Network Programming: Servers

For additional materials, please see http://www.coreservlets.com/. The Java tutorial section contains complete source code for all examples in this tutorial series, plus exercises and exercise solutions for each topic.

For customized training related to Java or JavaScript, please email hall@coreservlets.com
Marty is also available for consulting and development support

The instructor is author of several popular Java EE books, two of the most popular Safari videos on Java and JavaScript, and this tutorial.

Courses available at public venues, or custom versions can be held on-site at your organization.

- Courses developed and taught by Marty Hall
  - JSF 2.3, PrimeFaces, Java programming (using Java 8, for those new to Java), Java 8 (for Java 7 programmers), JavaScript, jQuery, Angular 2, Ext JS, Spring Framework, Spring MVC, Android, GWT, custom mix of topics.
  - Java 9 training coming soon.
  - Courses available in any state or country.
  - Maryland/DC companies can also choose afternoon/evening courses.
- Courses developed and taught by coreservlets.com experts (edited by Marty)
  - Hadoop, Spark, Hibernate/JPA, HTML5, RESTful Web Services

Contact hall@coreservlets.com for details
Topics in This Section

• **Steps for creating a server**
  1. Create a ServerSocket object
  2. Create a Socket object from ServerSocket
  3. Create an input stream
  4. Create an output stream
  5. Do I/O with input and output streams
  6. Close the socket

• **A generic network server**
  – Single threaded
  – Multithreaded

• **Accepting connections from browsers**

• **A simple HTTP server**

For additional materials, please see http://www.coreservlets.com/. The Java tutorial section contains complete source code for all examples in this tutorial series, plus exercises and exercise solutions for each topic.
Steps for Implementing a Server

1. Create a ServerSocket object
   \[\text{ServerSocket listenSocket} = \text{new ServerSocket(portNumber);}\]

2. Create a Socket object from ServerSocket
   \[\text{while(someCondition) \{}\]
   \[\text{Socket server} = \text{listenSocket.accept();}\]
   \[\text{doSomethingWith(server);}\]
   \[\text{\}}\]
   • It is common to have doSomethingWith spin off a separate thread

3. Create an input stream to read client input
   \[\text{BufferedReader in = }\]
   \[\text{new BufferedReader(new InputStreamReader(server.getInputStream()));}\]

4. Create an output stream that can be used to send info back to the client
   \[\text{// Last arg of true means autoflush stream}\]
   \[\text{// when println is called}\]
   \[\text{PrintWriter out} = \text{new PrintWriter(server.getOutputStream(), true);}\]

5. Do I/O with input and output streams
   • You usually read inside a loop
   • You usually respond in a separate thread
   • Most common way to read input: lines or readLine
   • Most common way to send output: printf

6. Close the socket when done
   \[\text{server.close();} \quad \text{// Or use try-with-resources}\]
   • This closes the associated input and output streams
Reminder of Helper Class: SocketUtils

• Idea
  – It is common to make BufferedReader and PrintWriter from a Socket, so simplify the syntax slightly

• Without SocketUtils (for Socket s)
  – PrintWriter out =
    new PrintWriter(s.getOutputStream(), true);
  – BufferedReader in =
    new BufferedReader
      (new InputStreamReader(s.getInputStream()));

• With SocketUtils (for Socket s)
  – PrintWriter out = SocketUtils.getWriter(s);
  – BufferedReader in = SocketUtils.getReader(s);

Exceptions

• IOException
  – Interruption or other unexpected problem
  • Client closing connection causes error for writing, but does not cause an error when reading: the Stream<String> from lines just finishes, and null is returned from readLine

• Note
  – ServerSocket implements AutoCloseable, so you can use the try-with-resources idea we first covered in file IO section
  • try(ServerSocket listener = new ServerSocket(…)) { … }
Simple Warmup: A Single-Threaded Server

Base Class for Single-Threaded Network Server

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

/** A starting point for network servers. */

class NetworkServer {
    private int port;

    /** Build a server on specified port. It will continue to
     * accept connections, passing each to handleConnection until
     * the server is killed (e.g., Control-C in the startup window)
     * or System.exit() from handleConnection or elsewhere
     * in the Java code).
     */
    public NetworkServer(int port) {
        this.port = port;
    }
}
A Generic Network Server (Continued)

/** Monitor a port for connections. Each time one is established,
* pass resulting Socket to handleConnection.
*/

public void listen() {
    try(ServerSocket listener = new ServerSocket(port)) {
        Socket socket;
        while(true) {  // Run until killed
            socket = listener.accept();
            handleConnection(socket);
        }
    } catch (IOException ioe) {
        System.out.println("IOException: " + ioe);
        ioe.printStackTrace();
    }
}

A Generic Network Server (Continued)

/** This is the method that provides the behavior to the
* server, since it determines what is done with the
* resulting socket. <b>Override this method in servers</b>
* you write.</b>
*/

protected abstract void handleConnection(Socket socket) throws IOException;

/** Gets port on which server is listening. */

public int getPort() {
    return(port);
}
public class NetworkServerTest extends NetworkServer {
    public NetworkServerTest(int port) {
        super(port);
    }

    @Override
    protected void handleConnection(Socket socket) throws IOException {
        PrintWriter out = SocketUtils.getWriter(socket);
        BufferedReader in = SocketUtils.getReader(socket);
        System.out.printf("Generic Server: got connection from \%s\n" +
            "with first line \"%s\".
        ,
            socket.getInetAddress().getHostName(),
            in.readLine());
        out.println("Generic Server");
        socket.close();
    }
}

public static void main(String[] args) {
    int port = 8080;
    try {
        port = Integer.parseInt(args[0]);
    } catch(NumberFormatException|ArrayIndexOutOfBoundsException e) {} 
    NetworkServerTest tester = new NetworkServerTest(port);
    tester.listen();
}

Network Server: Results

- Accepting a Connection from a browser
  - Suppose the above test program is started up on port 80 of server.com:
    
    > java coreservlets.NetworkServerTest 80

  - Then, a standard Web browser on client.com requests http://server.com/foo/bar, resulting in the following printed at server.com:

    Generic Network Server:
    got connection from client.com
    with first line 'GET /foo/bar HTTP/1.1'
import java.net.*;
import java.util.concurrent.*;
import java.io.*;

public class MultithreadedServer {
    private int port;

    public MultithreadedServer(int port) {
        this.port = port;
    }

    public int getPort() {
        return(port);
    }

    public void listen() {
        int poolSize = 50 * Runtime.getRuntime().availableProcessors();
        ExecutorService tasks = Executors.newFixedThreadPool(poolSize);
        try(ServerSocket listener = new ServerSocket(port)) {
            Socket socket;
            while(true) {  // Run until killed
                socket = listener.accept();
                tasks.execute(new ConnectionHandler(socket));
            }
        } catch (IOException ioe) {
            System.err.println("IOException: " + ioe);
            ioe.printStackTrace();
        }
    }
}

The upcoming EchoServer will extend this class to make an HTTP server.

Inner class whose run method calls back to handleConnection of this class.
private class ConnectionHandler implements Runnable {
    private Socket connection;

    public ConnectionHandler(Socket socket) {
        this.connection = socket;
    }

    public void run() {
        try {
            handleConnection(connection);
        } catch (IOException ioe) {
            System.err.println("IOException: " + ioe);
        }
    }
}

/** This is the method that provides the behavior to the
 *  server, since it determines what is done with the
 *  resulting socket. <b>Override this method in servers
 *  you write.</b>
 */

protected abstract void handleConnection(Socket connection)
    throws IOException;
A Simple Multithreaded HTTP Server

For additional materials, please see http://www.coreservlets.com/. The Java tutorial section contains complete source code for all examples in this tutorial series, plus exercises and exercise solutions for each topic.

---

**HTTP Requests and Responses**

**Request**

- GET /~gates/ HTTP/1.1
- Host: www.mainhost.com
- Connection: close
- Header3: ...
- ...
- HeaderN: ...
- Blank Line

- All request headers are optional except for Host (required for HTTP/1.1)
- If you send HEAD instead of GET, the server returns the same HTTP headers, but no document

**Response**

- HTTP/1.1 200 OK
- Content-Type: text/html
- Header2: ...
- ...
- HeaderN: ...

  Blank Line

  <!DOCTYPE ...>

  <html>

  ...

  </html>

- All response headers are optional except for Content-Type
A Simple HTTP Server

• Idea

1. Read lines sent by the browser, storing them in a List
   • Use readLine a line at a time until an empty line
     – Exception: with POST requests you have to read extra line

2. Send an HTTP response line (e.g. "HTTP/1.1 200 OK")

3. Send a Content-Type line then a blank line
   • This indicates the file type being returned (HTML in this case)

4. Send an HTML file showing the lines that were sent
   • Put the input in a <pre> section inside the body

5. Close the connection

---

EchoServer.java

/** A simple HTTP server that generates a Web page
 * showing all of the data that it received from
 * the Web client (usually a browser). */

public class EchoServer extends MultithreadedServer {
    public EchoServer(int port) {
        super(port);
    }

    public static void main(String[] args) {
        int port = 8080;
        try {
            port = Integer.parseInt(args[0]);
        } catch(NumberFormatException|
            ArrayIndexOutOfBoundsException e) {}  // Remove catch block
        EchoServer server = new EchoServer(port);
        server.listen();
    }
}
EchoServer.java: Reading the Request

```java
@Override
public void handleConnection(Socket socket) throws IOException{
    String serverName = "Multithreaded EchoServer";
    PrintWriter out = SocketUtils.getWriter(socket);
    BufferedReader in = SocketUtils.getReader(socket);
    List<String> inputLines = new ArrayList<>();
    String line;
    while((line = in.readLine()) != null) {
        inputLines.add(line);
        if (line.isEmpty()) { // Blank line.
            if (WebUtils.isUsingPost(inputLines)) {
                inputLines.add(WebUtils.postData(in));
            }
            break;
        }
    }
}
```

EchoServer.java: Sending the Response

```java
WebUtils.printHeader(out, serverName);
for (String inputLine: inputLines) {
    out.println(inputLine);
}
WebUtils.printTrailer(out);
socket.close();
```
public static void printHeader(PrintWriter out, String serverName) {
    out.println("HTTP/1.1 200 OK\r\n" +
            "Server: " + serverName + "\r\n" +
            "Content-Type: text/html\r\n" +
            "\r\n" +
            "<!DOCTYPE html>\n" +
            "<html lang="en">\n" +
            "<head>\n" +
            "  <meta charset="utf-8"/>\n" +
            "  <title>" + serverName + " Results</title>\n" +
            "</head>\n" +
            "\n" +
            "<body bgcolor="#fdf5e6">\n" +
            "<h1 align="center">" + serverName + " Results</h1>\n" +
            "Here are the request line and request headers\n" +
            "sent by your browser:\n" +
            "<pre>");
}

public static boolean isUsingPost(List<String> inputs) {
    return(inputs.get(0).toUpperCase().startsWith("POST"));
}

/** POST submissions have one extra line at the end, after the blank line,
 *  and NOT terminated by CR. Ignore multi-line posts, such as file uploads. */

public static String postData(BufferedReader in) throws IOException {
    char[] data = new char[1000]; // Assume 1000 chars max
    int chars = in.read(data);
    return(new String(data, 0, chars));
}
EchoServer in Action

Multithreaded EchoServer Results

Here are the request line and request headers sent by your browser:

GET /foo/bar/baz.html HTTP/1.1
Host: localhost
Connection: keep-alive
Accept: text/html,application/xhtml+xml,application/xml;q=0.9,image/webp,*/*;q=0.8
Upgrade-Insecure-Requests: 1
User-Agent: Mozilla/5.0 (Windows NT 6.1; WOW64) AppleWebKit/537.36 (KHTML, like Gecko) Chrome/48.0.2564.109 Safari/537.36
Accept-Encoding: gzip, deflate, sdch
Accept-Language: en-US,en;q=0.8

Wrap-Up

For additional materials, please see http://www.coreservlets.com/. The Java tutorial section contains complete source code for all examples in this tutorial series, plus exercises and exercise solutions for each topic.
Summary

- **Create a ServerSocket; specify port number**
  - Call accept to wait for a client connection
  - accept returns a Socket object (same class we saw in last lecture)

- **Browser requests:**
  - GET, POST, or HEAD line
  - 0 or more request headers
  - Blank line
  - One additional line (query data) for POST requests only

- **HTTP server response:**
  - Status line (HTTP/1.1 200 OK),
  - Content-Type (and, optionally, other response headers)
  - Blank line
  - Document

- **Always make servers multi-threaded**
  - Use MultithreadedServer as starting point

---

**coreservlets.com** – custom onsite training

---

**Questions?**

---

For additional materials, please see http://www.coreservlets.com/. The Java tutorial section contains complete source code for all examples in this tutorial series, plus exercises and exercise solutions for each topic.