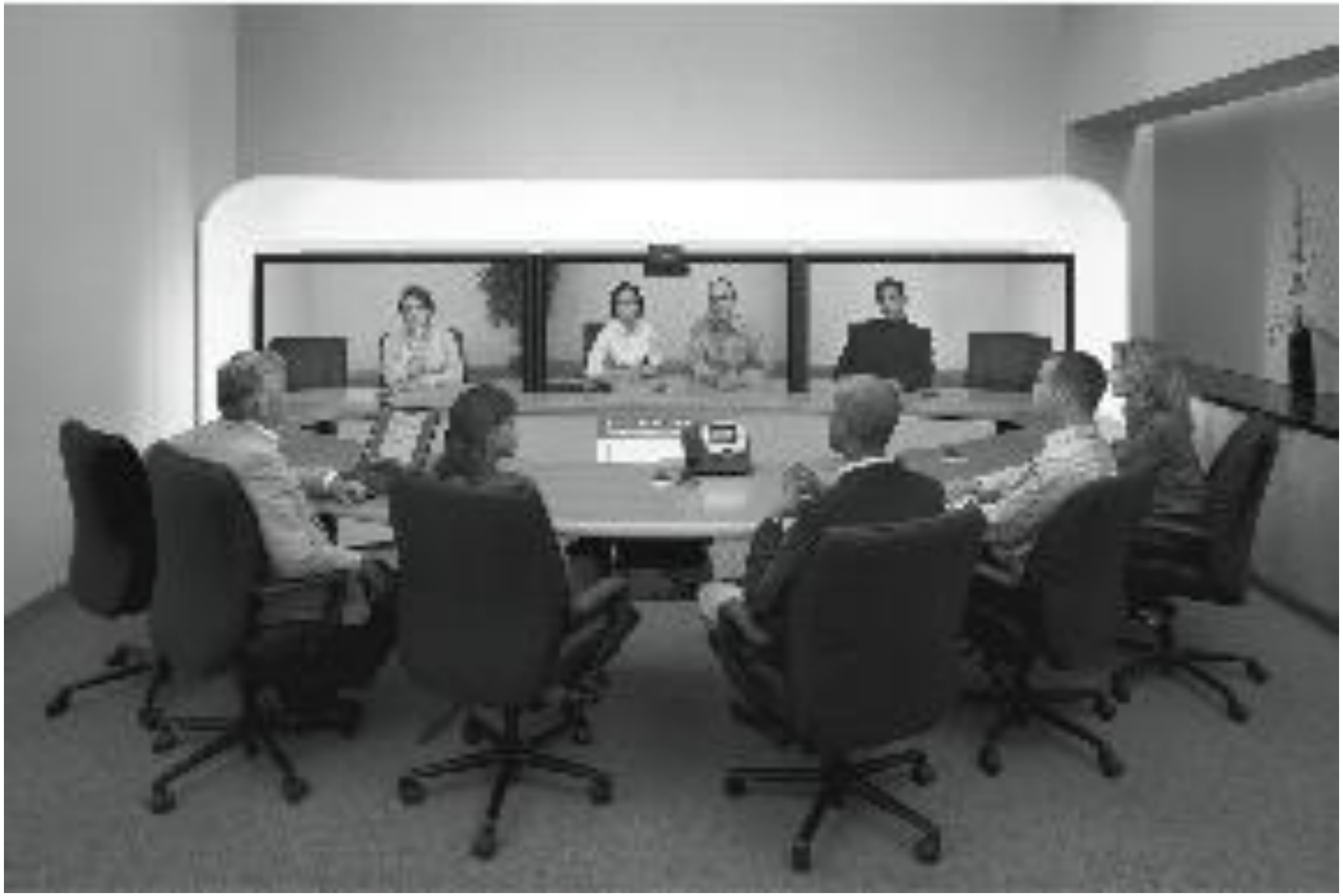

IM packet
LAN
Client computer with e-mail client software
IM packet
Server computer with IM server software
LAN
IM packet
Internet
IM packet
LAN
Client computer with IM client software

Video Conferencing

FIGURE 2-17

A Cisco telepresence system

Source: Courtesy Cisco Systems, Inc. Unauthorized use not permitted



Implications for Management

- Primary purpose of networks is to provide environment for applications
- The number and types of applications on the network is dramatically increasing