Stream-based Implementation of Application Protocols

Advanced Topics in Java

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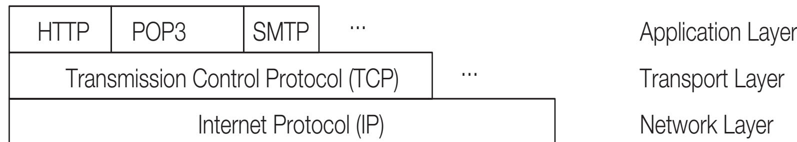
Overview

- Application Protocol: HTTP (HyperText Transmission Protocol)
- Implementation of Stream-based Clients and Servers on TCP/IP connection

Application Protocols

- An application protocol facilitates communication between applications through the services of the lower-level layers of the OSI (Open Systems Interconnection) model.
- TCP/IP Stack:



- An application protocol specification comprises the *syntax* and *semantics* of the protocol.
- An application protocol specification is published as a *RFC* (Request For Comment) document.
- Application Protocols: *stateless* and *request-response*-based
  - HTTP: HyperText Transmission Protocol (v1.0: RFC 1945, v1.1: RFC 2616)
  - SMTP: Simple Mail Transfer Protocol (RFC 2821) for Internet electronic mail delivery.
  - POP3: Post Office Protocol (RFC 1939) for retrieval of mail from a mail server.
- RFC web sites: `http://www.rfc-editor.org/`, `http://www.faqs.org/rfcs/`

HTTP: HyperText Transmission Protocol

- Used for retrieving resources from and posting information to a web server.
- Two important versions: HTTP/1.0 (RFC 1945), HTTP/1.1 (RFC 2616)
- A HTTP server usually runs on port 80 (or 8080).
- A *client* is a *user* of services.
- A *server* is a *provider* of services.
- The client *opens a connection* to the server and sends a *request* to the server. The client receives a *response* from the server and *closes the connection*.
- Regarding the Internet:

  A web browser is a HTTP client

  A web server is a HTTP server

  A resource is identified by a URI
  (Universal Resource Identifier)

- The web client should be able to construct an appropriate HTTP request, and interpret a HTTP response.
- The web server should be able to interpret the HTTP request, and construct an appropriate HTTP response.

Universal Resource Identifier: URI

- A URI is a superset of URL and URN. It is an identifier that identifies a resource. The resource may or may not exist. Neither does it imply how we can retrieve the resource.
  `ATIJ/lecture-notes-kam/atij-application-protocols`

Universal Resource Locator: URL

- A URL specifies a unique address/location for a resource on the Web.
- Common form:

  <protocol>`://`*<hostname>[*`:`*<TCP port number>]*`/`*<pathname>[*`?`*<query>][*`#`*<reference>]*

  `http://www.ii.uib.no:80/~khalid/pgjc2e/`

  `mailto:khalid@ii.uib.no?Subject=Urgent%20Message`

  `http://www.w3.org/TR/REC-html32#intro` <--- Tag to indicate particular part of a document.

Universal Resource Name: URN

- A URN is a unique identifier that identifies a resource, irrespective of its location and mode of retrieval.
  `ISBN: 0-201-72828-1`

HTTP Message Format

HTTP Message Parts	Explanation
The start line	Specifies the purpose of the message: a *method line* in case of a request and a *status line* in the case of a response.
The header section	Comprises a list of *request/response header fields* and/or *entity header fields*. Request/response header fields allows additional information about the message to be passed. Entity header fields specify the metainformation (size, type, encoding, etc.) about the content of the entity-body.
A blank line (CRLF)	Terminates the header section. Mandatory.
Optional entity-body	The content of the message.

- HTTP message is either a *request* from a client to a server, or a *response* from a server to a client.
- *Each line of the HTTP message is terminated with a CRLF* ("\r\n").

Cookies

- HTTP application protocol is stateless, i.e. it has no "memory".
- A cookie is small piece of *persistent* data stored in a text file on the client side, which the server side can utilize in its interaction with the client.
- The server introduces a cookie to the client by including a `Set-Cookie` header field as part of an HTTP response.
- Any future HTTP requests made by the client will include a transmittal of the cookie in a `Cookie` header field from the client back to the server.
- A cookies comprises of the following information:
  - a list of name/value pairs
  - a URI
  - an optional expiry date

  In subsequent requests involving this URI, the client will always include the list of name/value pairs from the cookie.
- Cookies facilitate tracking of client requests and customizing of server response for individual clients.

CGI: Common Gateway Interface

- CGI is an interface that allows servers to start server-side programs to handle client requests.
- CGI makes possible interaction or passing of information between a client and a server-side application.

MIME Type

- MIME (Multipurpose Internet Mail Extensions) is a message representation protocol, i.e. it specifies the structure of MIME messages.
- A *MIME type* specifies the media *type* and *subtype* of data in the body of a message (as the value of a `Content-Type` header field):

  <type>/*<subtype>*
- A MIME type allows an appropriate application to be used to interpret the data in a resource.

```
application/msword
application/zip
text/html
image/jpeg
video/mpeg
```

HTTP Request Specification

- The general syntax of *the method line* of a HTTP request is:
  <method name> <URI> <http version number>
- A HTTP *method* specifies the action that the client wants the server to perform.

- HTTP/1.0 methods that a web client can issue to a web server:

`GET` Retrieve the resource identified by the URI (specified as the local path):

```
GET <URI> <http version no.>
```

Examples:

```
GET /index.html HTTP/1.0
GET /book/chapter1/figure1.jpg HTTP/1.0
GET /servlet/register?first=khalid&last=mughal HTTP/1.0
```

HTTP method | URI | Query string | HTTP version

The first two examples specify a *passive* resource, where as the last one specifies an *active* resource which does processing.

The *query string* specifies *parameter-value pairs* which are passed to the server-side application. The URI may need to be *encoded*, and then *decoded* at the server-side. See classes `URLEncoder` and `URLDecoder`.

HEAD Retrieve only metainformation about the resource identified by the URI:

```
HEAD <URI> <http version no.>
```

Examples:

```
HEAD /index.html HTTP/1.0
HEAD /book/chapter1/figure1.jpg HTTP/1.0
```

The format of the `HEAD` request is identical to the `GET` request.

The response is identical to the response to a `GET` request, but the *response* does not contain a entity-body, only *the header fields*.

This method is often used for testing hypertext links for validity, accessibility, and recent modification.

POST The `POST` method is used to pass information in the entity-body to the active resource identified by the URI:

```
POST <URI> <http version no.>
<header section>
<CRLF>
<entity-body>
```

The headers describe the information in the entity-body, for example the type of the content (`Content-Type`) and the number of bytes in the entity-body (`Content-Length`).

Example:

```
POST /servlet/magicSocket HTTP/1.0
User-Agent: Mozilla/4.0 (compatible; MSIE 6.0; ...)
Content-Type: application/x-www-form-urlencoded
Content-Length: ...
<CRLF>
question=Socket,%20socket%20in%20the%20wall.%20Who%20is
fairest%20client%20of%20them%20all?
```

The entity-body is *encoded* for *unsafe* characters when sent server-side. See classes `URLEncoder` and `URLDecoder.`

HTTP Request Header Fields

Request Header Field	Description

`Accept`	Specify media types which are acceptable for the response.
	Example:
	`Accept: text/plain, text/html, audio/*`
	`Accept: text/*`
	
	`"/*"` indicates all subtypes in the specified media category.

`Accept-Charset`	Specify character sets which are acceptable for the response. Example: `Accept-Charset: iso-8859-5`
`Accept-Encoding`	Specify character encodings which are acceptable for the response. Example: `Accept-Encoding: compress, gzip`
`Accept-Language`	Specify natural languages that are preferred as a response. Example: `Accept-Language: no, en-us`

Request Header Field	Description
`From`	E-mail address of person controlling the requesting user-agent. `From: khalid.mughal@ii.uib.no`
`Host`	Specifies the Internet host and port number of the requested resource in the URI. No trailing port implies the default port for the service requested (for example, "80" for an HTTP URL). Example: `Host: localhost`
`If-Modified-Since`	Conditional request to return an entity only if it has been modified since the specified date. Example: `If-Modified-Since: Sat, 1 Mar 2004 12:45:15 GMT`
`If-Unmodified-Since`	Conditional request to return an entity only if it has *not* been modified since the specified date. Example: `If-Unmodified-Since: Sat, 1 Mar 2004 12:45:15 GMT`

Request Header Field	Description
`Referer`	Specify the URI of the resource that linked to the requested URI (*a back link*). Example: `Referer: http://www.ii.uib.no/~khalid/index.html`
`User-Agent`	Specify information about the user-agent (software) originating the request. Example: `User-Agent: Mozilla/4.0 (compatible; MSIE 6.0; ...)`
`Cookie:`	The name/value pairs of all cookies matching the requested URI are specified with this header. Example: `Cookie: passenger=High_Flyer`
`Connection:`	A general header which specifies options that are desired for that particular connection. Options `close` and `Keep-Alive` indicate a non-persistent and persistent connection, respectively. Example: `Connection: Keep-Alive`

HTTP Response Specification

- The general syntax of *the status line* of a HTTP response is:

  <http version number> <response status code> <description>

  Examples of single-line responses:

```
HTTP/1.0 200 OK
HTTP/1.0 404 Not Found
```

  Example of a multiple-line response:

```
HTTP/1.0 200 OK                    The status line
Content-Type: text/html            Header section
Content-Length: ...
<CRLF>                             End of header section
<html>                             Entity-body
<head>Answer</head>
<body>
   <h1>You are the lucky winner of $1000000!</h1>
</body>
</html>
```

- The metainformation about the content of the entity-body is given by the entity header fields.

Response Status Codes in HTTP Response Status Line

2xx	Successful	4xx	Client Error
200	OK	400	Bad Request
201	Created	401	Unauthorized
202	Accepted	403	Forbidden
204	No Content	404	Not Found
3xx	**Redirection**	**5xx**	**Server Error**
300	Multiple Choices	500	Internal Server Error
301	Moved Permanently	501	Not Implemented
302	Moved Temporarily	502	Bad Gateway
304	Not Modified	503	Service Unavailable

HTTP Response Header Fields

Response Header Field	Description
`Location:`	Specifies the absolute path of the resource in the case of redirection. Example: `Location: http://www.ii.uib.no/~khalid/pjgc2e/`
`Server:`	Specifies the software used by the server to handle the request. Example: `Server: MegaServer/1.0`
`Pragma:`	A general header which specifies implementation-specific directives. For example, to prevent caching of a resource, a server can specify the following directive: `Pragma: no-cache`
`Set-Cookie:`	Specifies a cookie which the client will include in all subsequent requests to the server. Example: `Set-cookie: passenger=High_Flyer; path=/`

HTTP Entity Header Fields in a HTTP Message

Entity Header Field	Description
`Content-Encoding:`	Specifies what additional content coding has been applied to the resource, and thus what decoding mechanism must be applied in order to obtain the media-type referenced by the `Content-Type` header field. Example: `Content-Encoding: gzip`
`Content-Length:`	Specifies the size of the entity body, i.e. the number of bytes comprising the entity-body. Client can take this information into consideration when dealing with the entity-body. Example: `Content-Length: 1949`
`Content-Type:`	Specifies the media type of the entity body. Example: `Content-Type: text/html`

Entity Header Field	Description
`Expires:`	Specifies the date/time when the resource would become stale. This does not imply that the original resource will be affected. Example: `Expires: WED, 24 Dec 2004 12:00:00 GMT`
`Last-Modified:`	Specifies the date/time when the resource was last modified. Example: `Last-modified: WED, 24 Dec 2004 12:00:00 GMT`

Some Useful Classes

- Lexical analysis of messages: the `java.util.StringTokenizer` class, the `java.util.Scanner` class (*See notes on new features in Java 5.0.*)
- Dealing with files and directories: the `java.io.File` class
- Encoding and decoding URLs: `java.net.URLEncoder`, `java.net.URLDecoder` classes
- Constructing messages: the `String`, `StringBuilder`, and `StringBuffer` classes
- Check out the `java.util.regex` class.

Lexical Analysis with the `StringTokenizer` Class

- A `StringTokenizer` breaks a string into *words*, also called *tokens*.
- *Delimiter characters* are used to recognize tokens in the string.

```
String input = "To be. Or not to be?";
StringTokenizer tokenlist1 = new StringTokenizer(input); // default " \t\n\r\f"
StringTokenizer tokenlist2 = new StringTokenizer(input, ".?"); // Delimiters ".?"
```

- Delimiters are not part of a token.
- The tokens in a `StringTokenizer` can be read as a `String` one at a time by calling the `nextToken()` method successively.
- The method `hasMoreTokens()` can be used to check if all tokens have been read.
- These two methods should be used *in sync*.

```
while (tokenlist1.hasMoreTokens()) {
            System.out.println(tokenlist1.nextToken());
}
```

- Delimiters can be changed on the fly when using a StringTokenizer.
  – use the overloaded method `nextToken(String delimiters)`.

Example: StringTokenizer

```
import java.util.*;
public class UsingStringTokenizer {
    public static void main(String[] args) {
        // Input string.
        String input = "To be. Or not to be?";
        // Create a tokenizer. Default delimiters: " \t\n\r\f"
        StringTokenizer tokenlist1 = new StringTokenizer(input);
        // Create a tokenizer. Delimiters ".?"
        StringTokenizer tokenlist2 = new StringTokenizer(input, ".?");
        System.out.println("--------------");
        printTokens(tokenlist1);
        System.out.println("--------------");
        printTokens(tokenlist2);
    }
    public static void printTokens(StringTokenizer tokenlist) {
        while (tokenlist.hasMoreTokens()) {
            String token = tokenlist.nextToken();
            System.out.println(token);
        }
    }
}
```


Running the program:

```
> java UsingStringTokenizer
--------------
To
be.
Or
not
to
be?
--------------
To be
 Or not to be
```

The `File` Class

- A `File` object is an immutable abstract representation of a pathname (URI) for a file or a directory.
- A `File` object can represent an *absolute* or a *relative* pathname.
- The `File` class provides methods to manipulate pathnames in a platform-independent way.
- The `File` class has many methods which return a `String` representation of the pathname components.

```
File myPathname = new File("..\\assignments\\week1"); // "../assignments/week1"
// Given that the current directory is d:\course\.
```

`getName()`	Returns the last component of the pathname ("week1").
`getParent()`	Returns the pathname minus the last component ("..\assignments").
`getPath()`	Returns whatever pathname is in the `File` object. ("..\assignments\week1")

`getAbsolutePath()`	Returns the absolute pathname which is a concatenation of the current directory, the file separator character, and the pathname of the `File` object. A file or directory can have many absolute paths. ("d:\course\..\assignments\week1")
`getCanonicalPath()`	Returns an absolute pathname in which all relative path references (such as ".", "..") have been completely resolved. A file or a directory has a *unique* canonical path. ("d:\assignments\week1")

Encoding and Decoding URLs

`static String encode( String urlStr, String encoding) throws UnsupportedEncodingException()`	This method is defined in class `URLEncoder`. It translates a string into MIME type `application/x-www-form-urlencoded` format using a specific encoding scheme.
`static String decode( String urlStr, String encoding)`	This method is defined in class `URLDecoder`. It decodes a string in MIME type `application/x-www-form-urlencoded` format using a specific encoding scheme.

- Encoding procedure :
  - The alphanumeric characters and the special characters `'.'`, `'-'`, `'*'`, and `'_'` are unchanged.
  - The space character `' '` is converted into a plus sign `'+'`. (Might also see `"%20"`.)
  - All other characters are unsafe and are first converted into one or more bytes using some encoding scheme (recommended: `"UTF8"`). Then each byte is represented by the 3-character string `"%xy"`, where `xy` is the two-digit hexadecimal representation of the byte.
- For example,
  `"/servlet/register?first=khalid azim&last=mughal"` is encoded as
  `"%2Fservlet%2Fregister%3Ffirst%3Dkhalid+azim%26last%3Dmughal"`.

Example: A Directory Navigator Server

Address http://localhost:80/

Google Search Web Powermarks

Directory: atij-application-protocols

SMTPClientDemo.java
Pop3ClientDemo.java
client-sever-interaction copy.eps
atij-app-protocols.fm.lck
HTTPServerDemo.java
TCP-IP-stack.ai
HTTPServer.java
atij-app-protocols.backup.fm
SMTPSender.java
HTTPServer$ConnectionHandler.class
HTTPServer.class
SMTPClientDemo.class
SMTPSender.class
HTTPServerDemo.class
Pop3ClientDemo.class
Pop3Client.class
Pop3Client.java
client-sever-examples
TCP-IP-stack copy.eps
client-sever-interaction.ai
SMTPClientDemo.out
atij-app-protocols.pdf

Address http://localhost/HTTPServer.java

Google Search Web Search Site PageR

File: HTTPServer.java

```
import java.io.*;
import java.net.*;
import java.util.*;

// A server that lists a given directory for a client using HTTP
public class HTTPServer {

  private ServerSocket serverSocket;
  private int     port;            // local port
  private String directory;        // Content Directory

  public HTTPServer(String directory, int port) throws IOExcepti
    this.directory = directory;
    this.port      = port;
    // Create the socket server.
    serverSocket   = new ServerSocket(this.port);
  }

  public void handleClients() {
    for (;;) {
      try {
        // Accept a new socket connection for the next client
        Socket clientSocket = serverSocket.accept();

        // Start a new handler instance to process the request
        new ConnectionHandler(clientSocket, directory).start();
      } catch (IOException ioe) {
        ioe.printStackTrace();
```

Running the Directory Navigator Server

- Source: `HTTPServerDemo.java, HTTPServerV3.java`

1. Run the following command at the command line:
```
>java HTTPServerDemo
```
2. Point the web browser to the following URI:
```
http://localhost/
```
3. Navigate by clicking on the links in the web page.
4. The output at the command line shows the HTML content that the server is sending to the web client.

Content Type in HTTP Responses: HTML

- For a file:
```
<html><head><title>File: HTTPServer.java</title></head>
<body><h1>File: HTTPServer.java</h1>
<pre>
   ... contents of the file ...
</pre>
</body></html>
```

- For a directory:
```
<html><head><title>Directory: client-sever-examples</title></head>
<body><h1>Directory: client-sever-examples</h1>
<table border="0">
<tr><td><a href="ThreadedEchoServer.java">ThreadedEchoServer.java</a></td></tr>
<tr><td><a href="EchoServer.java">EchoServer.java</a></td></tr>
</table>
</body>
</html>
```

Implementation of the Directory Navigator Server

- Source: `HTTPServerV3.java`, `HTTPServerDemo.java`

1. Create a server socket on a local port (`HTTPServerV2()`):

```
serverSocket   = new ServerSocket(this.port);
```

2. Accept a connection on this local port, and spin off a new thread (`handleClients()`).

```
for (;;) {
  try {
    // Accept a new socket connection for the next client
    Socket clientSocket = serverSocket.accept();

    // Start a new handler instance to process the request
    new ConnectionHandler(clientSocket, directory).start();
  } catch (IOException ioe) {
    ioe.printStackTrace();
  }
}
```


3. Implementation of connection handler.

```
class ConnectionHandler extends Thread { // Nested class.
  private Socket socket;
  private PrintWriter socketWriter;
  private BufferedReader socketReader;
  private File directory;
  private String  methodLine;

  public ConnectionHandler(Socket socket, String directory)
                         throws IOException {
    this.socket = socket;
    // Get the canonical form of the pathname
    this.directory = new File(directory).getCanonicalFile();
  }

  private String getMethodLine() throws IOException {
    String line = socketReader.readLine();
    System.out.println("<" + line);
    return line;
  }
```

```
    private String getURLFromMethodLine() throws IOException {
        StringTokenizer tokens = new StringTokenizer(methodLine," ");
        tokens.nextToken();        // Skip method name
        return tokens.nextToken(); // Requested resource
    }

    private void readHeaderSection() throws IOException {
      for (;;) {
        String line = socketReader.readLine();
        if (line == null)
          throw new IOException("No more input on socket.");
        System.out.println("<" + line);
        if (line.equals("")) break;
      }
    }

    private String getEntityBody() throws IOException {
      String content = "";
      for (;;) {
        String line = socketReader.readLine();
        if (line == null) break;
        System.out.println("<" + line);
        content += line;
```



```
      }
      return content;
    }

    private void sendResponseLine(String line) {
/*
      final String CRLF = "\r\n";
      socketWriter.print(line + CRLF);
      socketWriter.flush();  // ONLY println() flushes!!!
*/
      socketWriter.println(line);  // Flushes.
      System.out.println(">" + line);
    }

    private void sendBlankLine() {
      sendResponseLine("");
    }

    private File constructCanonicalPathname(String baseURL,
                                            String relURL)
                                throws IOException { ... }

    public void run() { ... }
```

```
  private void doNotImplemented() { ... }

  private void doGetMethod() throws IOException { ... }

  private void doPostMethod() throws IOException { ... }

  private void determineResponse(File file) throws IOException
    { ... }

  private void sendFileResponse(PrintWriter socketWriter,
                                File file)
                     throws IOException { ... }

  private void sendDirResponse(PrintWriter socketWriter, File dir)
    { ... }
}
```


4. Create input and output streams for response/request messages (`run()`):

```
// Connect socketReader and socketWriter to input and output
// streams of the socket.
socketReader = new BufferedReader(new InputStreamReader(
                                  socket.getInputStream()));
socketWriter = new PrintWriter(socket.getOutputStream(),
                               true);// Flushes with println()
```

5. Determine the Http method in the request (`run()`):

```
// Read the method line of the HTTP request from client.
methodLine = getMethodLine();

// Any request at all?
if(methodLine != null) {
    // Handle GET and POST requests.
    if(methodLine.toUpperCase().startsWith("GET"))
      doGetMethod();
    else if(methodLine.toUpperCase().startsWith("POST"))
      doPostMethod();
    else
      doNotImplemented();
```

6. Handle a GET method request (`doGetMethod()`):

```
// Get requested resource
String reqPathname = getURLFromMethodLine();

// Construct the full pathname.
File file =
      constructCanonicalPathname(directory.getPath(),
                                 reqPathname);
determineResponse(file);
```


7. Handle a POST method request (`doPostMethod()`):

```
// Get requested/base resource
String relURL1 = getURLFromMethodLine();
// Read the header section.
readHeaderSection();

// Entity-body is a relative URL.
String relURL2 = getEntityBody();

// First construct the requested pathname from
// relURL1 and URL2.
String reqPathname;
if(relURL2.startsWith("/") ||
   relURL2.startsWith("\\"))
  reqPathname = relURL1 + relURL2;
else
  reqPathname = relURL1 + File.separator + relURL2;
// Construct a full pathname using
// the directory pathname.
File file =
      constructCanonicalPathname(directory.getPath(),
                                 reqPathname);
determineResponse(file);
```

8. Construct the full pathname of the URI (`constructCanonicalPathname()`).

```
String pathname;
if(relURL.startsWith("/") ||
   relURL.startsWith("\\"))
  pathname = baseURL + relURL;
else
  pathname = baseURL + File.separator + relURL;

// Decode pathname.
pathname = URLDecoder.decode(pathname, "UTF8");
// Return the canonical pathname of the resource.
return new File(pathname).getCanonicalFile();
```


9. Determine if the URI identifies a file or a directory (`determineResponse()`)

```
// Check to see if requested resource doesn't start
// with specified directory
if(!file.getCanonicalPath().
   startsWith(this.directory.getCanonicalPath())) {
  sendResponseLine("HTTP/1.0 403 Forbidden");
  sendBlankLine();
} else if(!file.exists()) {
  sendResponseLine("HTTP/1.0 404 File Not Found");
  sendBlankLine();
} else if(!file.canRead()) {
  sendResponseLine("HTTP/1.0 403 Forbidden");
  sendBlankLine();
} else if(file.isDirectory())  // A directory
  sendDirResponse(socketWriter, file);
else                           // A file
  sendFileResponse(socketWriter, file);
```

10. Response for a file (`sendFileResponse()`):

```
BufferedReader source = new BufferedReader(
            new InputStreamReader(new FileInputStream(file)));
// Send the status line
sendResponseLine("HTTP/1.0 200 OK");
// Send the entity header fields
sendResponseLine("Content-Type: text/html");
// Mark end of the response headers section
sendBlankLine();

// Send entity body
sendResponseLine("<html><head><title>File: " +
                  file.getName() + "</title></head>");
sendResponseLine("<body><h1>File: " +
                  file.getName() + "</h1>");
sendResponseLine("<pre>");
for(;;) {
  String txtLine = source.readLine();
  if (txtLine == null) break;
  sendResponseLine(txtLine);
}
sendResponseLine("</pre>");
sendResponseLine("</body></html>");
```


11. Response for a directory (`sendDirResponse()`):

```
// Send the status line
sendResponseLine("HTTP/1.0 200 Okay");

// Send the entity header fields
sendResponseLine("Content-Type: text/html");

// Mark end of the response headers
sendBlankLine();

// Send entity body
sendResponseLine("<html><head><title>Directory: " +
                 dir.getName() + "</title></head>");
sendResponseLine("<body><h1>Directory: " + dir.getName() +
                 "</h1>");
File[] contents = dir.listFiles();
sendResponseLine("<table border=\"0\">");
for(int i=0; i < contents.length; i++) {
  String row = "<tr><td><a href=\"" + contents[i].getName();
  if(contents[i].isDirectory())
    row += "/";
  row += "\">";
```

```
          if(contents[i].isDirectory())
            row += "<i>";
          row += contents[i].getName();
          if(contents[i].isDirectory())
            row += "</i>";
          row += "</a></td></tr>";
          sendResponseLine(row);
        }
        sendResponseLine("</table></body></html>");
```

12. Close the socket (`run()`).
    ```
    socket.close();
    ```