Chapter 26
Networking

OBJECTIVES

In this chapter you'll learn:

- Java networking with URLs, sockets and datagrams.
- To implement Java networking applications by using sockets and datagrams.
- To implement Java clients and servers that communicate with one another.
- To implement network-based collaborative applications.
- To construct a simple multithreaded server.

26.1 Introduction

- package java.net
- Stream-based communications that enable applications to view networking as streams of data.
- Packet-based communications for transmitting individual packets of information—commonly used to transmit data images, audio and video over the Internet.
- We focus on both sides of the client/server relationship.

client /the server performs the action and responds to the client.

26.1 Introduction (cont.)

- Socket-based(基于套接字） communications enable applications to view networking as if it were file I/O.
  - With stream sockets, a process establishes a connection to another process.
  - While the connection is in place, data flows between the processes in continuous streams.
  - Stream sockets are said to provide a connection-oriented service.
  - The protocol used for transmission is the popular TCP (Transmission Control Protocol

26.1 Introduction (cont.)

- With datagram sockets, individual packets of information are transmitted.
  - UDP—the User Datagram Protocol—is a connectionless service, and thus does not guarantee that packets arrive in any particular order.
  - Packets can even be lost or duplicated.

26.2 Manipulating URLs

- HyperText Transfer Protocol (HTTP) forms the basis of the World Wide Web
  - uses URIs (Uniform Resource Identifiers) to identify data on the Internet.
- URIs that specify the locations of documents are called URLs (Uniform Resource Locators).
- AppletContext method showDocument causes the browser to access and display a resource.

```
1  <html>
2  <head>
3     <title>Site Selector</title>
4  </head>
5  <body>
6     <applet code = "SiteSelector.class" width = "300" height = "75">
7        <param name = "title0" value = "Java Home Page">
8        <param name = "location0"
9           value = "http://www.oracle.com/technetwork/java/">
10       <param name = "title1" value = "Deitel">
11       <param name = "location1" value = "http://www.deitel.com/">
12       <param name = "title2" value = "JGuru">
13       <param name = "location2" value = "http://www.jGuru.com/">
14       <param name = "title3" value = "JavaWorld">
15       <param name = "location3" value = "http://www.javaworld.com/">
16    </applet>
17 </body>
18 </html>
```

Fig. 27.1 | HTML document to load `SiteSelector` applet.

```
1  // Fig. 27.2: SiteSelector.java
2  // Loading a document from a URL into a browser.
3  import java.net.MalformedURLException;
4  import java.net.URL;
5  import java.util.HashMap;
6  import java.util.ArrayList;
7  import java.awt.BorderLayout;
8  import java.applet.AppletContext;
9  import javax.swing.JApplet;
10 import javax.swing.JLabel;
11 import javax.swing.JList;
12 import javax.swing.JScrollPane;
13 import javax.swing.event.ListSelectionEvent;
14 import javax.swing.event.ListSelectionListener;
15
```

Fig. 27.2 | Loading a document from a URL into a browser. (Part 1 of 6.)

```
16  public class SiteSelector extends JApplet
17  {
18     private HashMap< String, URL > sites; // site names and URLs
19     private ArrayList< String > siteNames; // site names
20     private JList siteChooser; // list of sites to choose from
21
22     // read parameters and set up GUI
23     public void init()
24     {
25        sites = new HashMap< String, URL >(); // create HashMap
26        siteNames = new ArrayList< String >(); // create ArrayList
27
28        // obtain parameters from HTML document
29        getSitesFromHTMLParameters();
30
```

Fig. 27.2 | Loading a document from a URL into a browser. (Part 2 of 6.)

```
31          // create GUI components and lay out interface
32          add( new JLabel( "Choose a site to browse" ), BorderLayout.NORTH );
33
34          siteChooser = new JList( siteNames.toArray() ); // populate JList
35          siteChooser.addListSelectionListener(
36             new ListSelectionListener() // anonymous inner class
37             {
38                // go to site user selected
39                public void valueChanged( ListSelectionEvent event )
40                {
41                   // get selected site name
42                   Object object = siteChooser.getSelectedValue();
43
44                   // use site name to locate corresponding URL
45                   URL newDocument = sites.get( object );
46
47                   // get applet container
48                   AppletContext browser = getAppletContext();
49
50                   // tell applet container to change pages
51                   browser.showDocument( newDocument );
52                } // end method valueChanged
53             } // end anonymous inner class
54          ); // end call to addListSelectionListener
```

Fig. 27.2 | Loading a document from a URL into a browser. (Part 3 of 6.)

```
55
56          add( new JScrollPane( siteChooser ), BorderLayout.CENTER );
57       } // end method init
58
59       // obtain parameters from HTML document
60       private void getSitesFromHTMLParameters()
61       {
62          String title; // site title
63          String location; // location of site
64          URL url; // URL of location
65          int counter = 0; // count number of sites
66
67          title = getParameter( "title" + counter ); // get first site title
68
```

Fig. 27.2 | Loading a document from a URL into a browser. (Part 4 of 6.)

```
69          // loop until no more parameters in HTML document
70          while ( title != null )
71          {
72             // obtain site location
73             location = getParameter( "location" + counter );
74
75             try // place title/URL in HashMap and title in ArrayList
76             {
77                url = new URL( location ); // convert location to URL
78                sites.put( title, url ); // put title/URL in HashMap
79                siteNames.add( title ); // put title in ArrayList
80             } // end try
81             catch ( MalformedURLException urlException )
82             {
83                urlException.printStackTrace();
84             } // end catch
85
86             ++counter;
87             title = getParameter( "title" + counter ); // get next site title
88          } // end while
89       } // end method getSitesFromHTMLParameters
90    } // end class SiteSelector
```

Fig. 27.2 | Loading a document from a URL into a browser. (Part 5 of 6.)

Fig. 27.2 | Loading a document from a URL into a browser. (Part 6 of 6.)

26.3 Reading a File on a Web Server

- Swing GUI component JEditorPane (from package `javax.swing`) can display the contents of a file on a web server.
- Class `JEditorPane` can render both plain text and XHTML-formatted text
  - this application acts as a simple web browser.
- Can process HyperlinkEvents when the user clicks a hyperlink in the `JEditorPane`.

```
1  // Fig. 27.3: ReadServerFile.java
2  // Reading a file by opening a connection through a URL.
3  import java.awt.BorderLayout;
4  import java.awt.event.ActionEvent;
5  import java.awt.event.ActionListener;
6  import java.io.IOException;
7  import javax.swing.JEditorPane;
8  import javax.swing.JFrame;
9  import javax.swing.JOptionPane;
10 import javax.swing.JScrollPane;
11 import javax.swing.JTextField;
12 import javax.swing.event.HyperlinkEvent;
13 import javax.swing.event.HyperlinkListener;
14
15 public class ReadServerFile extends JFrame
16 {
17    private JTextField enterField; // JTextField to enter site name
18    private JEditorPane contentsArea; // to display website
19
```

Fig. 27.3 | Reading a file by opening a connection through a URL. (Part 1 of 4.)

```
20       // set up GUI
21       public ReadServerFile()
22       {
23          super( "Simple Web Browser" );
24
25          // create enterField and register its listener
26          enterField = new JTextField( "Enter file URL here" );
27          enterField.addActionListener(
28             new ActionListener()
29             {
30                // get document specified by user
31                public void actionPerformed( ActionEvent event )
32                {
33                   getThePage( event.getActionCommand() );
34                } // end method actionPerformed
35             } // end inner class
36          ); // end call to addActionListener
37
38          add( enterField, BorderLayout.NORTH );
```

Fig. 27.3 | ...ning a connection through a URL. (Part 2 of 4.)

```
39
40          contentsArea = new JEditorPane(); // create contentsArea
41          contentsArea.setEditable( false );
42          contentsArea.addHyperlinkListener(
43             new HyperlinkListener()
44             {
45                // if user clicked hyperlink, go to specified page
46                public void hyperlinkUpdate( HyperlinkEvent event )
47                {
48                   if ( event.getEventType() ==
49                        HyperlinkEvent.EventType.ACTIVATED )
50                      getThePage( event.getURL().toString() );
51                } // end method hyperlinkUpdate
52             } // end inner class
53          ); // end call to addHyperlinkListener
54
55          add( new JScrollPane( contentsArea ), BorderLayout.CENTER );
56          setSize( 400, 300 ); // set size of window
57          setVisible( true ); // show window
58       } // end ReadServerFile constructor
59
```

Fig. 27.3 ...g a connection through a URL. (Part 3 of 4.)

```
60      // load document
61      private void getThePage( String location )
62      {
63         try // load document and display location
64         {
65            contentsArea.setPage( location ); // set the page
66            enterField.setText( location ); // set the text
67         } // end try
68         catch ( IOException ioException )
69         {
70            JOptionPane.showMessageDialog( this,
71               "Error retrieving specified URL", "Bad URL",
72               JOptionPane.ERROR_MESSAGE );
73         } // end catch
74      } // end method getThePage
75   } // end class ReadServerFile
```

Fig. 27.3 | Reading a file by opening a connection through a URL. (Part 4 of 4.)

```
1  // Fig. 27.4: ReadServerFileTest.java
2  // Create and start a ReadServerFile.
3  import javax.swing.JFrame;
4
5  public class ReadServerFileTest
6  {
7     public static void main( String[] args )
8     {
9        ReadServerFile application = new ReadServerFile();
10       application.setDefaultCloseOperation( JFrame.EXIT_ON_CLOSE );
11    } // end main
12 } // end class ReadServerFileTest
```

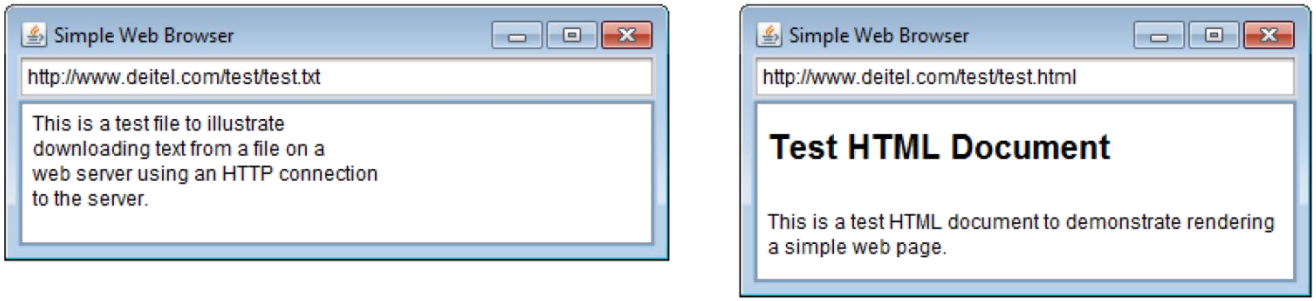


Fig. 27.4 | Test class for `ReadServerFile`.

26.3 Reading a File on a Web Server (cont.)

- `JEditorPane` method setPage downloads a document and displays it.
  - If there is an error, throws an `IOException`.
  - if an invalid URL, throws a `MalformedURLException`.
- If a `JEditorPane` contains an XHTML document and the user clicks a hyperlink, the `JEditorPane` generates a HyperlinkEvent (package `javax.swing.event`) and notifies all registered HyperlinkListeners (package `javax.swing.event`) of that event.
- When a `HyperlinkEvent` occurs, the program calls method hyperlinkUpdate on the registered listener(s).

26.3 Reading a File on a Web Server (cont.)

- `HyperlinkEvent` method `getEventType` returns the type of the `HyperlinkEvent`.
- `HyperlinkEvent` nested class `EventType` declares three `static` `EventType` objects
  - `ACTIVATED` indicates that the user clicked a hyperlink to change web pages
  - `ENTERED` indicates that the user moved the mouse over a hyperlink
  - `EXITED` indicates that the user moved the mouse away from a hyperlink
- `HyperlinkEvent` method `getURL` obtains the `URL` represented by the hyperlink.

Look-and-Feel Observation 27.1

A `JEditorPane` *generates* `HyperlinkEvent`*s only if it's uneditable.*

26.4 Establishing a Simple Server Using Stream Sockets

- Establishing a simple server in Java requires five steps.
- *Step 1 is to create a ServerSocket object.*
- **`ServerSocket` constructor**
  - `ServerSocket server = new ServerSocket( portNumber, queveLength );`
- The constructor establishes the port number where the server waits for connections from clients—a process known as binding the server to the port.
- Each client will ask to connect to the server on this port.

Software Engineering Observation 27.1

Port numbers can be between 0 and 65,535. Most operating systems reserve port numbers below 1024 for system services (e.g., e-mail and World Wide Web servers). Generally, these ports should not be specified as connection ports in user programs. In fact, some operating systems require special access privileges to bind to port numbers below 1024.

26.4 Establishing a Simple Server Using Stream Sockets (cont.)

- Programs manage each client connection with a Socket object.
- In *Step 2,* the server listens indefinitely (or blocks) for an attempt by a client to connect.
- To listen for a client connection, the program calls `ServerSocket` method accept, as in
  - `Socket connection = server.accept();`
  - returns a `Socket` when a connection with a client is established.
- The `Socket` allows the server to interact with the client.

26.4 Establishing a Simple Server Using Stream Sockets (cont.)

- *Step 3* is to get the `OutputStream` and `InputStream` objects that enable the server to communicate with the client by sending and receiving bytes.
  - The server invokes method **getOutputStream** on the `Socket` to get a reference to the `Socket`'s `OutputStream` and invokes method **getInputStream** on the `Socket` to get a reference to the `Socket`'s `InputStream`.

26.4 Establishing a Simple Server Using Stream Sockets (cont.)

- *Step 4* is the processing phase, in which the server and the client communicate via the `OutputStream` and `InputStream` objects.
- In *Step 5*, when the transmission is complete, the server closes the connection by invoking the **close** method on the streams and on the `Socket`.

Software Engineering Observation 27.2

With sockets, network I/O appears to Java programs to be similar to sequential file I/O. Sockets hide much of the complexity of network programming.

Software Engineering Observation 27.3

A multithreaded server can take the `Socket` *returned by each call to* `accept` *and create a new thread that manages network I/O across that* `Socket`*. Alternatively, a multithreaded server can maintain a pool of threads (a set of already existing threads) ready to manage network I/O across the new* `Socket`*s as they're created. These techniques enable multithreaded servers to manage many simultaneous client connections.*

Performance Tip 27.2

In high-performance systems in which memory is abundant, a multithreaded server can create a pool of threads that can be assigned quickly to handle network I/O for new `Socket`*s as they're created. Thus, when the server receives a connection, it* need not incur thread-creation overhead. *When the connection is closed, the thread is returned to the pool for reuse.*

26.5 Establishing a Simple Client Using Stream Sockets

- Establishing a simple client in Java requires four steps.
- In *Step 1,* the `Socket` constructor establishes a connection to the server.
  - `Socket connection = new Socket(`*serverAddress*`, `*port*`);`
  - If the connection attempt is successful, this statement returns a `Socket`.
  - A connection attempt that fails throws an instance of a subclass of `IOException`.
  - An `UnknownHostException` occurs when the system is unable to resolve the server name.

26.5 Establishing a Simple Client Using Stream Sockets (cont.)

- In *Step 2*, the client uses `Socket` methods **`getInputStream`** and **`getOutputStream`** to obtain references to the `Socket`'s `InputStream` and `OutputStream`.
- *Step 3* is the processing phase in which the client and the server communicate via the `InputStream` and `OutputStream` objects.
- In *Step 4*, the client closes the connection when the transmission is complete by invoking the **`close`** method on the streams and on the `Socket`.

26.6 Client/Server Interaction with Stream Socket Connections

- Figures 26.5 and 26.7 present a simple client-/server chat application.

```
1  // Fig. 27.5: Server.java
2  // Server portion of a client/server stream-socket connection.
3  import java.io.EOFException;
4  import java.io.IOException;
5  import java.io.ObjectInputStream;
6  import java.io.ObjectOutputStream;
7  import java.net.ServerSocket;
8  import java.net.Socket;
9  import java.awt.BorderLayout;
10 import java.awt.event.ActionEvent;
11 import java.awt.event.ActionListener;
12 import javax.swing.JFrame;
13 import javax.swing.JScrollPane;
14 import javax.swing.JTextArea;
15 import javax.swing.JTextField;
16 import javax.swing.SwingUtilities;
17
18 public class Server extends JFrame
19 {
20    private JTextField enterField; // inputs message from user
21    private JTextArea displayArea; // display information to user
22    private ObjectOutputStream output; // output stream to client
23    private ObjectInputStream input; // input stream from client
```

Fig. 27.5 | Server portion of a client/server stream-socket connection. (Part 1 of 9.)

```
24      private ServerSocket server; // server socket
25      private Socket connection; // connection to client
26      private int counter = 1; // counter of number of connections
27
28      // set up GUI
29      public Server()
30      {
31         super( "Server" );
32
33         enterField = new JTextField(); // create enterField
34         enterField.setEditable( false );
35         enterField.addActionListener(
36            new ActionListener()
37            {
38               // send message to client
39               public void actionPerformed( ActionEvent event )
40               {
41                  sendData( event.getActionCommand() );
42                  enterField.setText( "" );
43               } // end method actionPerformed
44            } // end anonymous inner class
45         ); // end call to addActionListener
46
```

Fig. 27.5 | Server portion of a client/server stream-socket connection. (Part 2 of 9.)

```
47          add( enterField, BorderLayout.NORTH );
48
49          displayArea = new JTextArea(); // create displayArea
50          add( new JScrollPane( displayArea ), BorderLayout.CENTER );
51
52          setSize( 300, 150 ); // set size of window
53          setVisible( true ); // show window
54       } // end Server constructor
55
56       // set up and run server
57       public void runServer()
58       {
59          try // set up server to receive connections; process connections
60          {
61             server = new ServerSocket( 12345, 100 ); // create ServerSocket
62
63             while ( true )
64             {
65                try
66                {
67                   waitForConnection(); // wait for a connection
68                   getStreams(); // get input & output streams
69                   processConnection(); // process connection
70                } // end try
```

Fig. 27.5 | Server portion of a client/server stream-socket connection. (Part 3 of 9.)

```
71              catch ( EOFException eofException )
72              {
73                 displayMessage( "\nServer terminated connection" );
74              } // end catch
75              finally
76              {
77                 closeConnection(); // close connection
78                 ++counter;
79              } // end finally
80           } // end while
81        } // end try
82        catch ( IOException ioException )
83        {
84           ioException.printStackTrace();
85        } // end catch
86     } // end method runServer
87
88     // wait for connection to arrive, then display connection info
89     private void waitForConnection() throws IOException
90     {
91        displayMessage( "Waiting for connection\n" );
92        connection = server.accept(); // allow server to accept connection
93        displayMessage( "Connection " + counter + " received from: " +
94           connection.getInetAddress().getHostName() );
95     } // end method waitForConnection
```

Fig. 27.5 stream-socket connection. (Part 4 of 9.)

```
96
97       // get streams to send and receive data
98       private void getStreams() throws IOException
99       {
100         // set up output stream for objects
101         output = new ObjectOutputStream( connection.getOutputStream() );
102         output.flush(); // flush output buffer to send header information
103
104         // set up input stream for objects
105         input = new ObjectInputStream( connection.getInputStream() );
106
107         displayMessage( "\nGot I/O streams\n" );
108      } // end method getStreams
109
110      // process connection with client
111      private void processConnection() throws IOException
112      {
113         String message = "Connection successful";
114         sendData( message ); // send connection successful message
115
116         // enable enterField so server user can send messages
117         setTextFieldEditable( true );
118
```

Fig. 27.5 | Server portion of a client/server stream-socket connection. (Part 5 of 9.)

```
119         do // process messages sent from client
120         {
121            try // read message and display it
122            {
123               message = ( String ) input.readObject(); // read new message
124               displayMessage( "\n" + message ); // display message
125            } // end try
126            catch ( ClassNotFoundException classNotFoundException )
127            {
128               displayMessage( "\nUnknown object type received" );
129            } // end catch
130
131         } while ( !message.equals( "CLIENT>>> TERMINATE" ) );
132      } // end method processConnection
133
134      // close streams and socket
135      private void closeConnection()
136      {
137         displayMessage( "\nTerminating connection\n" );
138         setTextFieldEditable( false ); // disable enterField
139
140         try
141         {
```

Fig. 27.5 | Server portion of a client/server stream-socket connection. (Part 6 of 9.)

```
142            output.close(); // close output stream
143            input.close(); // close input stream
144            connection.close(); // close socket
145         } // end try
146         catch ( IOException ioException )
147         {
148            ioException.printStackTrace();
149         } // end catch
150      } // end method closeConnection
151
152      // send message to client
153      private void sendData( String message )
154      {
155         try // send object to client
156         {
157            output.writeObject( "SERVER>>> " + message );
158            output.flush(); // flush output to client
159            displayMessage( "\nSERVER>>> " + message );
160         } // end try
161         catch ( IOException ioException )
162         {
163            displayArea.append( "\nError writing object" );
164         } // end catch
165      } // end method sendData
```

Fig. 27.5 | Server portion of a client/server stream-socket connection. (Part 7 of 9.)

```
166
167    // manipulates displayArea in the event-dispatch thread
168    private void displayMessage( final String messageToDisplay )
169    {
170       SwingUtilities.invokeLater(
171          new Runnable()
172          {
173             public void run() // updates displayArea
174             {
175                displayArea.append( messageToDisplay ); // append message
176             } // end method run
177          } // end anonymous inner class
178       ); // end call to SwingUtilities.invokeLater
179    } // end method displayMessage
180
```

Fig. 27.5 | Server portion of a client/server stream-socket connection. (Part 8 of 9.)

```
181     // manipulates enterField in the event-dispatch thread
182     private void setTextFieldEditable( final boolean editable )
183     {
184        SwingUtilities.invokeLater(
185           new Runnable()
186           {
187              public void run() // sets enterField's editability
188              {
189                 enterField.setEditable( editable );
190              } // end method run
191           }  // end inner class
192        ); // end call to SwingUtilities.invokeLater
193     } // end method setTextFieldEditable
194  } // end class Server
```

Fig. 27.5 | Server portion of a client/server stream-socket connection. (Part 9 of 9.)

```
1  // Fig. 27.6: ServerTest.java
2  // Test the Server application.
3  import javax.swing.JFrame;
4
5  public class ServerTest
6  {
7     public static void main( String[] args )
8     {
9        Server application = new Server(); // create server
10       application.setDefaultCloseOperation( JFrame.EXIT_ON_CLOSE );
11       application.runServer(); // run server application
12    } // end main
13 } // end class ServerTest
```

Fig. 27.6 | Test class for Server.

26.6 Client/Server Interaction with Stream Socket Connections (cont.)

- SwingUtilities method invokeLater receives a `Runnable` object as its argument and places it into the event-dispatch thread for execution.
  - Ensures that we don't modify a GUI component from a thread other than the event-dispatch thread.

Common Programming Error 27.1

Specifying a port that's already in use or specifying an invalid port number when creating a `ServerSocket` *results in a* `BindException`.

26.6 Client/Server Interaction with Stream Socket Connections (cont.)

- `Socket` method getInet-Address returns an InetAddress (package `java.net`) containing information about the client computer.
- `InetAddress` method getHostName returns the host name of the client computer.
- IP address (127.0.0.1) and host name (localhost) are useful for testing networking applications on your local computer
  - known as the loopback address

26.6 Client/Server Interaction with Stream Socket Connections (cont.)

- Note the call to `ObjectOutputStream` method flush.
  - Causes the `ObjectOutputStream` on the server to send a stream header to the corresponding client's `ObjectInputStream`.
  - The stream header contains such information as the version of object serialization being used to send objects.
  - This information is required by the `ObjectInputStream` so that it can prepare to receive those objects correctly.

Software Engineering Observation 27.4

When using `ObjectOutputStream` *and* `ObjectInputStream` *to send and receive data over a network connection, always create the* `ObjectOutputStream` *first and* `flush` *the stream so that the client's* `ObjectInputStream` *can prepare to receive the data. This is required for networking applications that communicate using* `ObjectOutputStream` *and* `ObjectInputStream`.

Performance Tip 27.3

A computer's I/O components are typically much slower than its memory. Output buffers are used to increase the efficiency of an application by sending larger amounts of data fewer times, reducing the number of times an application accesses the computer's I/O components.

26.6 Client/Server Interaction with Stream Socket Connections (cont.)

- In this example, you can execute the client from any computer on the Internet and specify the IP address or host name of the server computer as a command-line argument to the program.
- The following command attempts to connect to the `Server` on the computer with IP address `192.168.1.15`
  - `java Client 192.168.1.15`

```
1  // Fig. 27.7: Client.java
2  // Client portion of a stream-socket connection between client and server.
3  import java.io.EOFException;
4  import java.io.IOException;
5  import java.io.ObjectInputStream;
6  import java.io.ObjectOutputStream;
7  import java.net.InetAddress;
8  import java.net.Socket;
9  import java.awt.BorderLayout;
10 import java.awt.event.ActionEvent;
11 import java.awt.event.ActionListener;
12 import javax.swing.JFrame;
13 import javax.swing.JScrollPane;
14 import javax.swing.JTextArea;
15 import javax.swing.JTextField;
16 import javax.swing.SwingUtilities;
17
18 public class Client extends JFrame
19 {
20    private JTextField enterField; // enters information from user
21    private JTextArea displayArea; // display information to user
22    private ObjectOutputStream output; // output stream to server
23    private ObjectInputStream input; // input stream from server
```

Fig. 27.7 | Client portion of a stream-socket connection between client and server.
(Part 1 of 9.)

```
24      private String message = ""; // message from server
25      private String chatServer; // host server for this application
26      private Socket client; // socket to communicate with server
27
28      // initialize chatServer and set up GUI
29      public Client( String host )
30      {
31         super( "Client" );
32
33         chatServer = host; // set server to which this client connects
34
35         enterField = new JTextField(); // create enterField
36         enterField.setEditable( false );
37         enterField.addActionListener(
38            new ActionListener()
39            {
40               // send message to server
41               public void actionPerformed( ActionEvent event )
42               {
43                  sendData( event.getActionCommand() );
44                  enterField.setText( "" );
45               } // end method actionPerformed
46            } // end anonymous inner class
47         ); // end call to addActionListener
```

Fig. 27.7 | Client portion of a stream-socket connection between client and server. (Part 2 of 3)

```
48
49          add( enterField, BorderLayout.NORTH );
50
51          displayArea = new JTextArea(); // create displayArea
52          add( new JScrollPane( displayArea ), BorderLayout.CENTER );
53
54          setSize( 300, 150 ); // set size of window
55          setVisible( true ); // show window
56       } // end Client constructor
57
58       // connect to server and process messages from server
59       public void runClient()
60       {
61          try // connect to server, get streams, process connection
62          {
63             connectToServer(); // create a Socket to make connection
64             getStreams(); // get the input and output streams
65             processConnection(); // process connection
66          } // end try
67          catch ( EOFException eofException )
68          {
69             displayMessage( "\nClient terminated connection" );
70          } // end catch
```

Fig. 27.7 | Client portion of a stream-socket connection between client and server. (Part 3 of 9.)

```
71          catch ( IOException ioException )
72          {
73             ioException.printStackTrace();
74          } // end catch
75          finally
76          {
77             closeConnection(); // close connection
78          } // end finally
79       } // end method runClient
80
81       // connect to server
82       private void connectToServer() throws IOException
83       {
84          displayMessage( "Attempting connection\n" );
85
86          // create Socket to make connection to server
87          client = new Socket( InetAddress.getByName( chatServer ), 12345 );
88
89          // display connection information
90          displayMessage( "Connected to: " +
91             client.getInetAddress().getHostName() );
92       } // end method connectToServer
```

Fig. 27.7 | Client portion of a stream-socket connection between client and server. (Part 4 of 9.)

```
93
94       // get streams to send and receive data
95       private void getStreams() throws IOException
96       {
97          // set up output stream for objects
98          output = new ObjectOutputStream( client.getOutputStream() );
99          output.flush(); // flush output buffer to send header information
100
101         // set up input stream for objects
102         input = new ObjectInputStream( client.getInputStream() );
103
104         displayMessage( "\nGot I/O streams\n" );
105      } // end method getStreams
106
107      // process connection with server
108      private void processConnection() throws IOException
109      {
110         // enable enterField so client user can send messages
111         setTextFieldEditable( true );
112
113         do // process messages sent from server
114         {
```

Fig. 27.7 | Client portion of a stream-socket connection between client and server. (Part 5 of 9.)

```
115            try // read message and display it
116            {
117               message = ( String ) input.readObject(); // read new message
118               displayMessage( "\n" + message ); // display message
119            } // end try
120            catch ( ClassNotFoundException classNotFoundException )
121            {
122               displayMessage( "\nUnknown object type received" );
123            } // end catch
124
125         } while ( !message.equals( "SERVER>>> TERMINATE" ) );
126      } // end method processConnection
127
128      // close streams and socket
129      private void closeConnection()
130      {
131         displayMessage( "\nClosing connection" );
132         setTextFieldEditable( false ); // disable enterField
133
134         try
135         {
136            output.close(); // close output stream
```

Fig. 27.7 | Client portion of a stream-socket connection between client and server. (Part 6 of 9.)

```
137            input.close(); // close input stream  1
138            client.close(); // close socket
139         } // end try
140         catch ( IOException ioException )
141         {
142            ioException.printStackTrace();
143         } // end catch
144      } // end method closeConnection
145
146      // send message to server
147      private void sendData( String message )
148      {
149         try // send object to server
150         {
151            output.writeObject( "CLIENT>>> " + message );
152            output.flush(); // flush data to output
153            displayMessage( "\nCLIENT>>> " + message );
154         } // end try
155         catch ( IOException ioException )
156         {
157            displayArea.append( "\nError writing object" );
158         } // end catch
159      } // end method sendData
```

Fig. 27.7 | Client portion of a stream-socket connection between client and server. (Part 7 of 9.)

```
160
161     // manipulates displayArea in the event-dispatch thread
162     private void displayMessage( final String messageToDisplay )
163     {
164        SwingUtilities.invokeLater(
165           new Runnable()
166           {
167              public void run() // updates displayArea
168              {
169                 displayArea.append( messageToDisplay );
170              } // end method run
171           }  // end anonymous inner class
172        ); // end call to SwingUtilities.invokeLater
173     } // end method displayMessage
174
175     // manipulates enterField in the event-dispatch thread
176     private void setTextFieldEditable( final boolean editable )
177     {
178        SwingUtilities.invokeLater(
179           new Runnable()
180           {
```

Fig. 27.7 | Client portion of a stream-socket connection between client and server. (Part 8 of 9.)

```
181             public void run() // sets enterField's editability
182             {
183                enterField.setEditable( editable );
184             } // end method run
185          } // end anonymous inner class
186       ); // end call to SwingUtilities.invokeLater
187    } // end method setTextFieldEditable
188 } // end class Client
```

Fig. 27.7 | Client portion of a stream-socket connection between client and server. (Part 9 of 9.)

```
1  // Fig. 27.8: ClientTest.java
2  // Class that tests the Client.
3  import javax.swing.JFrame;
4
5  public class ClientTest
6  {
7     public static void main( String[] args )
8     {
9        Client application; // declare client application
10
11       // if no command line args
12       if ( args.length == 0 )
13          application = new Client( "127.0.0.1" ); // connect to localhost
14       else
15          application = new Client( args[ 0 ] ); // use args to connect
16
17       application.setDefaultCloseOperation( JFrame.EXIT_ON_CLOSE );
18       application.runClient(); // run client application
19    } // end main
20 } // end class ClientTest
```

Fig. 27.8 | Class that tests the `Client`. (Part 1 of 2.)

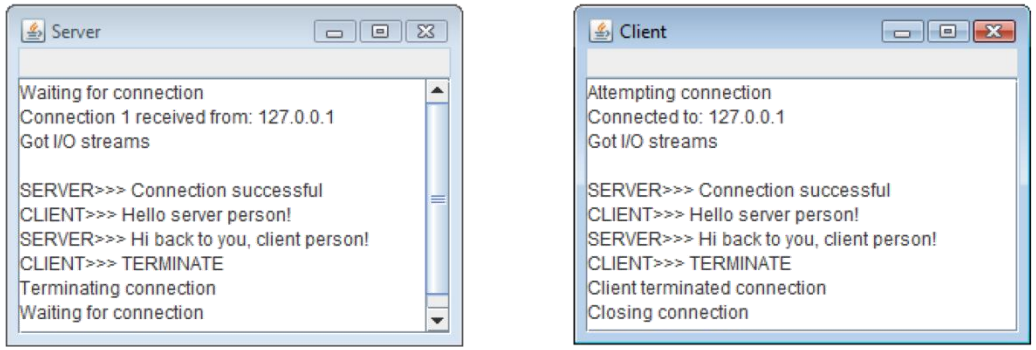


Fig. 27.8 | Class that tests the `Client`. (Part 2 of 2.)

26.6 Client/Server Interaction with Stream Socket Connections (cont.)

- `InetAddress` `static` method getByName returns an `InetAddress` object containing the specified IP address
  - Method `getByName` can receive a `String` containing either the actual IP address or the host name of the server.
- The first argument also could have been written other ways.
- For the `localhost` address `127.0.0.1`, the first argument could be specified with either of the following expressions:
  - `InetAddress.getByName( "localhost" )`
    `InetAddress.getLocalHost()`

26.7 Connectionless Client/Server Interaction with Datagrams

- Connectionless transmission with datagrams.
- Connection-oriented transmission is like the telephone system
  - You dial and are given a connection to the telephone of the person with whom you wish to communicate.
  - The connection is maintained for your phone call, even when you're not talking.
- Connectionless transmission with datagrams is more like the way mail is carried via the postal service.
  - If a large message will not fit in one envelope, you break it into separate pieces that you place in sequentially numbered envelopes.
  - All of the letters are then mailed at once.
  - The letters could arrive in order, out of order or not at all (the last case is rare).

26.7 Connectionless Client/Server Interaction with Datagrams (cont.)

- Class `Server` declares two DatagramPackets that the server uses to send and receive information and one DatagramSocket that sends and receives the packets.
- The `DatagramSocket` constructor that takes an integer port-number argument binds the server to a port where it can receive packets from clients.
  - `Client`s sending packets to this `Server` specify the same port number in the packets they send.
  - A SocketException is thrown if the `DatagramSocket` constructor fails to bind the `DatagramSocket` to the specified port.

Common Programming Error 27.2

Specifying a port that's already in use or specifying an invalid port number when creating a `DatagramSocket` *results in a* `SocketException`.

```
1  // Fig. 27.9: Server.java
2  // Server side of connectionless client/server computing with datagrams.
3  import java.io.IOException;
4  import java.net.DatagramPacket;
5  import java.net.DatagramSocket;
6  import java.net.SocketException;
7  import java.awt.BorderLayout;
8  import javax.swing.JFrame;
9  import javax.swing.JScrollPane;
10 import javax.swing.JTextArea;
11 import javax.swing.SwingUtilities;
12
13 public class Server extends JFrame
14 {
15    private JTextArea displayArea; // displays packets received
16    private DatagramSocket socket; // socket to connect to client
17
```

Fig. 27.9 | Server side of connectionless client/server computing with datagrams. (Part 1 of 5.)

```
18      // set up GUI and DatagramSocket
19      public Server()
20      {
21         super( "Server" );
22
23         displayArea = new JTextArea(); // create displayArea
24         add( new JScrollPane( displayArea ), BorderLayout.CENTER );
25         setSize( 400, 300 ); // set size of window
26         setVisible( true ); // show window
27
28         try // create DatagramSocket for sending and receiving packets
29         {
30            socket = new DatagramSocket( 5000 );
31         } // end try
32         catch ( SocketException socketException )
33         {
34            socketException.printStackTrace();
35            System.exit( 1 );
36         } // end catch
37      } // end Server constructor
38
```

Fig. 27.9 | Server side of connectionless client/server computing with datagrams. (Part 2 of 5.)

```
39      // wait for packets to arrive, display data and echo packet to client
40      public void waitForPackets()
41      {
42         while ( true )
43         {
44            try // receive packet, display contents, return copy to client
45            {
46               byte[] data = new byte[ 100 ]; // set up packet
47               DatagramPacket receivePacket =
48                  new DatagramPacket( data, data.length );
49
50               socket.receive( receivePacket ); // wait to receive packet
51
52               // display information from received packet
53               displayMessage( "\nPacket received:" +
54                  "\nFrom host: " + receivePacket.getAddress() +
55                  "\nHost port: " + receivePacket.getPort() +
56                  "\nLength: " + receivePacket.getLength() +
57                  "\nContaining:\n\t" + new String( receivePacket.getData(),
58                     0, receivePacket.getLength() ) );
59
60               sendPacketToClient( receivePacket ); // send packet to client
61            } // end try
```

Fig. 27.9 | Server side of connectionless client/server computing with datagrams. (Part 3 of 5.)

```
62            catch ( IOException ioException )
63            {
64               displayMessage( ioException + "\n" );
65               ioException.printStackTrace();
66            } // end catch
67         } // end while
68      } // end method waitForPackets
69
70      // echo packet to client
71      private void sendPacketToClient( DatagramPacket receivePacket )
72         throws IOException
73      {
74         displayMessage( "\n\nEcho data to client..." );
75
76         // create packet to send
77         DatagramPacket sendPacket = new DatagramPacket(
78            receivePacket.getData(), receivePacket.getLength(),
79            receivePacket.getAddress(), receivePacket.getPort() );
80
81         socket.send( sendPacket ); // send packet to client
82         displayMessage( "Packet sent\n" );
83      } // end method sendPacketToClient
```

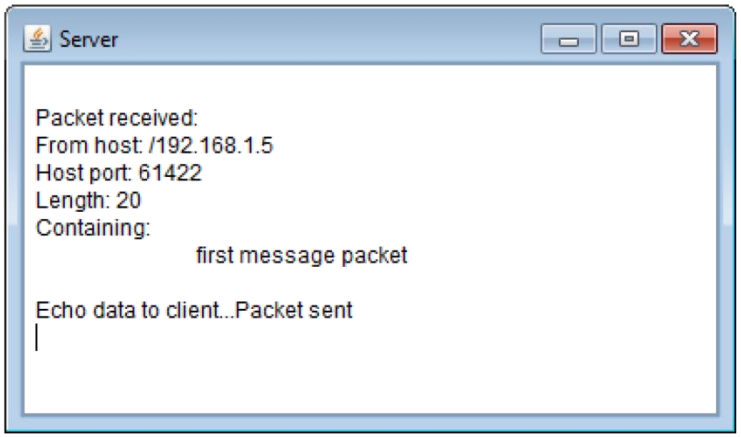
Fig. 27.9 | Server side of connectionless client/server computing with datagrams. (Part 4 of 5.)

```
84
85      // manipulates displayArea in the event-dispatch thread
86      private void displayMessage( final String messageToDisplay )
87      {
88         SwingUtilities.invokeLater(
89            new Runnable()
90            {
91               public void run() // updates displayArea
92               {
93                  displayArea.append( messageToDisplay ); // display message
94               } // end method run
95            } // end anonymous inner class
96         ); // end call to SwingUtilities.invokeLater
97      } // end method displayMessage
98   } // end class Server
```

Fig. 27.9 | Server side of connectionless client/server computing with datagrams. (Part 5 of 5.)

```
1  // Fig. 27.10: ServerTest.java
2  // Class that tests the Server.
3  import javax.swing.JFrame;
4
5  public class ServerTest
6  {
7     public static void main( String[] args )
8     {
9        Server application = new Server(); // create server
10       application.setDefaultCloseOperation( JFrame.EXIT_ON_CLOSE );
11       application.waitForPackets(); // run server application
12    } // end main
13 } // end class ServerTest
```

Fig. 27.10 | Class that tests the `Server`. (Part 1 of 2.)



`Server` window after packet of data is received from `Client`

Fig. 27.10 | Class that tests the `Server`. (Part 2 of 2.)

26.7 Connectionless Client/Server Interaction with Datagrams (cont.)

- `DatagramSocket` method receive waits for a packet to arrive at the `Server`.
  - Blocks until a packet arrives, then stores the packet in its `DatagramPacket` argument.
  - The method throws an `IOException` if an error occurs while receiving a packet.
- `DatagramPacket` method getAddress returns an `InetAddress` object containing the IP address of the computer from which the packet was sent.
- Method getPort returns an integer specifying the port number through which the client computer sent the packet.
- Method getLength returns an integer representing the number of bytes of data received.
- Method getData returns a `byte` array containing the data.
- `DatagramSocket` method send throws an `IOException` if an error occurs while sending a packet.

```
1  // Fig. 27.11: Client.java
2  // Client side of connectionless client/server computing with datagrams.
3  import java.io.IOException;
4  import java.net.DatagramPacket;
5  import java.net.DatagramSocket;
6  import java.net.InetAddress;
7  import java.net.SocketException;
8  import java.awt.BorderLayout;
9  import java.awt.event.ActionEvent;
10 import java.awt.event.ActionListener;
11 import javax.swing.JFrame;
12 import javax.swing.JScrollPane;
13 import javax.swing.JTextArea;
14 import javax.swing.JTextField;
15 import javax.swing.SwingUtilities;
16
17 public class Client extends JFrame
18 {
19    private JTextField enterField; // for entering messages
20    private JTextArea displayArea; // for displaying messages
21    private DatagramSocket socket; // socket to connect to server
22
```

Fig. 27.11 | Client side of connectionless client/server computing with datagrams. (Part 1 of 7.)

```
23      // set up GUI and DatagramSocket
24      public Client()
25      {
26         super( "Client" );
27
28         enterField = new JTextField( "Type message here" );
29         enterField.addActionListener(
30            new ActionListener()
31            {
32               public void actionPerformed( ActionEvent event )
33               {
```

Fig. 27.11 | Client side of connectionless client/server computing with datagrams. (Part 2 of 7.)

```
34                try // create and send packet
35                {
36                   // get message from textfield
37                   String message = event.getActionCommand();
38                   displayArea.append( "\nSending packet containing: " +
39                      message + "\n" );
40
41                   byte[] data = message.getBytes(); // convert to bytes
42
43                   // create sendPacket
44                   DatagramPacket sendPacket = new DatagramPacket( data,
45                      data.length, InetAddress.getLocalHost(), 5000 );
46
47                   socket.send( sendPacket ); // send packet
48                   displayArea.append( "Packet sent\n" );
49                   displayArea.setCaretPosition(
50                      displayArea.getText().length() );
51                } // end try
```

Fig. 27.11 | Client side of connectionless client/server computing with datagrams. (Part 3 of 7.)

```
52                catch ( IOException ioException )
53                {
54                   displayMessage( ioException + "\n" );
55                   ioException.printStackTrace();
56                } // end catch
57             } // end actionPerformed
58          } // end inner class
59       ); // end call to addActionListener
60
61       add( enterField, BorderLayout.NORTH );
62
63       displayArea = new JTextArea();
64       add( new JScrollPane( displayArea ), BorderLayout.CENTER );
65
66       setSize( 400, 300 ); // set window size
67       setVisible( true ); // show window
68
```

Fig. 27.11 | Client side of connectionless client/server computing with datagrams. (Part 4 of 7.)

```
69          try // create DatagramSocket for sending and receiving packets
70          {
71             socket = new DatagramSocket();
72          } // end try
73          catch ( SocketException socketException )
74          {
75             socketException.printStackTrace();
76             System.exit( 1 );
77          } // end catch
78       } // end Client constructor
79
```

Fig. 27.11 | Client side of connectionless client/server computing with datagrams. (Part 5 of 7.)

```
80      // wait for packets to arrive from Server, display packet contents
81      public void waitForPackets()
82      {
83         while ( true )
84         {
85            try // receive packet and display contents
86            {
87               byte[] data = new byte[ 100 ]; // set up packet
88               DatagramPacket receivePacket = new DatagramPacket(
89                  data, data.length );
90
91               socket.receive( receivePacket ); // wait for packet
92
93               // display packet contents
94               displayMessage( "\nPacket received:" +
95                  "\nFrom host: " + receivePacket.getAddress() +
96                  "\nHost port: " + receivePacket.getPort() +
97                  "\nLength: " + receivePacket.getLength() +
98                  "\nContaining:\n\t" + new String( receivePacket.getData(),
99                     0, receivePacket.getLength() ) );
100           } // end try
```

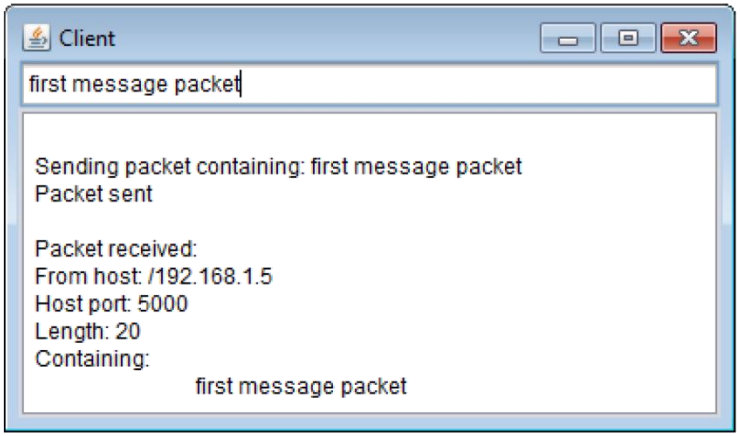
Fig. 27.11 | Client side of connectionless client/server computing with datagrams. (Part 6 of 7.)

```
101           catch ( IOException exception )
102           {
103              displayMessage( exception + "\n" );
104              exception.printStackTrace();
105           } // end catch
106        } // end while
107     } // end method waitForPackets
108
109     // manipulates displayArea in the event-dispatch thread
110     private void displayMessage( final String messageToDisplay )
111     {
112        SwingUtilities.invokeLater(
113           new Runnable()
114           {
115              public void run() // updates displayArea
116              {
117                 displayArea.append( messageToDisplay );
118              } // end method run
119           }  // end inner class
120        ); // end call to SwingUtilities.invokeLater
121     } // end method displayMessage
122  }  // end class Client
```

Fig. 27.11 | Client side of connectionless client/server computing with datagrams. (Part 7 of 7.)

```
1  // Fig. 27.12: ClientTest.java
2  // Tests the Client class.
3  import javax.swing.JFrame;
4
5  public class ClientTest
6  {
7     public static void main( String[] args )
8     {
9        Client application = new Client(); // create client
10       application.setDefaultCloseOperation( JFrame.EXIT_ON_CLOSE );
11       application.waitForPackets(); // run client application
12    } // end main
13 } // end class ClientTest
```

Fig. 27.12 | Class that tests the `Client`. (Part 1 of 2.)



`Client` window after sending packet to `Server` and receiving packet back from `Server`

Fig. 27.12 | Class that tests the `Client`. (Part 2 of 2.)

26.8 Client/Server Tic-Tac-Toe Using a Multithreaded Server

- Tic-Tac-Toe implemented by using client/server techniques with stream sockets.
- Sample outputs are shown in Fig. 27.17.
- As the `TicTacToeServer` receives each client connection, it creates an instance of inner-class `Player` to process the client in a separate thread.
- These threads enable the clients to play the game independently.
- The first client to connect to the server is player X and the second is player O.
- Player X makes the first move.
- The server maintains the information about the board so it can determine if a player's move is valid.

```
1  // Fig. 27.13: TicTacToeServer.java
2  // Server side of client/server Tic-Tac-Toe program.
3  import java.awt.BorderLayout;
4  import java.net.ServerSocket;
5  import java.net.Socket;
6  import java.io.IOException;
7  import java.util.Formatter;
8  import java.util.Scanner;
9  import java.util.concurrent.ExecutorService;
10 import java.util.concurrent.Executors;
11 import java.util.concurrent.locks.Lock;
12 import java.util.concurrent.locks.ReentrantLock;
13 import java.util.concurrent.locks.Condition;
14 import javax.swing.JFrame;
15 import javax.swing.JTextArea;
16 import javax.swing.SwingUtilities;
17
```

Fig. 27.13 | Server side of client/server Tic-Tac-Toe program. (Part 1 of 17.)

```
18  public class TicTacToeServer extends JFrame
19  {
20     private String[] board = new String[ 9 ]; // tic-tac-toe board
21     private JTextArea outputArea; // for outputting moves
22     private Player[] players; // array of Players
23     private ServerSocket server; // server socket to connect with clients
24     private int currentPlayer; // keeps track of player with current move
25     private final static int PLAYER_X = 0; // constant for first player
26     private final static int PLAYER_O = 1; // constant for second player
27     private final static String[] MARKS = { "X", "O" }; // array of marks
28     private ExecutorService runGame; // will run players
29     private Lock gameLock; // to lock game for synchronization
30     private Condition otherPlayerConnected; // to wait for other player
31     private Condition otherPlayerTurn; // to wait for other player's turn
32
33     // set up tic-tac-toe server and GUI that displays messages
34     public TicTacToeServer()
35     {
36        super( "Tic-Tac-Toe Server" ); // set title of window
37
38        // create ExecutorService with a thread for each player
39        runGame = Executors.newFixedThreadPool( 2 );
40        gameLock = new ReentrantLock(); // create lock for game
41
```

Fig. 27.13 | Server side of client/server Tic-Tac-Toe program. (Part 2 of 17.)

```
42          // condition variable for both players being connected
43          otherPlayerConnected = gameLock.newCondition();
44
45          // condition variable for the other player's turn
46          otherPlayerTurn = gameLock.newCondition();
47
48          for ( int i = 0; i < 9; i++ )
49             board[ i ] = new String( "" ); // create tic-tac-toe board
50          players = new Player[ 2 ]; // create array of players
51          currentPlayer = PLAYER_X; // set current player to first player
52
53          try
54          {
55             server = new ServerSocket( 12345, 2 ); // set up ServerSocket
56          } // end try
57          catch ( IOException ioException )
58          {
59             ioException.printStackTrace();
60             System.exit( 1 );
61          } // end catch
62
```

Fig. 27.13 | Server side of client/server Tic-Tac-Toe program. (Part 3 of 17.)

```
63          outputArea = new JTextArea(); // create JTextArea for output
64          add( outputArea, BorderLayout.CENTER );
65          outputArea.setText( "Server awaiting connections\n" );
66
67          setSize( 300, 300 ); // set size of window
68          setVisible( true ); // show window
69       } // end TicTacToeServer constructor
70
```

Fig. 27.13 | Server side of client/server Tic-Tac-Toe program. (Part 4 of 17.)

```
71      // wait for two connections so game can be played
72      public void execute()
73      {
74         // wait for each client to connect
75         for ( int i = 0; i < players.length; i++ )
76         {
77            try // wait for connection, create Player, start runnable
78            {
79               players[ i ] = new Player( server.accept(), i );
80               runGame.execute( players[ i ] ); // execute player runnable
81            } // end try
82            catch ( IOException ioException )
83            {
84               ioException.printStackTrace();
85               System.exit( 1 );
86            } // end catch
87         } // end for
88
```

Fig. 27.13 | Server side of client/server Tic-Tac-Toe program. (Part 5 of 17.)

```
89          gameLock.lock(); // lock game to signal player X's thread
90
91          try
92          {
93             players[ PLAYER_X ].setSuspended( false ); // resume player X
94             otherPlayerConnected.signal(); // wake up player X's thread
95          } // end try
96          finally
97          {
98             gameLock.unlock(); // unlock game after signalling player X
99          } // end finally
100      } // end method execute
101
```

Fig. 27.13 | Server side of client/server Tic-Tac-Toe program. (Part 6 of 17.)

```
102     // display message in outputArea
103     private void displayMessage( final String messageToDisplay )
104     {
105        // display message from event-dispatch thread of execution
106        SwingUtilities.invokeLater(
107           new Runnable()
108           {
109              public void run() // updates outputArea
110              {
111                 outputArea.append( messageToDisplay ); // add message
112              } // end  method run
113           } // end inner class
114        ); // end call to SwingUtilities.invokeLater
115     } // end method displayMessage
116
```

Fig. 27.13 | Server side of client/server Tic-Tac-Toe program. (Part 7 of 17.)

```
117     // determine if move is valid
118     public boolean validateAndMove( int location, int player )
119     {
120        // while not current player, must wait for turn
121        while ( player != currentPlayer )
122        {
123           gameLock.lock(); // lock game to wait for other player to go
124
125           try
126           {
127              otherPlayerTurn.await(); // wait for player's turn
128           } // end try
129           catch ( InterruptedException exception )
130           {
131              exception.printStackTrace();
132           } // end catch
133           finally
134           {
135              gameLock.unlock(); // unlock game after waiting
136           } // end finally
137        } // end while
138
```

Fig. 27.13 | Server side of client/server Tic-Tac-Toe program. (Part 8 of 17.)

```
139         // if location not occupied, make move
140         if ( !isOccupied( location ) )
141         {
142            board[ location ] = MARKS[ currentPlayer ]; // set move on board
143            currentPlayer = ( currentPlayer + 1 ) % 2; // change player
144
145            // let new current player know that move occurred
146            players[ currentPlayer ].otherPlayerMoved( location );
147
148            gameLock.lock(); // lock game to signal other player to go
149
150            try
151            {
152               otherPlayerTurn.signal(); // signal other player to continue
153            } // end try
154            finally
155            {
156               gameLock.unlock(); // unlock game after signaling
157            } // end finally
158
```

Fig. 27.13 | Server side of client/server Tic-Tac-Toe program. (Part 9 of 17.)

```
159            return true; // notify player that move was valid
160         } // end if
161         else // move was not valid
162            return false; // notify player that move was invalid
163      } // end method validateAndMove
164
165      // determine whether location is occupied
166      public boolean isOccupied( int location )
167      {
168         if ( board[ location ].equals( MARKS[ PLAYER_X ] ) ||
169            board [ location ].equals( MARKS[ PLAYER_O ] ) )
170            return true; // location is occupied
171         else
172            return false; // location is not occupied
173      } // end method isOccupied
174
175      // place code in this method to determine whether game over
176      public boolean isGameOver()
177      {
178         return false; // this is left as an exercise
179      } // end method isGameOver
180
```

Fig. 27.13 | Server side of client/server Tic-Tac-Toe program. (Part 10 of 17.)

```
181    // private inner class Player manages each Player as a runnable
182    private class Player implements Runnable
183    {
184       private Socket connection; // connection to client
185       private Scanner input; // input from client
186       private Formatter output; // output to client
187       private int playerNumber; // tracks which player this is
188       private String mark; // mark for this player
189       private boolean suspended = true; // whether thread is suspended
190
191       // set up Player thread
192       public Player( Socket socket, int number )
193       {
194          playerNumber = number; // store this player's number
195          mark = MARKS[ playerNumber ]; // specify player's mark
196          connection = socket; // store socket for client
197
```

Fig. 27.13 | Server side of client/server Tic-Tac-Toe program. (Part 11 of 17.)

```
198          try // obtain streams from Socket
199          {
200             input = new Scanner( connection.getInputStream() );
201             output = new Formatter( connection.getOutputStream() );
202          } // end try
203          catch ( IOException ioException )
204          {
205             ioException.printStackTrace();
206             System.exit( 1 );
207          } // end catch
208       } // end Player constructor
209
210       // send message that other player moved
211       public void otherPlayerMoved( int location )
212       {
213          output.format( "Opponent moved\n" );
214          output.format( "%d\n", location ); // send location of move
215          output.flush(); // flush output
216       } // end method otherPlayerMoved
217
```

Fig. 27.13 | Server side of client/server Tic-Tac-Toe program. (Part 12 of 17.)

```
218         // control thread's execution
219         public void run()
220         {
221            // send client its mark (X or O), process messages from client
222            try
223            {
224               displayMessage( "Player " + mark + " connected\n" );
225               output.format( "%s\n", mark ); // send player's mark
226               output.flush(); // flush output
227
```

Fig. 27.13 | Server side of client/server Tic-Tac-Toe program. (Part 13 of 17.)

```
228             // if player X, wait for another player to arrive
229             if ( playerNumber == PLAYER_X )
230             {
231                output.format( "%s\n%s", "Player X connected",
232                   "Waiting for another player\n" );
233                output.flush(); // flush output
234
235                gameLock.lock(); // lock game to  wait for second player
236
237                try
238                {
239                   while( suspended )
240                   {
241                      otherPlayerConnected.await(); // wait for player O
242                   } // end while
243                } // end try
244                catch ( InterruptedException exception )
245                {
246                   exception.printStackTrace();
247                } // end catch
248                finally
249                {
250                   gameLock.unlock(); // unlock game after second player
251                } // end finally
```

Fig. 27.13 | Server side of client/server Tic-Tac-Toe program. (Part 14 of 17.)

```
252
253                // send message that other player connected
254                output.format( "Other player connected. Your move.\n" );
255                output.flush(); // flush output
256             } // end if
257             else
258             {
259                output.format( "Player O connected, please wait\n" );
260                output.flush(); // flush output
261             } // end else
262
263             // while game not over
264             while ( !isGameOver() )
265             {
266                int location = 0; // initialize move location
267
268                if ( input.hasNext() )
269                   location = input.nextInt(); // get move location
270
```

Fig. 27.13 | Server side of client/server Tic-Tac-Toe program. (Part 15 of 17.)

```
271                // check for valid move
272                if ( validateAndMove( location, playerNumber ) )
273                {
274                   displayMessage( "\nlocation: " + location );
275                   output.format( "Valid move.\n" ); // notify client
276                   output.flush(); // flush output
277                } // end if
278                else // move was invalid
279                {
280                   output.format( "Invalid move, try again\n" );
281                   output.flush(); // flush output
282                } // end else
283             } // end while
284          } // end try
```

Fig. 27.13 | Server side of client/server Tic-Tac-Toe program. (Part 16 of 17.)

```
285            finally
286            {
287               try
288               {
289                  connection.close(); // close connection to client
290               } // end try
291               catch ( IOException ioException )
292               {
293                  ioException.printStackTrace();
294                  System.exit( 1 );
295               } // end catch
296            } // end finally
297         } // end method run
298
299         // set whether or not thread is suspended
300         public void setSuspended( boolean status )
301         {
302            suspended = status; // set value of suspended
303         } // end method setSuspended
304      } // end class Player
305   } // end class TicTacToeServer
```

Fig. 27.13 | Server side of client/server Tic-Tac-Toe program. (Part 17 of 17.)

```
1  // Fig. 27.14: TicTacToeServerTest.java
2  // Class that tests Tic-Tac-Toe server.
3  import javax.swing.JFrame;
4
5  public class TicTacToeServerTest
6  {
7     public static void main( String[] args )
8     {
9        TicTacToeServer application = new TicTacToeServer();
10       application.setDefaultCloseOperation( JFrame.EXIT_ON_CLOSE );
11       application.execute();
12    } // end main
13 } // end class TicTacToeServerTest
```

Fig. 27.14 | Class that tests Tic-Tac-Toe server. (Part 1 of 2.)

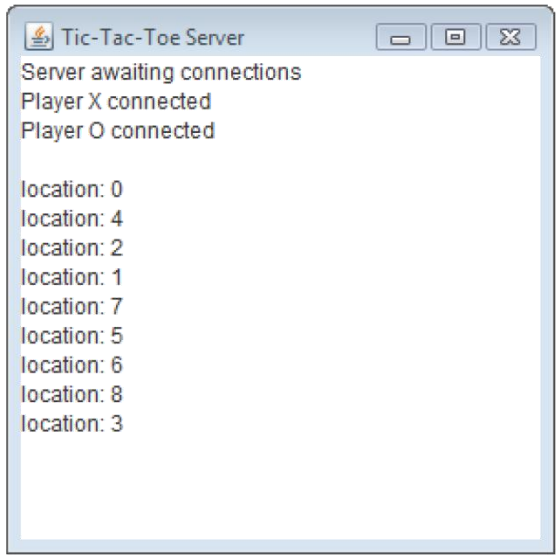


Fig. 27.14 | Class that tests Tic-Tac-Toe server. (Part 2 of 2.)

26.8 Client/Server Tic-Tac-Toe Using a Multithreaded Server (cont.)

- When a client connects, a new `Player` object is created to manage the connection as a separate thread, and the thread is executed in the `runGame` thread pool.
- The `Player` constructor receives the `Socket` object representing the connection to the client and gets the associated input and output streams.
- The `Player`'s `run` method controls the information that is sent to and received from the client.

```
1  // Fig. 27.15: TicTacToeClient.java
2  // Client side of client/server Tic-Tac-Toe program.
3  import java.awt.BorderLayout;
4  import java.awt.Dimension;
5  import java.awt.Graphics;
6  import java.awt.GridLayout;
7  import java.awt.event.MouseAdapter;
8  import java.awt.event.MouseEvent;
9  import java.net.Socket;
10 import java.net.InetAddress;
11 import java.io.IOException;
12 import javax.swing.JFrame;
13 import javax.swing.JPanel;
14 import javax.swing.JScrollPane;
15 import javax.swing.JTextArea;
16 import javax.swing.JTextField;
17 import javax.swing.SwingUtilities;
18 import java.util.Formatter;
19 import java.util.Scanner;
20 import java.util.concurrent.Executors;
21 import java.util.concurrent.ExecutorService;
22
```

Fig. 27.15 | Client side of client/server Tic-Tac-Toe program. (Part 1 of 14.)

```
23  public class TicTacToeClient extends JFrame implements Runnable
24  {
25     private JTextField idField; // textfield to display player's mark
26     private JTextArea displayArea; // JTextArea to display output
27     private JPanel boardPanel; // panel for tic-tac-toe board
28     private JPanel panel2; // panel to hold board
29     private Square[][] board; // tic-tac-toe board
30     private Square currentSquare; // current square
31     private Socket connection; // connection to server
32     private Scanner input; // input from server
33     private Formatter output; // output to server
34     private String ticTacToeHost; // host name for server
35     private String myMark; // this client's mark
36     private boolean myTurn; // determines which client's turn it is
37     private final String X_MARK = "X"; // mark for first client
38     private final String O_MARK = "O"; // mark for second client
39
```

Fig. 27.15 | Client side of client/server Tic-Tac-Toe program. (Part 2 of 14.)

```
40      // set up user-interface and board
41      public TicTacToeClient( String host )
42      {
43         ticTacToeHost = host; // set name of server
44         displayArea = new JTextArea( 4, 30 ); // set up JTextArea
45         displayArea.setEditable( false );
46         add( new JScrollPane( displayArea ), BorderLayout.SOUTH );
47
48         boardPanel = new JPanel(); // set up panel for squares in board
49         boardPanel.setLayout( new GridLayout( 3, 3, 0, 0 ) );
50
51         board = new Square[ 3 ][ 3 ]; // create board
52
53         // loop over the rows in the board
54         for ( int row = 0; row < board.length; row++ )
55         {
56            // loop over the columns in the board
57            for ( int column = 0; column < board[ row ].length; column++ )
58            {
59               // create square
60               board[ row ][ column ] = new Square( ' ', row * 3 + column );
61               boardPanel.add( board[ row ][ column ] ); // add square
62            } // end inner for
63         } // end outer for
```

Fig. 27.15 | Client side of client/server Tic-Tac-Toe program. (Part 3 of 14.)

```
64
65          idField = new JTextField(); // set up textfield
66          idField.setEditable( false );
67          add( idField, BorderLayout.NORTH );
68
69          panel2 = new JPanel(); // set up panel to contain boardPanel
70          panel2.add( boardPanel, BorderLayout.CENTER ); // add board panel
71          add( panel2, BorderLayout.CENTER ); // add container panel
72
73          setSize( 300, 225 ); // set size of window
74          setVisible( true ); // show window
75
76          startClient();
77       } // end TicTacToeClient constructor
78
```

Fig. 27.15 | Client side of client/server Tic-Tac-Toe program. (Part 4 of 14.)

```
79      // start the client thread
80      public void startClient()
81      {
82         try // connect to server and get streams
83         {
84            // make connection to server
85            connection = new Socket(
86               InetAddress.getByName( ticTacToeHost ), 12345 );
87
88            // get streams for input and output
89            input = new Scanner( connection.getInputStream() );
90            output = new Formatter( connection.getOutputStream() );
91         } // end try
92         catch ( IOException ioException )
93         {
94            ioException.printStackTrace();
95         } // end catch
96
97         // create and start worker thread for this client
98         ExecutorService worker = Executors.newFixedThreadPool( 1 );
99         worker.execute( this ); // execute client
100     } // end method startClient
101
```

Fig. 27.15 | Client side of client/server Tic-Tac-Toe program. (Part 5 of 14.)

```
102     // control thread that allows continuous update of displayArea
103     public void run()
104     {
105        myMark = input.nextLine(); // get player's mark (X or O)
106
107        SwingUtilities.invokeLater(
108           new Runnable()
109           {
110              public void run()
111              {
112                 // display player's mark
113                 idField.setText( "You are player \"" + myMark + "\"" );
114              } // end method run
115           } // end anonymous inner class
116        ); // end call to SwingUtilities.invokeLater
117
118        myTurn = ( myMark.equals( X_MARK ) ); // determine if client's turn
119
120        // receive messages sent to client and output them
121        while ( true )
122        {
123           if ( input.hasNextLine() )
124              processMessage( input.nextLine() );
125        } // end while
126     } // end method run
```

Fig. 27.15 -Tac-Toe program. (Part 6 of 14.)

```
127
128     // process messages received by client
129     private void processMessage( String message )
130     {
131        // valid move occurred
132        if ( message.equals( "Valid move." ) )
133        {
134           displayMessage( "Valid move, please wait.\n" );
135           setMark( currentSquare, myMark ); // set mark in square
136        } // end if
137        else if ( message.equals( "Invalid move, try again" ) )
138        {
139           displayMessage( message + "\n" ); // display invalid move
140           myTurn = true; // still this client's turn
141        } // end else if
```

Fig. 27.15 | Client side of client/server Tic-Tac-Toe program. (Part 7 of 14.)

```
142         else if ( message.equals( "Opponent moved" ) )
143         {
144            int location = input.nextInt(); // get move location
145            input.nextLine(); // skip newline after int location
146            int row = location / 3; // calculate row
147            int column = location % 3; // calculate column
148
149            setMark(  board[ row ][ column ],
150               ( myMark.equals( X_MARK ) ? O_MARK : X_MARK ) ); // mark move
151            displayMessage( "Opponent moved. Your turn.\n" );
152            myTurn = true; // now this client's turn
153         } // end else if
154         else
155            displayMessage( message + "\n" ); // display the message
156      } // end method processMessage
157
```

Fig. 27.15 | Client side of client/server Tic-Tac-Toe program. (Part 8 of 14.)

```
158     // manipulate displayArea in event-dispatch thread
159     private void displayMessage( final String messageToDisplay )
160     {
161        SwingUtilities.invokeLater(
162           new Runnable()
163           {
164              public void run()
165              {
166                 displayArea.append( messageToDisplay ); // updates output
167              } // end method run
168           }  // end inner class
169        ); // end call to SwingUtilities.invokeLater
170     } // end method displayMessage
171
```

Fig. 27.15 | Client side of client/server Tic-Tac-Toe program. (Part 9 of 14.)

```
172     // utility method to set mark on board in event-dispatch thread
173     private void setMark( final Square squareToMark, final String mark )
174     {
175        SwingUtilities.invokeLater(
176           new Runnable()
177           {
178              public void run()
179              {
180                 squareToMark.setMark( mark ); // set mark in square
181              } // end method run
182           } // end anonymous inner class
183        ); // end call to SwingUtilities.invokeLater
184     } // end method setMark
185
```

Fig. 27.15 | Client side of client/server Tic-Tac-Toe program. (Part 10 of 14.)

```
186     // send message to server indicating clicked square
187     public void sendClickedSquare( int location )
188     {
189        // if it is my turn
190        if ( myTurn )
191        {
192           output.format( "%d\n", location ); // send location to server
193           output.flush();
194           myTurn = false; // not my turn any more
195        } // end if
196     } // end method sendClickedSquare
197
198     // set current Square
199     public void setCurrentSquare( Square square )
200     {
201        currentSquare = square; // set current square to argument
202     } // end method setCurrentSquare
203
```

Fig. 27.15 | Client side of client/server Tic-Tac-Toe program. (Part 11 of 14.)

```
204    // private inner class for the squares on the board
205    private class Square extends JPanel
206    {
207       private String mark; // mark to be drawn in this square
208       private int location; // location of square
209
210       public Square( String squareMark, int squareLocation )
211       {
212          mark = squareMark; // set mark for this square
213          location = squareLocation; // set location of this square
214
215          addMouseListener(
216             new MouseAdapter()
217             {
218                public void mouseReleased( MouseEvent e )
219                {
220                   setCurrentSquare( Square.this ); // set current square
221
222                   // send location of this square
223                   sendClickedSquare( getSquareLocation() );
224                } // end method mouseReleased
225             } // end anonymous inner class
226          ); // end call to addMouseListener
227       } // end Square constructor
```

Fig. 27.15 | Client side of client/server Tic-Tac-Toe program. (Part 12 of 14.)

```
228
229         // return preferred size of Square
230         public Dimension getPreferredSize()
231         {
232            return new Dimension( 30, 30 ); // return preferred size
233         } // end method getPreferredSize
234
235         // return minimum size of Square
236         public Dimension getMinimumSize()
237         {
238            return getPreferredSize(); // return preferred size
239         } // end method getMinimumSize
240
241         // set mark for Square
242         public void setMark( String newMark )
243         {
244            mark = newMark; // set mark of square
245            repaint(); // repaint square
246         } // end method setMark
247
```

Fig. 27.15 | Client side of client/server Tic-Tac-Toe program. (Part 13 of 14.)

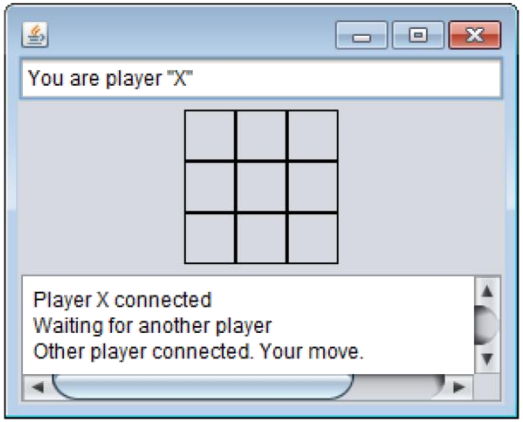
```
248         // return Square location
249         public int getSquareLocation()
250         {
251            return location; // return location of square
252         } // end method getSquareLocation
253
254         // draw Square
255         public void paintComponent( Graphics g )
256         {
257            super.paintComponent( g );
258
259            g.drawRect( 0, 0, 29, 29 ); // draw square
260            g.drawString( mark, 11, 20 ); // draw mark
261         } // end method paintComponent
262      } // end inner-class Square
263   } // end class TicTacToeClient
```

Fig. 27.15 | Client side of client/server Tic-Tac-Toe program. (Part 14 of 14.)

```
1  // Fig. 27.16: TicTacToeClientTest.java
2  // Test class for Tic-Tac-Toe client.
3  import javax.swing.JFrame;
4
5  public class TicTacToeClientTest
6  {
7     public static void main( String[] args )
8     {
9        TicTacToeClient application; // declare client application
10
11       // if no command line args
12       if ( args.length == 0 )
13          application = new TicTacToeClient( "127.0.0.1" ); // localhost
14       else
15          application = new TicTacToeClient( args[ 0 ] ); // use args
16
17       application.setDefaultCloseOperation( JFrame.EXIT_ON_CLOSE );
18    } // end main
19 } // end class TicTacToeClientTest
```

Fig. 27.16 | Test class for Tic-Tac-Toe client.

a) Player X connected to server.



b) Player O connected to server.

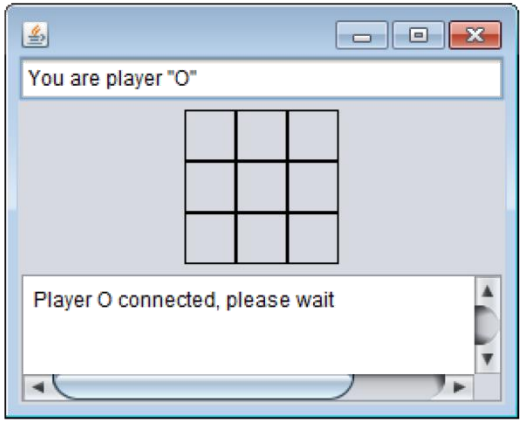
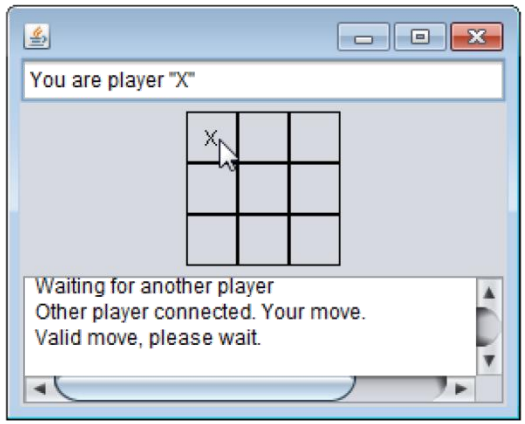


Fig. 27.17 | Sample outputs from the client/server Tic-Tac-Toe program. (Part 1 of 4.)

c) Player X moved.



d) Player O sees Player X's move.

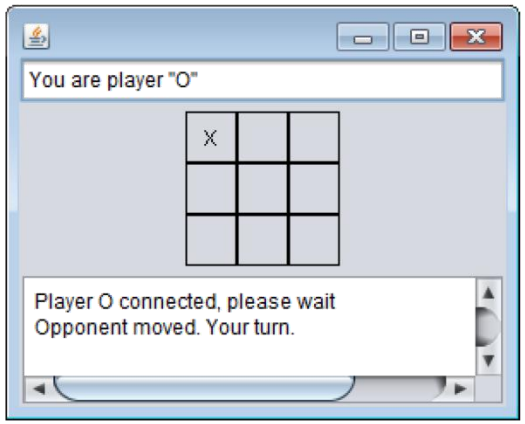
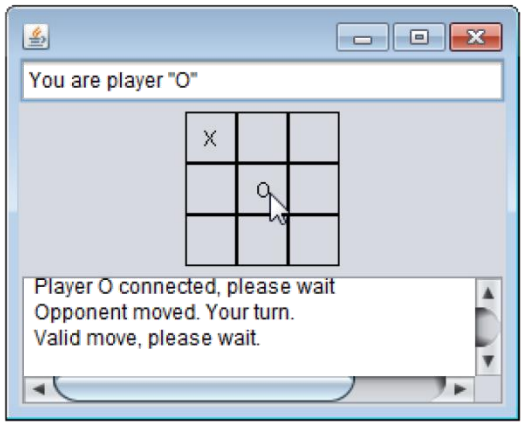


Fig. 27.17 | Sample outputs from the client/server Tic-Tac-Toe program. (Part 2 of 4.)

e) Player O moved.



f) Player X sees Player O's move.

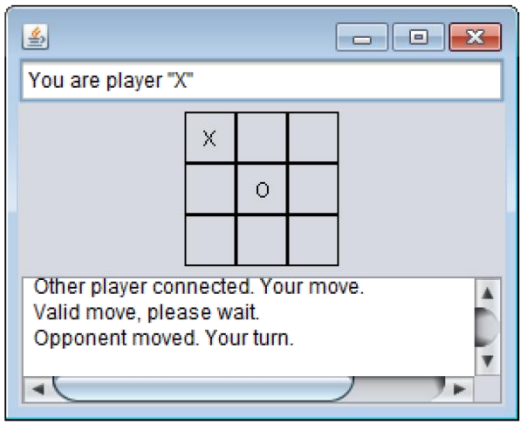
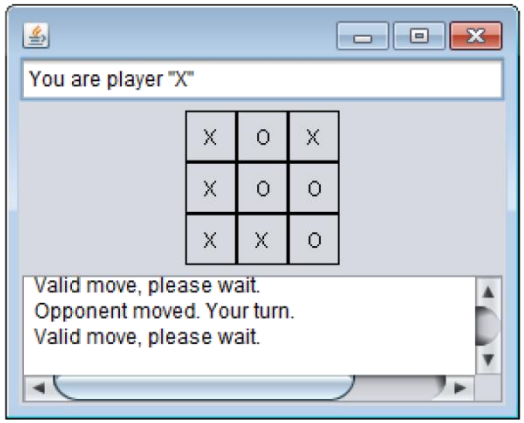


Fig. 27.17 | Sample outputs from the client/server Tic-Tac-Toe program. (Part 3 of 4.)

g) Player X moved.



h) Player O sees Player X's last move.

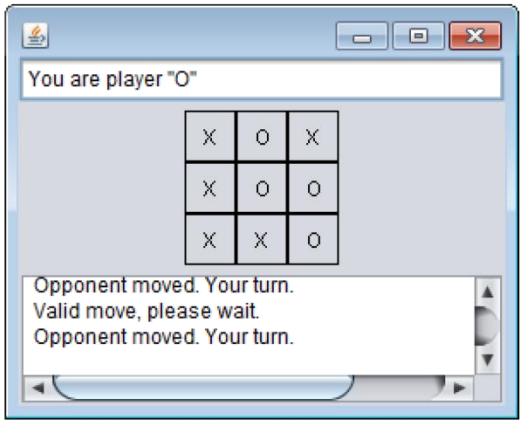


Fig. 27.17 | Sample outputs from the client/server Tic-Tac-Toe program. (Part 4 of 4.)