Chapter 9: Application Design and Development

Database System Concepts, 6th Ed.

Chapter 9: Application Design and Development

- User Interfaces and Tools
- Web Interfaces to Databases
- Web Fundamentals
- Servlets and JSP
- Building Large Web Applications
- Application Security

User Interfaces and Tools

- Most database users do *not* use a query language like SQL.
  - Forms
  - Graphical user interfaces
- Many interfaces are Web-based
- Back-end (Web server) uses such technologies as
  - Java servlets
  - Java Server Pages (JSP)
  - Active Server Pages (ASP)

The World Wide Web

- The Web is a distributed information system based on hypertext.
- Most Web documents are hypertext documents formatted via the HyperText Markup Language (HTML)
- HTML documents contain
  - text along with font specifications, and other formatting instructions
  - hypertext links to other documents, which can be associated with regions of the text.
  - forms, enabling users to enter data which can then be sent back to the Web server

A formatted report

Acme Supply Company, Inc.
Quarterly Sales Report

Period: Jan. 1 to March 31, 2009

Region	Category	Sales	Subtotal
North	Computer Hardware	1,000,000	
	Computer Software	500,000	
	All categories		1,500,000
South	Computer Hardware	200,000	
	Computer Software	400,000	
	All categories		600,000
		Total Sales	2,100,000

Web Interfaces to Databases

Why interface databases to the Web?

1. Web browsers have become the de-facto standard user interface to databases
   - Enable large numbers of users to access databases from anywhere
   - Avoid the need for downloading/installing specialized code, while providing a good graphical user interface
   - Examples: banks, airline and rental car reservations, university course registration and grading, an so on.

Web Interfaces to Database (Cont.)

2. Dynamic generation of documents
   - Limitations of static HTML documents
     - Cannot customize fixed Web documents for individual users.
     - Problematic to update Web documents, especially if multiple Web documents replicate data.
   - Solution: Generate Web documents dynamically from data stored in a database.
     - Can tailor the display based on user information stored in the database.
       - E.g. tailored ads, tailored weather and local news, …
     - Displayed information is up-to-date, unlike the static Web pages
       - E.g. stock market information, ..

Uniform Resources Locators

- In the Web, functionality of pointers is provided by Uniform Resource Locators (URLs).
- URL example:

  http://www.bell-labs.com/topics/book/db-book

  - The first part indicates how the document is to be accessed
    - "http" indicates that the document is to be accessed using the Hyper Text Transfer Protocol.
  - The second part gives the unique name of a machine on the Internet.
  - The rest of the URL identifies the document within the machine.
- The local identification can be:
  - The path name of a file on the machine, or
  - An identifier (path name) of a program, plus arguments to be passed to the program
    - E.g. http://www.google.com/search?q=silberschatz

HTML and HTTP

- HTML provides formatting, hypertext link, and image display features.
- HTML also provides input features
  - Select from a set of options
    - Pop-up menus, radio buttons, check lists
  - Enter values
    - Text boxes
  - Filled in input sent back to the server, to be acted upon by an executable at the server
- HyperText Transfer Protocol (HTTP) used for communication with the Web server

Sample HTML Source Text

```
<html>
<body>
  <table border>
     <tr> <th>ID</th> <th>Name</th> <th>Department</th> </tr>
     <tr> <td>00128</td> <td>Zhang</td> <td>Comp. Sci.</td> </tr>
     ....
  </table>
   <form action="PersonQuery" method=get>
     Search for:
       <select name="persontype">
          <option value="student" selected>Student </option>
          <option value="instructor"> Instructor </option>
       </select> <br>
     Name: <input type=text size=20 name="name">
     <input type=submit value="submit">
  </form>
</body> </html>
```

Display of Sample HTML Source

ID	Name	Department
00128	Zhang	Comp. Sci.
12345	Shankar	Comp. Sci.
19991	Brandt	History

Search for: Student

Name:

submit

Client Side Scripting and Applets

- Browsers can fetch certain scripts (client-side scripts) or programs along with documents, and execute them in "safe mode" at the client site
  - Javascript
  - Macromedia Flash and Shockwave for animation/games
  - VRML
  - Applets
- Client-side scripts/programs allow documents to be active
  - E.g., animation by executing programs at the local site
  - E.g. ensure that values entered by users satisfy some correctness checks
  - Permit flexible interaction with the user.
    - Executing programs at the client site speeds up interaction by avoiding many round trips to server

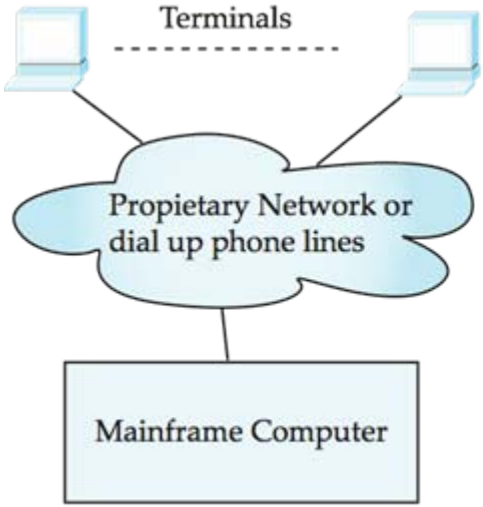
Client Side Scripting and Security

- Security mechanisms needed to ensure that malicious scripts do not cause damage to the client machine
  - Easy for limited capability scripting languages, harder for general purpose programming languages like Java
- E.g. Java's security system ensures that the Java applet code does not make any system calls directly
  - Disallows dangerous actions such as file writes
  - Notifies the user about potentially dangerous actions, and allows the option to abort the program or to continue execution.

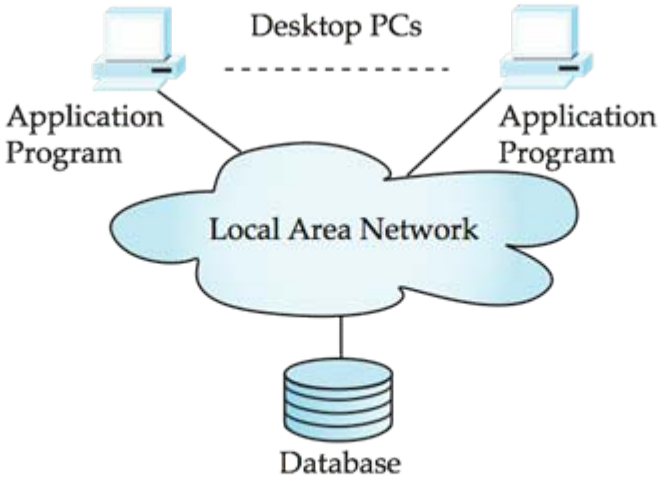
Web Servers

- A Web server can easily serve as a front end to a variety of information services.
- The document name in a URL may identify an executable program, that, when run, generates a HTML document.
  - When a HTTP server receives a request for such a document, it executes the program, and sends back the HTML document that is generated.
  - The Web client can pass extra arguments with the name of the document.
- To install a new service on the Web, one simply needs to create and install an executable that provides that service.
  - The Web browser provides a graphical user interface to the information service.
- Common Gateway Interface (CGI): a standard interface between web and application server

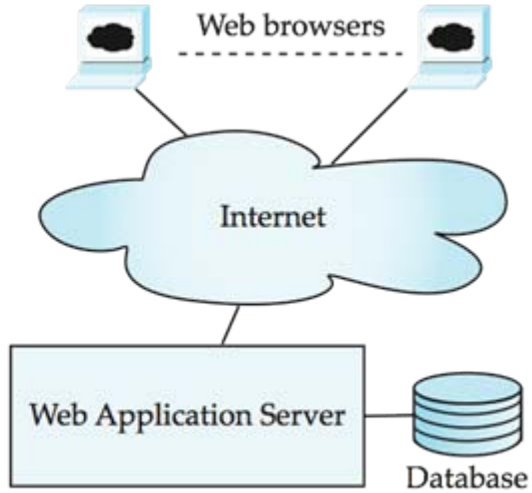
Three-Tier Web Architecture



(a) Mainframe Era



(b) Personal Computer Era

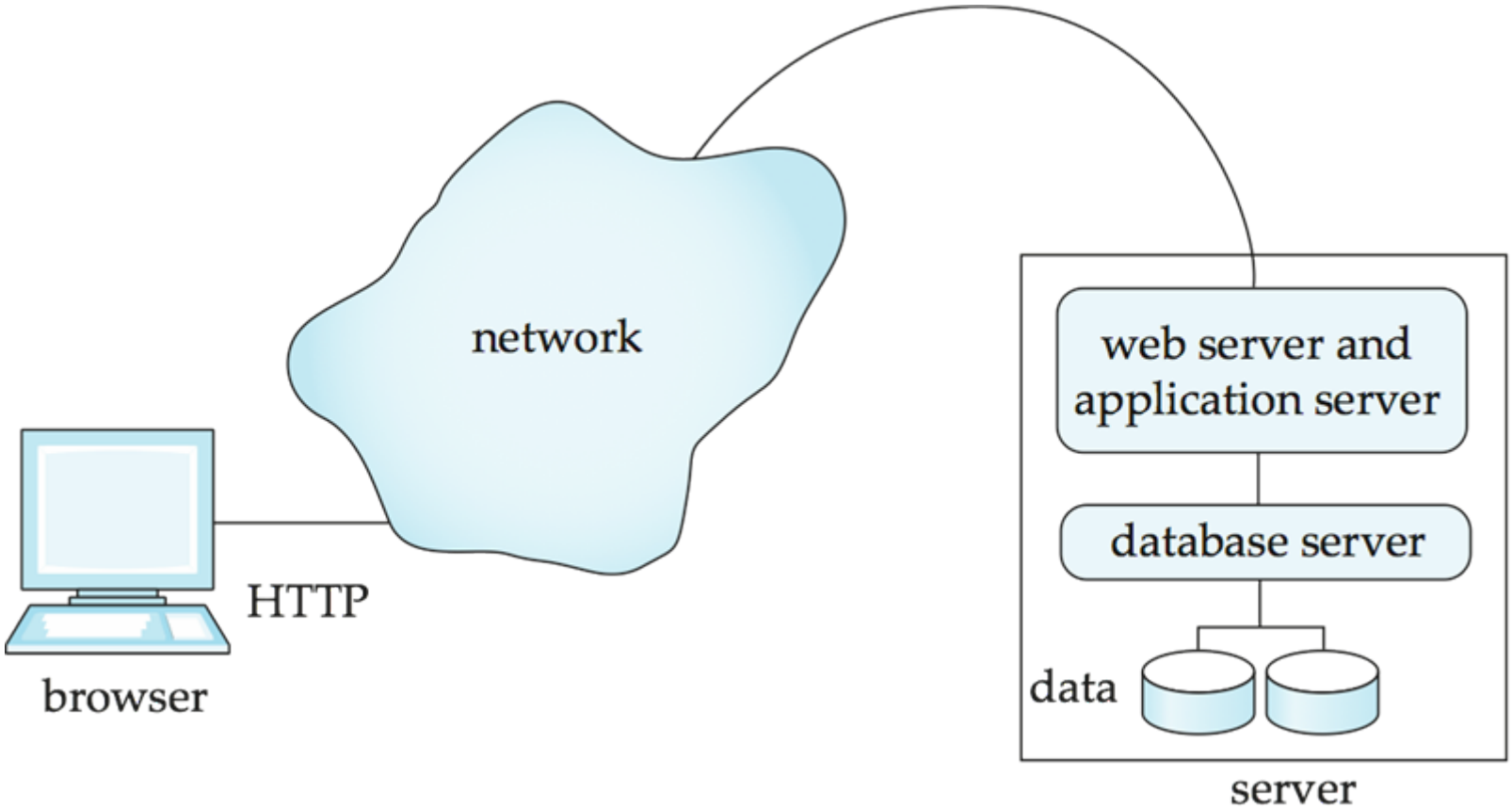


(c) Web era

Two-Tier Web Architecture

- Multiple levels of indirection have overheads

  Alternative: two-tier architecture



HTTP and Sessions

- The HTTP protocol is connectionless
  - That is, once the server replies to a request, the server closes the connection with the client, and forgets all about the request
  - In contrast, Unix logins, and JDBC/ODBC connections stay connected until the client disconnects
    - retaining user authentication and other information
  - Motivation: reduces load on server
    - operating systems have tight limits on number of open connections on a machine
- Information services need session information
  - E.g. user authentication should be done only once per session
- Solution: use a cookie

Sessions and Cookies

- A cookie is a small piece of text containing identifying information
  - Sent by server to browser on first interaction
  - Sent by browser to the server that created the cookie on further interactions
    - part of the HTTP protocol
  - Server saves information about cookies it issued, and can use it when serving a request
    - E.g., authentication information, and user preferences
- Cookies can be stored permanently or for a limited time

Servlets

- Java Servlet specification defines an API for communication between the Web server and application program
  - E.g. methods to get parameter values and to send HTML text back to client
- Application program (also called a servlet) is loaded into the Web server
  - Two-tier model
  - Each request spawns a new thread in the Web server
    - thread is closed once the request is serviced
- Servlet API provides a getSession() method
  - Sets a cookie on first interaction with browser, and uses it to identify session on further interactions
  - Provides methods to store and look-up per-session information
    - E.g. user name, preferences, ..

Example Servlet Code

```
import java.io.*;
import javax.servlet.*;
import javax.servlet.http.*;
public class PersonQueryServlet extends HttpServlet {
   public void doGet(HttpServletRequest request, HttpServletResponse response)
                        throws ServletException, IOException
   {
      response.setContentType("text/html");
      PrintWriter out = response.getWriter();
      out.println("<HEAD><TITLE> Query Result</TITLE></HEAD>");
      out.println("<BODY>");
         ….. BODY OF SERVLET (next slide) …
      out.println("</BODY>");
      out.close();
   }
}
```

Example Servlet Code

```
String persontype = request.getParameter("persontype");
String number = request.getParameter("name");
if(persontype.equals("student")) {
    ... code to find students with the specified name ...
    ... using JDBC to communicate with the database ..
    out.println("<table BORDER COLS=3>");
    out.println(" <tr> <td>ID</td> <td>Name: </td>" + " <td>Department</td> </tr>");
    for(... each result ...){
        ... retrieve ID, name and dept name
        ... into variables ID, name and deptname
        out.println("<tr> <td>" + ID + "</td>" + "<td>" + name + "</td>" + "<td>" + deptname
                + "</td></tr>");
    };
    out.println("</table>");
}
else {
    ... as above, but for instructors ...
}
```

Servlet Sessions

- To check if session is already active:
  - if (request.getSession(false) == true)
    - .. then existing session
    - else .. redirect to authentication page
  - authentication page
    - check login/password
    - request.getSession(true): creates new session
- Store/retrieve attribute value pairs for a particular session
  - session.setAttribute(“userid”, userid)
  - session.getAttribute(“userid”)

Jave Server Pages (JSP)

- A JSP page with embedded Java code

```
<html>
<head> <title> Hello </title> </head>
<body>
< % if (request.getParameter(“name”) == null)
{ out.println(“Hello World”); }
else { out.println(“Hello, ” + request.getParameter(“name”)); }
%>
</body>
</html>
```

Server-Side Scripting

- Server-side scripting simplifies the task of connecting a database to the Web
  - Define a HTML document with embedded executable code/SQL queries.
  - Input values from HTML forms can be used directly in the embedded code/SQL queries.
  - When the document is requested, the Web server executes the embedded code/SQL queries to generate the actual HTML document.
- Numerous server-side scripting languages
  - JSP, Server-side Javascript, ColdFusion Markup Language (cfml), PHP, Jscript
  - General purpose scripting languages: VBScript, Perl, Python

Improving Web Server Performance

- Performance is an issue for popular Web sites
  - May be accessed by millions of users every day, thousands of requests per second at peak time
- Caching techniques used to reduce cost of serving pages by exploiting commonalities between requests
  - At the server site:
    - Caching of JDBC connections between servlet requests
    - Caching results of database queries
      - Cached results must be updated if underlying database changes
    - Caching of generated HTML
  - At the client's network
    - Caching of pages by Web proxy

Application Security

- Data may be *encrypted* when database authorization provisions do not offer sufficient protection.
- Properties of good encryption technique:
  - Relatively simple for authorized users to encrypt and decrypt data.
  - Encryption scheme depends not on the secrecy of the algorithm but on the secrecy of a parameter of the algorithm called the encryption key.
  - Extremely difficult for an intruder to determine the encryption key.

Encryption (Cont.)

- *Data Encryption Standard* (DES) substitutes characters and rearranges their order on the basis of an encryption key which is provided to authorized users via a secure mechanism. Scheme is no more secure than the key transmission mechanism since the key has to be shared.
- Advanced Encryption Standard (AES) is a new standard replacing DES, and is based on the Rijndael algorithm, but is also dependent on shared secret keys
- *Public-key encryption* is based on each user having two keys:
  - *public key* – publicly published key used to encrypt data, but cannot be used to decrypt data
  - *private key* -- key known only to individual user, and used to decrypt data.
    Need not be transmitted to the site doing encryption.

  Encryption scheme is such that it is impossible or extremely hard to decrypt data given only the public key.
- The RSA public-key encryption scheme is based on the hardness of factoring a very large number (100's of digits) into its prime components.

Authentication

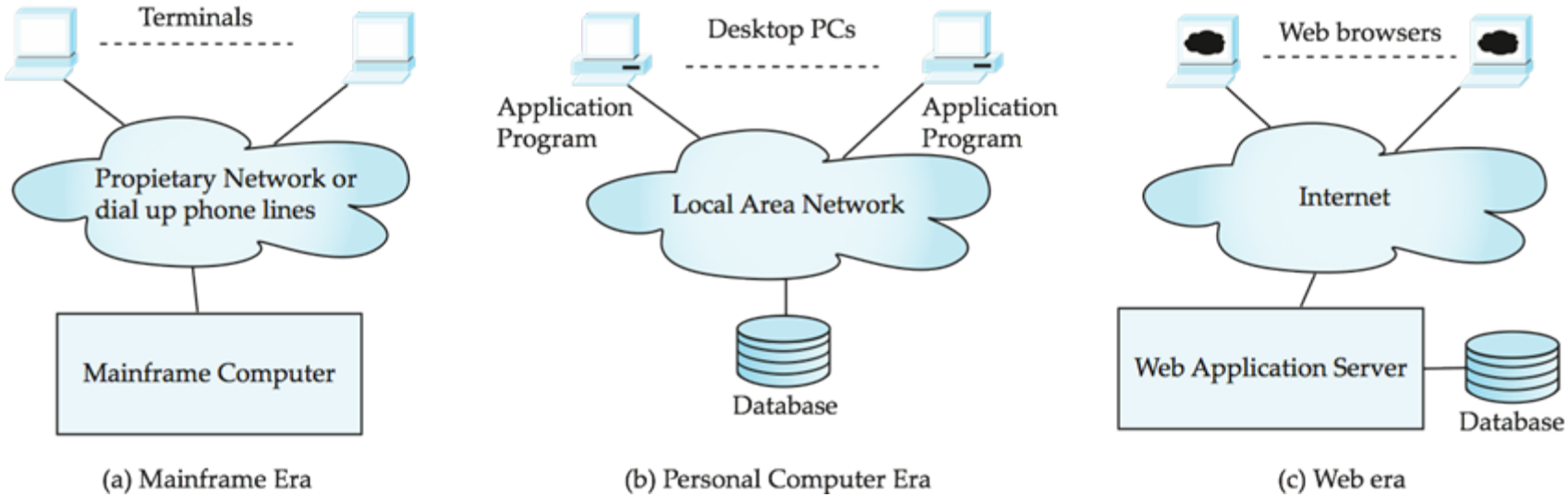
- Password based authentication is widely used, but is susceptible to sniffing on a network
- **Challenge-response** systems avoid transmission of passwords
  - DB sends a (randomly generated) challenge string to user
  - User encrypts string and returns result.
  - DB verifies identity by decrypting result
  - Can use public-key encryption system by DB sending a message encrypted using user's public key, and user decrypting and sending the message back
- **Digital signatures** are used to verify authenticity of data
  - E.g. use private key (in reverse) to encrypt data, and anyone can verify authenticity by using public key (in reverse) to decrypt data. Only holder of private key could have created the encrypted data.
  - Digital signatures also help ensure **nonrepudiation:** sender cannot later claim to have not created the data

Digital Certificates

- **Digital certificates** are used to verify authenticity of public keys.
- Problem: when you communicate with a web site, how do you know if you are talking with the genuine web site or an imposter?
  - Solution: use the public key of the web site
  - Problem: how to verify if the public key itself is genuine?
- Solution:
  - Every client (e.g. browser) has public keys of a few root-level **certification authorities**
  - A site can get its name/URL and public key signed by a certification authority: signed document is called a **certificate**
  - Client can use public key of certification authority to verify certificate
  - Multiple levels of certification authorities can exist. Each certification authority
    - presents its own public-key certificate signed by a higher level authority, and
    - Uses its private key to sign the certificate of other web sites/authorities

End of Chapter

Figure 9.01

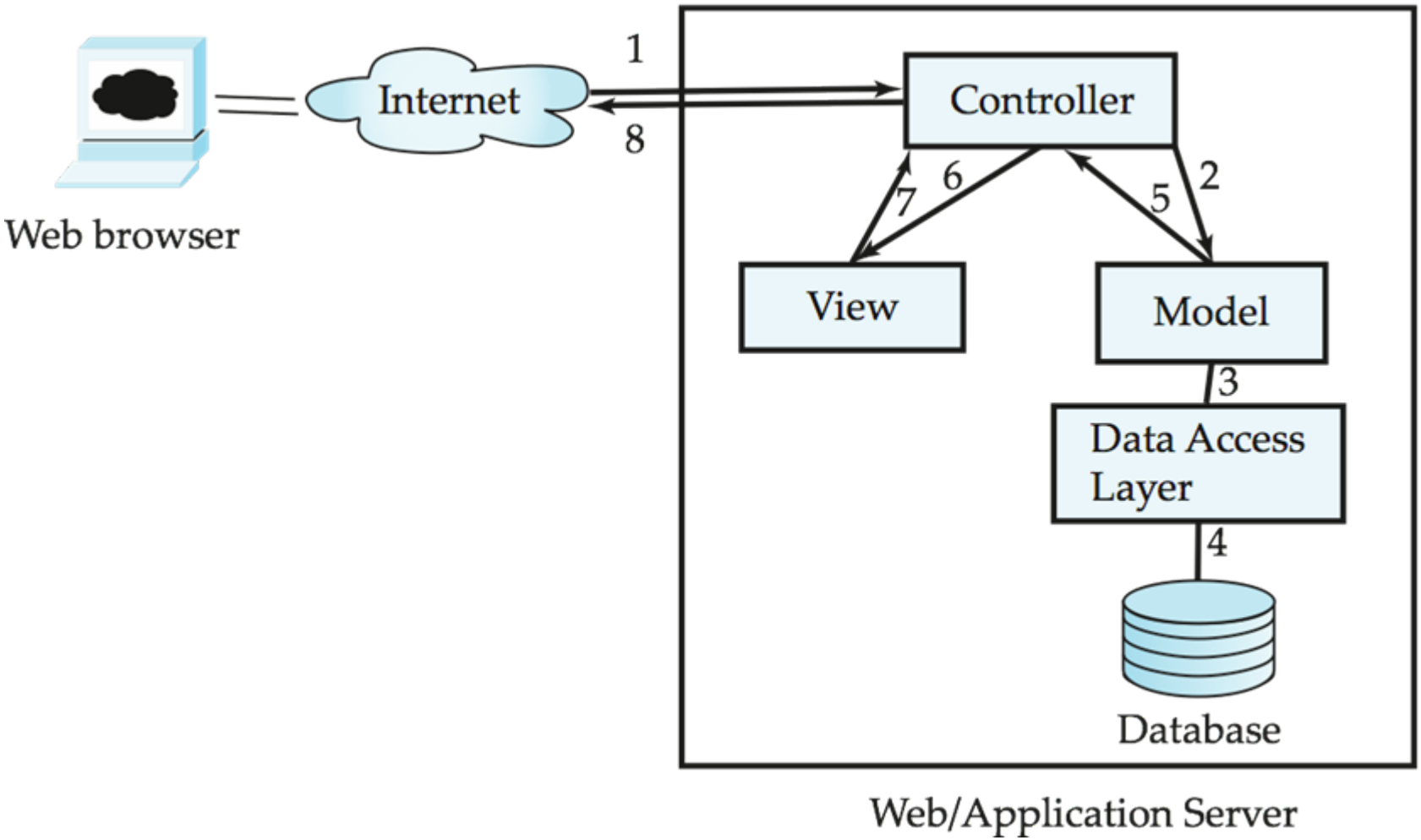


(a) Mainframe Era

(b) Personal Computer Era

(c) Web era

Figure 9.11


Web browser
Internet
1
8
Controller
2
5
6
7
View
Model
3
Data Access Layer
4
Database
Web/Application Server