

CNT 4714: Enterprise Computing Fall 2011

Java Networking and the Internet – Part 3

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Using Java's High-level Networking Capabilities

- As we saw earlier, the TCP and UDP protocols are at the transport layer within the Internet Reference Model. As far as Java is concerned, these provide “low-level” networking capability.
- Java also provides application layer networking protocol capabilities to allow for communication between applications.
- In the examples we have seen so far, it was the developer's responsibility to establish a connection between the client and the server (in the case of the UDP protocol, its more a process of establishing the sockets since there is no connection between the client and the server in this protocol).



Using Java's High-level Networking Capabilities (cont.)

- The next example illustrate Java's application layer capabilities which remove the responsibility of establishing the network connection from the developer.
- The example relies on a Web browser to establish the communication link to a Web server. (This one uses an applet to open a specific URL. Using a URL as an argument to the `showDocument` method of interface `AppletContext`, causes the browser in which the applet is executing to display that resource.)



Example 1 – SiteSelector Applet

```
<html>
<title>Site Selector</title>
<body>
  <applet code = "SiteSelector.class" width = "300" height = "75">
    <param name = "title0" value = "Java Home Page">
    <param name = "location0" value = "http://www.java.sun.com/">
    <param name = "title1" value = "CNT 47174 Home Page">
    <param name = "location1" value = "http://www.cs.ucf.edu/courses/cnt4714/fall2011">
    <param name = "title2" value = "World Cycling News">
    <param name = "location2" value = "http://www.cyclingnews.com/">
    <param name = "title3" value = "Formula 1 News">
    <param name = "location3" value = "http://www.formula1.com/">
  </applet>
</body>
</html>
```

HTML document to load the SiteSelector Applet



Example 1 – SiteSelector Applet (cont.)

```
// SiteSelector.java
// This program loads a document from a URL.
import java.net.MalformedURLException;
import java.net.URL;
import java.util.HashMap;
import java.util.ArrayList;
import java.awt.BorderLayout;
import java.applet.AppletContext;
import javax.swing.JApplet;
import javax.swing.JLabel;
import javax.swing.JList;
import javax.swing.JScrollPane;
import javax.swing.event.ListSelectionEvent;
import javax.swing.event.ListSelectionListener;

public class SiteSelector extends JApplet
{
    private HashMap< Object, URL > sites; // site names and URLs
    private ArrayList< String > siteNames; // site names
    private JList siteChooser; // list of sites to choose from

    // read HTML parameters and set up GUI
```



Example 1 – SiteSelector Applet (cont.)

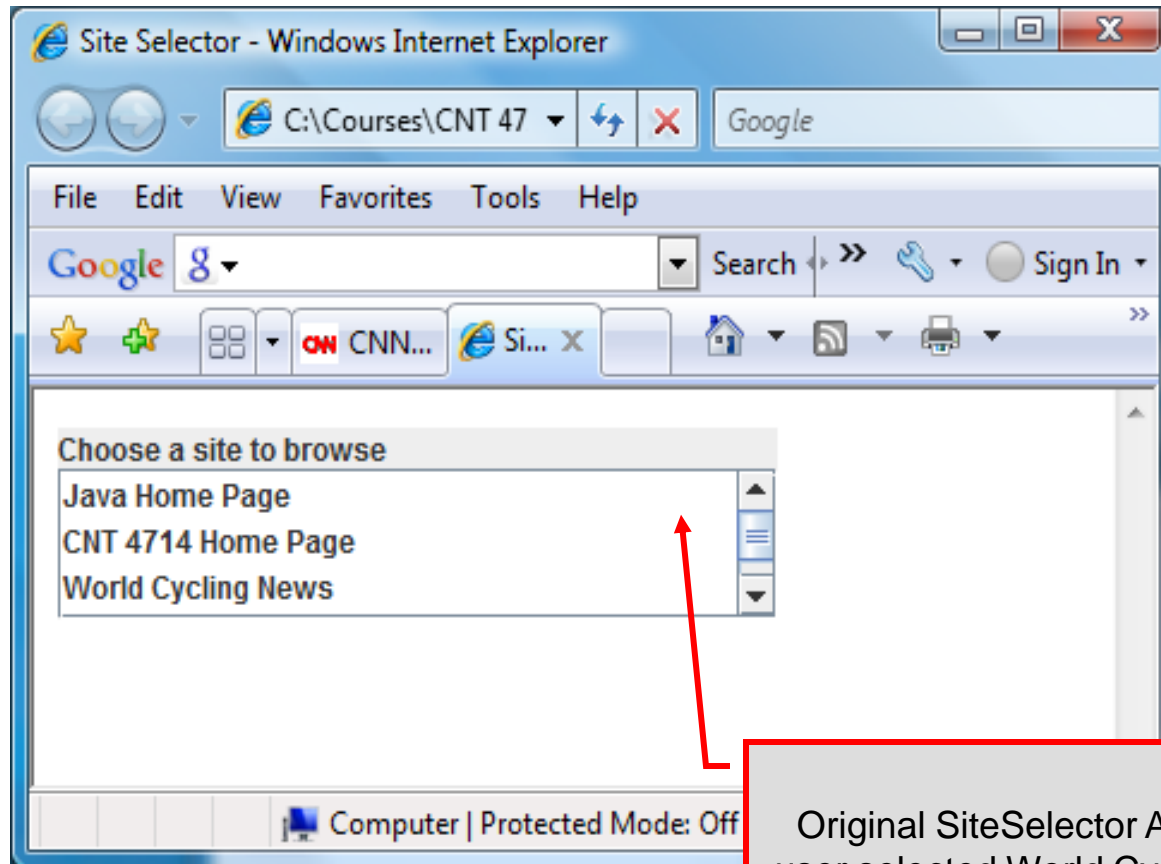
```
public void init()
{
    sites = new HashMap< Object, URL >(); // create HashMap
    siteNames = new ArrayList< String >(); // create ArrayList
    // obtain parameters from HTML document
    getSitesFromHTMLParameters();
    // create GUI components and layout interface
    add( new JLabel( "Choose a site to browse" ), BorderLayout.NORTH );
    siteChooser = new JList( siteNames.toArray() ); // populate JList
    siteChooser.addListSelectionListener(
        new ListSelectionListener() // anonymous inner class
        {
            // go to site user selected
            public void valueChanged( ListSelectionEvent event )
            {
                // get selected site name
                Object object = siteChooser.getSelectedValue();
                // use site name to locate corresponding URL
                URL newDocument = sites.get( object );
                // get applet container
                AppletContext browser = getAppletContext();
                // tell applet container to change pages
                browser.showDocument( newDocument );
            } // end method valueChanged
        } // end anonymous inner class
    ); // end call to addListSelectionListener
}
```



Example 1 – SiteSelector Applet (cont.)

```
add( new JScrollPane( siteChooser ), BorderLayout.CENTER );
} // end method init
// obtain parameters from HTML document
private void getSitesFromHTMLParameters()
{
    String title; // site title
    String location; // location of site
    URL url; // URL of location
    int counter = 0; // count number of sites
    title = getParameter( "title" + counter ); // get first site title
    // loop until no more parameters in HTML document
    while ( title != null )
    {
        // obtain site location
        location = getParameter( "location" + counter );
        try // place title/URL in HashMap and title in ArrayList
        {
            url = new URL( location ); // convert location to URL
            sites.put( title, url ); // put title/URL in HashMap
            siteNames.add( title ); // put title in ArrayList
        } // end try
        catch ( MalformedURLException urlException )
        {
            urlException.printStackTrace();
        } // end catch
        counter++;
        title = getParameter( "title" + counter
    ); // get next site title
    } // end while
} // end method
getSitesFromHTMLParameters
} // end class SiteSelector
```





Original SiteSelector Applet before user selected World Cycling News as the resource to be opened. Once selected this brought up the webpage shown behind the applet invocation.



Cycling News & Race Results | Cyclingnews.com - Windows Internet Explorer


http://www.cyclingnews.com/

File Edit View Favorites Tools Help

Google

Favorites Suggested Sites Free Hotmail Web Slice Gallery

Cycling News & Race Results | Cyclingnews.com



Yeti ASR5 Carbon w/ SRAM
Now \$3,699 /Reg \$5,4



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Major Races: Tour de France Giro d'Italia Vuelta a España 2012 Olympics

Today on **cyclingnews**

- Interbike 2011: Mad Fiber unveils clever new carbon clinchers**
Sub 1250g wheel has a carbon-aluminium combination
- Boom strikes in Stoke-on-Trent**
Dutchman takes over race lead at Tour of Britain
- Gilbert plays mind games with his world championship rivals**
Belgian insists he is not the favourite for Copenhagen
- 2011 Eurobike: Component highlights from Ritchey, Hope, Deda, Syncros, Tune, AX Light**
- Wloszczowska wins Bike the Rock in Heubach**
Vogel victorious in men's race

Site Selector - Windows Internet Explorer

C:\Courses\CNT 47 Google

File Edit View Favorites Tools Help

Google Search Sign In

Favorites CNN Si...

Choose a site to browse

- Java Home Page
- CNT 4714 Home Page
- World Cycling News

Computer | Protected Mode: Off 100%

Original SiteSelector Applet before user selected World Cycling News as the resource to be opened. Once selected this brought up the webpage shown behind the applet invocation.



Secure Sockets Layer (SSL)

- Most e-business uses SSL for secure on-line transactions.
- SSL does not explicitly secure transactions, but rather secures connections.
- SSL implements public-key technology using the RSA algorithm (developed in 1977 at MIT by Ron Rivest, Adi Shamir, and Leonard Adleman) and digital certificates to authenticate the server in a transaction and to protect private information as it passes from one part to another over the Internet.
- SSL transactions do not require client authentication as most servers consider a valid credit-card number to be sufficient for authenticating a secure purchase.



How SSL Works

- Initially, a client sends a message to a server.
- The server responds and sends its digital certificate to the client for authentication.
- Using public-key cryptography to communicate securely, the client and server negotiate **session keys** to continue the transaction.
- Once the session keys are established, the communication proceeds between the client and server using the session keys and digital certificates.
- Encrypted data are passed through TCP/IP (just as regular packets over the Internet). However, before sending a message with TCP/IP, the SSL protocol breaks the information into blocks and compresses and encrypts those blocks.



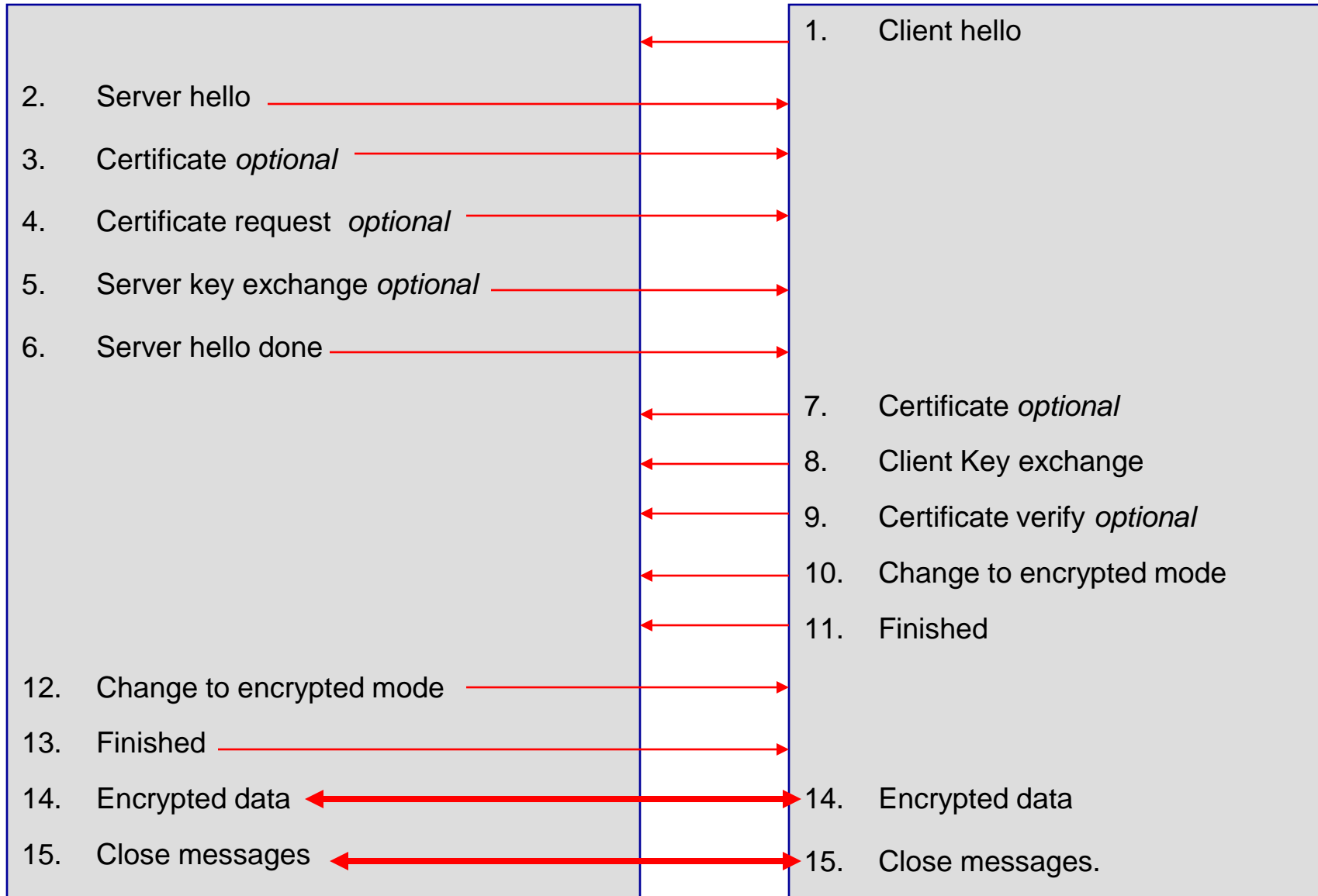
How SSL Works (cont.)

- Once the data reach the receiver through TCP/IP, the SSL protocol decrypts the packets, then decompresses and assembles the data. It is these extra processes that provide an extra layer of security between TCP/IP and applications.
- SSL is used primarily to secure point-to-point connections using TCP/IP rather than UDP/IP.
- The SSL protocol allows for authentication of the server, the client, both, or neither. Although typically in Internet SSL sessions only the server is authenticated.



SERVER

CLIENT



Details Of The SSL Protocol

- Use the diagram on the previous page to index the steps.
 1. **Client hello.** The client sends the server information including the highest level of SSL it supports and a list of the cipher suites it supports including cryptographic algorithms and key sizes.
 2. **Server hello.** The server chooses the highest version of SSL and the best cipher suite that both the client and server support and sends this information to the client.



Details Of The SSL Protocol (cont.)

- 3. Certificate.** The server sends the client a certificate or a certificate chain. Optional but used whenever server authentication is required.
- 4. Certificate Request.** If the server needs to authenticate the client, it sends the client a certificate request. In most Internet applications this message is rarely sent.
- 5. Server key exchange.** The server sends the client a server key exchange message when the public key information sent in (3) above is not sufficient for key exchange.



Details Of The SSL Protocol (cont.)

6. **Server hello done.** The server tells the client that it is finished with its initial negotiation messages.
7. **Certificate.** If the server requests a certificate from the client in (4), the client sends its certificate chain, just as the server did in (3).
8. **Client key exchange.** The client generates information used to create a key to use for symmetric encryption. For RSA, the client then encrypts this key information with the server's public key and sends it to the server.



Details Of The SSL Protocol (cont.)

9. **Certificate verify.** This message is sent when a client presents a certificate as above. Its purpose is to allow the server to complete the process of authenticating the client. When this message is used, the client sends information that it digitally signs using a cryptographic hash function. When the server decrypts this information with the client's public key, the server is able to authenticate the client.
10. **Change to encrypted mode.** The client sends a message telling the server to change to encrypted mode.
11. **Finished.** The client tells the server that it is ready for secure data communication to begin.



Details Of The SSL Protocol (cont.)

12. **Change to encrypted mode.** The server sends a message telling the client to switch to encrypted mode.
13. **Finished.** The server tells the client that it is ready for secure data communication to begin. This marks the end of the SSL handshake.
14. **Encrypted data.** The client and the server communicate using the symmetric encryption algorithm and the cryptographic hash function negotiated in (1) and (2), and using the secret key that the client sent to the server in (8).
15. **Close messages.** At the end of the connection, each side will send a `close_notify` message to inform the peer that the connection is closed.



Java Secure Socket Extension (JSSE)

- SSL encryption has been integrated into Java technology through the Java Secure Socket Extension (JSSE). JSSE has been an integral part of Java (not a separately loaded extension) since version 1.4.
- JSSE provides encryption, message integrity checks, and authentication of the server and client.
- JSSE uses **keystores** to secure storage of key pairs and certificates used in PKI (Public Key Infrastructure which integrates public-key cryptography with digital certificates and certificate authorities to authenticate parties in a transaction.)
- A **truststore** is a keystore that contains keys and certificates used to validate the identities of servers and clients.



Java Secure Socket Extension (JSSE) (cont.)

- Using secure sockets in Java is very similar to using the non-secure sockets that we have already seen.
- JSSE hides the details of the SSL protocol and encryption from the programmer entirely.
- The final example in this set of notes involves a client application that attempts to logon to a server using SSL.
- **NOTE:** Before attempting to execute this application, look at the code first and then go to page 26 for execution details. This application will not execute correctly unless you follow the steps beginning on page 26.



```
// LoginServer.java
// LoginServer uses an SSLServerSocket to demonstrate JSSE's SSL implementation.
package securitystuff.jsse;
```

```
// Java core packages
import java.io.*;
```

```
// Java extension packages
import javax.net.ssl.*;
```

```
public class LoginServer {
    private static final String CORRECT_USER_NAME = "Mark";
    private static final String CORRECT_PASSWORD = "CNT 4714";
    private SSLServerSocket serverSocket;
```

```
// LoginServer constructor
```

```
public LoginServer() throws Exception
{
```

```
    // SSLServerSocketFactory for building SSLServerSockets
```

```
    SSLServerSocketFactory socketFactory =
        ( SSLServerSocketFactory )
        SSLServerSocketFactory.getDefault();
```

```
    // create SSLServerSocket on specified port
```

```
    serverSocket = ( SSLServerSocket )
        socketFactory.createServerSocket( 7070 );
```

```
} // end LoginServer constructor
```

LoginServer.java
SSL Server Implementation

Use default
SSLServerSocketFactory to
create SSL sockets

SSL socket will listen on port 7070



```

// start server and listen for clients
private void runServer()
{
    // perpetually listen for clients
    while ( true ) {
        // wait for client connection and check login information
        try {
            System.err.println( "Waiting for connection..." );
            // create new SSLSocket for client
            SSLSocket socket = ( SSLSocket ) serverSocket.accept();
            // open BufferedReader for reading data from client
            BufferedReader input = new BufferedReader(
                new InputStreamReader( socket.getInputStream() ) );
            // open PrintWriter for writing data to client
            PrintWriter output = new PrintWriter(
                new OutputStreamWriter( socket.getOutputStream() ) );
            String userName = input.readLine();
            String password = input.readLine();
            if ( userName.equals( CORRECT_USER_NAME ) &&
                password.equals( CORRECT_PASSWORD ) ) {
                output.println( "Welcome, " + userName );
            }
            else {
                output.println( "Login Failed." );
            }
        }
    }
}

```

Accept new client connection. This is a blocking call that returns an SSLSocket when a client connects.

Get input and output streams just as with normal sockets.

Validate user name and password against constants on the server.



```
// clean up streams and SSLSocket
```

```
output.close();
```

```
input.close();
```

```
socket.close();
```

Close down I/O streams and the socket

```
} // end try
```

```
// handle exception communicating with client
```

```
catch ( IOException ioException ) {
```

```
    ioException.printStackTrace();
```

```
}
```

```
} // end while
```

```
} // end method runServer
```

```
// execute application
```

```
public static void main( String args[] ) throws Exception
```

```
{
```

```
    LoginServer server = new LoginServer();
```

```
    server.runServer();
```

```
}
```

```
} //end LoginServer class
```



```
// LoginClient.java
// LoginClient uses an SSLSocket to transmit fake login information to LoginServer.
```

```
package securitystuff.jsse;
// Java core packages
import java.io.*;
// Java extension packages
import javax.swing.*;
import javax.net.ssl.*;
```

LoginClient.java
Client Class for SSL Implementation

```
public class LoginClient {
    // LoginClient constructor
    public LoginClient()
    {
        // open SSLSocket connection to server and send login
        try {
            // obtain SSLSocketFactory for creating SSLSockets
            SSLSocketFactory socketFactory = ( SSLSocketFactory ) SSLSocketFactory.getDefault();
            // create SSLSocket from factory
            SSLSocket socket = ( SSLSocket ) socketFactory.createSocket( "localhost", 7070 );
            // create PrintWriter for sending login to server
            PrintWriter output = new PrintWriter(
                new OutputStreamWriter( socket.getOutputStream() ) );
            // prompt user for user name
            String userName = JOptionPane.showInputDialog( null, "Enter User Name:" );
            // send user name to server
            output.println( userName );
        }
    }
}
```

Use default SSLSocketFactory
to create SSL sockets

SSL socket will listen on port 7070




```

// prompt user for password
String password = JOptionPane.showInputDialog( null, "Enter Password:" );
// send password to server
output.println( password );
output.flush();
// create BufferedReader for reading server response
BufferedReader input = new BufferedReader(
    new InputStreamReader( socket.getInputStream ( ) ) );
// read response from server
String response = input.readLine();
// display response to user
JOptionPane.showMessageDialog( null, response );
// clean up streams and SSLSocket
output.close();
input.close();
socket.close();
} // end try
// handle exception communicating with server
catch ( IOException ioException ) {
    ioException.printStackTrace();
}
// exit application
finally {
    System.exit( 0 );
}
} // end LoginClient constructor

```

```

// execute application
public static void main( String
args[] )
{
    new LoginClient();
}
}

```



Creating Keystore and Certificate

- Before you can execute the LoginServer and LoginClient application using SSL you will need to create a keystore and certificate for the SSL to operate correctly.
- Utilizing the [keytool](#) (a key and certificate management tool) in Java generate a keystore and a certificate for this server application. See the next slide for an example.
- We'll use the same keystore for both the server and the client although in reality these are often different. The client's truststore, in real-world applications, would contain trusted certificates, such as those from certificate authorities (e.g. VeriSign (www.verisign.com), etc.).



Creating Keystore and Certificate

```
Administrator: Command Prompt
C:\Program Files\Java\jdk1.6.0_10\bin>keytool -genkey -keystore SSLStore -alias
SSLCertificate
Enter keystore password:
Keystore password is too short - must be at least 6 characters
Enter keystore password:
Re-enter new password:
What is your first and last name?
  [Unknown]: Mark Llewellyn
What is the name of your organizational unit?
  [Unknown]: UCF CS Dept
What is the name of your organization?
  [Unknown]: UCF
What is the name of your City or Locality?
  [Unknown]: Orlando
What is the name of your State or Province?
  [Unknown]: Florida
What is the two-letter country code for this unit?
  [Unknown]: US
Is CN=Mark Llewellyn, OU=UCF CS Dept, O=UCF, L=Orlando, ST=Florida, C=US correct
?
  [no]: yes

Enter key password for <SSLCertificate>
  (RETURN if same as keystore password):
Re-enter new password:

C:\Program Files\Java\jdk1.6.0_10\bin>
```

Note requirements for password.



Creating Keystore and Certificate

```
C:\> Command Prompt (2)
C:\Program Files\Java\jdk1.5.0\bin>keytool -list -v -keystore SSLStore
Enter keystore password: master

Keystore type: jks
Keystore provider: SUN

Your keystore contains 1 entry

Alias name: sslcertificate
Creation date: Sep 20, 2005
Entry type: keyEntry
Certificate chain length: 1
Certificate[1]:
Owner: CN=Mark Llewellyn, OU=School of Computer Science, O=UCF, L=Orlando, ST=Florida, C=US
Issuer: CN=Mark Llewellyn, OU=School of Computer Science, O=UCF, L=Orlando, ST=Florida, C=US
Serial number: 43307e4f
Valid from: Tue Sep 20 16:25:35 GMT-05:00 2005 until: Mon Dec 19 16:25:35 GMT-05:00 2005
Certificate fingerprints:
    MD5: 93:D5:5A:70:70:98:89:0C:B8:C8:95:5B:1D:BD:F5:9D
    SHA1: 70:6F:65:69:AA:E7:F2:CC:24:97:C6:ED:0D:2F:9C:53:5A:E6:73:26

*****
*****
C:\Program Files\Java\jdk1.5.0\bin>
```

Viewing the keystore contents after its creation.

Notice the entry type is keyEntry which means that this entry has a private key associated with it.



Creating Keystore and Certificate

```
Administrator: Command Prompt
C:\Program Files\Java\jdk1.6.0_10\bin>keytool -export -rfc -alias sslcertificate
-keystore SSLStore -file mycert.cer
Enter keystore password:
Certificate stored in file <mycert.cer>
C:\Program Files\Java\jdk1.6.0_10\bin>
```

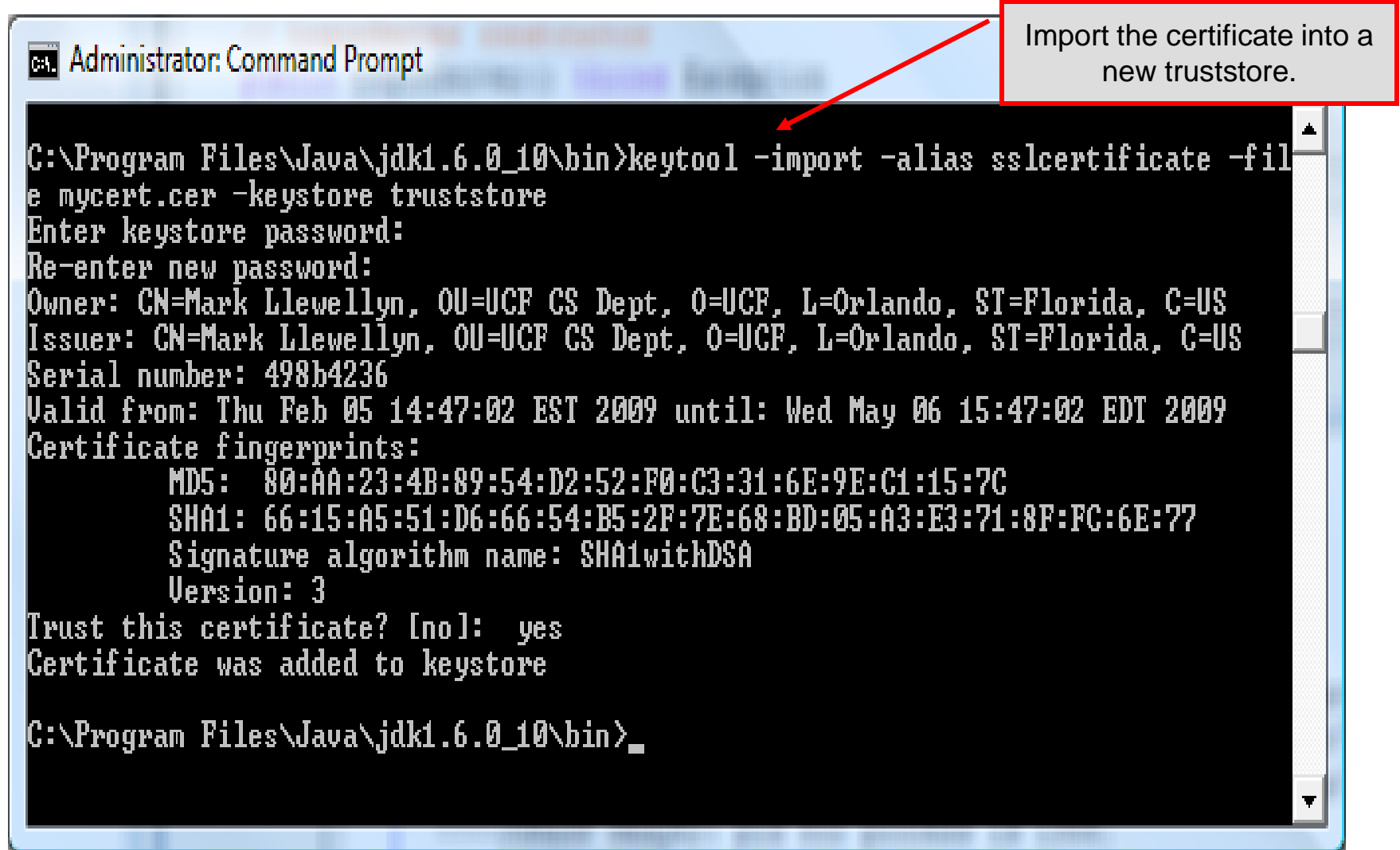
Export the certificate into a certificate file.

```
Administrator: Command Prompt
Certificate stored in file <mycert.cer>
C:\Program Files\Java\jdk1.6.0_10\bin>type mycert.cer
-----BEGIN CERTIFICATE-----
MIIDFjCCAtSgAwIBAgIESYtCNjAlBgqhkJ0OAQDBQAwbjELMAkGA1UEBhMCUUMxEDAOBgN
UBAgTB0Zsb3JpZGExEDAOBgNUBAcTB09ybGFuZG8xDDAKBgNUBAoTA1UDRjEUMBI
GA1UECxMLUUNGIENTIERlcHQxZmZlbnVBAmtDk1hcmsgTGxld2UsbHluMB4XD
TA5MDIwNTE5NDcwMloXDTA5MDUwNjE5NDcwMlowb
jELMAkGA1UEBhMCUUMxEDAOBgNUBAgTB0Zsb3JpZGExEDAOBgNUBAcTB09ybGFuZG8x
DDAKBgNUBAoTA1UDRjEUMBI
GA1UECxMLUUNGIENTIERlcHQxZmZlbnVBAmtDk1hcmsgTGxld2UsbHluMI
IBuDCCASwGBYqGSM44BAEwggEFAoGBAP1/U4EddRIpUt9KnC7s5Of2EbdSP09EAMMeP4C2
USZpRU1AI1H7WT2NWPq/xfW6MPbLm1Us14E7gB00b/JmYLdrMUClpJ+f6AR7ECLCT7up1/63xhv4
O1fnxqimFQ8E+4P208UewwI1UBNaFpEy9nXzrith1yrv8iIDGZ3RSAHHAhUA12BQjxUjC8yykrnC
ouuEC/BYHPUCgYEA9+GghdabPd7LvKtcNrhXuXmUr7v6OugC+UdMCz0HgmdRWUe0utRZT+ZxBxCB
gLRJFneEj6EwoFh03zwyjMim4TwWeotUfI0o4K0uHiuzpnWRbqN/C/ohNWLx+2J6ASQ7zKTxvqHR
kImog9/hWuWfBpKLZ16Ae1U1ZAFMO/7PSSoDgYUAAoGBAPv/bmegtq4IMK46AA3PLZ2WpesJaKUK
CM8FNmsnObgNiKYljHGxL+9KPJjyWy2uWxU79Is/TxmfGL92kdUa8+LfmDvA3iPSzQlihdLv2FKf
2REZqwKhT80tZ3Qa360829+H8hzsLwFiOUUbasKDHshMPdLx2kobbbGTLUM+DoFF4MAAsGBYqGSM44
BAMFAAMvADAsAhRwz+MMw5Y9akly5y0KMnxJBa1UUwIUSUjEbg7GUUDuMwS WJKFBOsFDv0=
-----END CERTIFICATE-----
C:\Program Files\Java\jdk1.6.0_10\bin>
```

Contents of the certificate.



Creating Keystore and Certificate



```
Administrator: Command Prompt

C:\Program Files\Java\jdk1.6.0_10\bin>keytool -import -alias sslcertificate -file mycert.cer -keystore truststore
Enter keystore password:
Re-enter new password:
Owner: CN=Mark Llewellyn, OU=UCF CS Dept, O=UCF, L=Orlando, ST=Florida, C=US
Issuer: CN=Mark Llewellyn, OU=UCF CS Dept, O=UCF, L=Orlando, ST=Florida, C=US
Serial number: 498b4236
Valid from: Thu Feb 05 14:47:02 EST 2009 until: Wed May 06 15:47:02 EDT 2009
Certificate fingerprints:
    MD5:  80:AA:23:4B:89:54:D2:52:F0:C3:31:6E:9E:C1:15:7C
    SHA1: 66:15:A5:51:D6:66:54:B5:2F:7E:68:BD:05:A3:E3:71:8F:FC:6E:77
    Signature algorithm name: SHA1withDSA
    Version: 3
Trust this certificate? [no]: yes
Certificate was added to keystore

C:\Program Files\Java\jdk1.6.0_10\bin>
```

Import the certificate into a new truststore.



Creating Keystore and Certificate

```
Administrator: Command Prompt
C:\Program Files\Java\jdk1.6.0_10\bin>keytool -list -v -keystore truststore
Enter keystore password:

Keystore type: JKS
Keystore provider: SUN

Your keystore contains 1 entry

Alias name: sslcertificate
Creation date: Feb 5, 2009
Entry type: trustedCertEntry

Owner: CN=Mark Llewellyn, OU=UCF CS Dept, O=UCF, L=Orlando, ST=Florida, C=US
Issuer: CN=Mark Llewellyn, OU=UCF CS Dept, O=UCF, L=Orlando, ST=Florida, C=US
Serial number: 498b4236
Valid from: Thu Feb 05 14:47:02 EST 2009 until: Wed May 06 15:47:02 EDT 2009
Certificate fingerprints:
    MD5:  80:AA:23:4B:89:54:D2:52:F0:C3:31:6E:9E:C1:15:7C
    SHA1: 66:15:A5:51:D6:66:54:B5:2F:7E:68:BD:05:A3:E3:71:8F:FC:6E:77
Signature algorithm name: SHA1withDSA
Version: 3

*****
*****

C:\Program Files\Java\jdk1.6.0_10\bin>
```

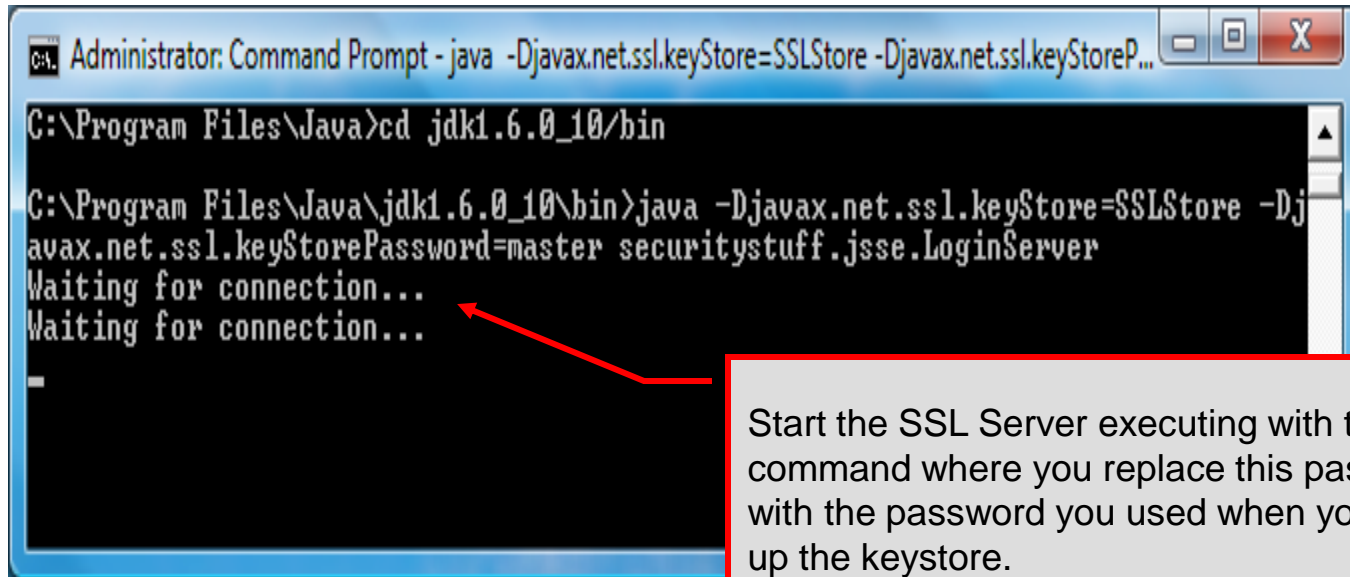
View the contents of the truststore.

Note that the entry type is trustedCertEntry, which means that a private key is not available for this entry. It also means that this file is not suitable as a KeyManager's keystore.



Launching the Secure Server

- Now you are ready to start the server executing from a command prompt...
- Once started, the server simply waits for a connection from a client. The example below illustrates the server after waiting for several minutes.



```
Administrator: Command Prompt - java -Djavax.net.ssl.keyStore=SSLStore -Djavax.net.ssl.keyStoreP...
C:\Program Files\Java>cd jdk1.6.0_10/bin
C:\Program Files\Java\jdk1.6.0_10\bin>java -Djavax.net.ssl.keyStore=SSLStore -Dj
avax.net.ssl.keyStorePassword=master securitystuff.jsse.LoginServer
Waiting for connection...
Waiting for connection...
```

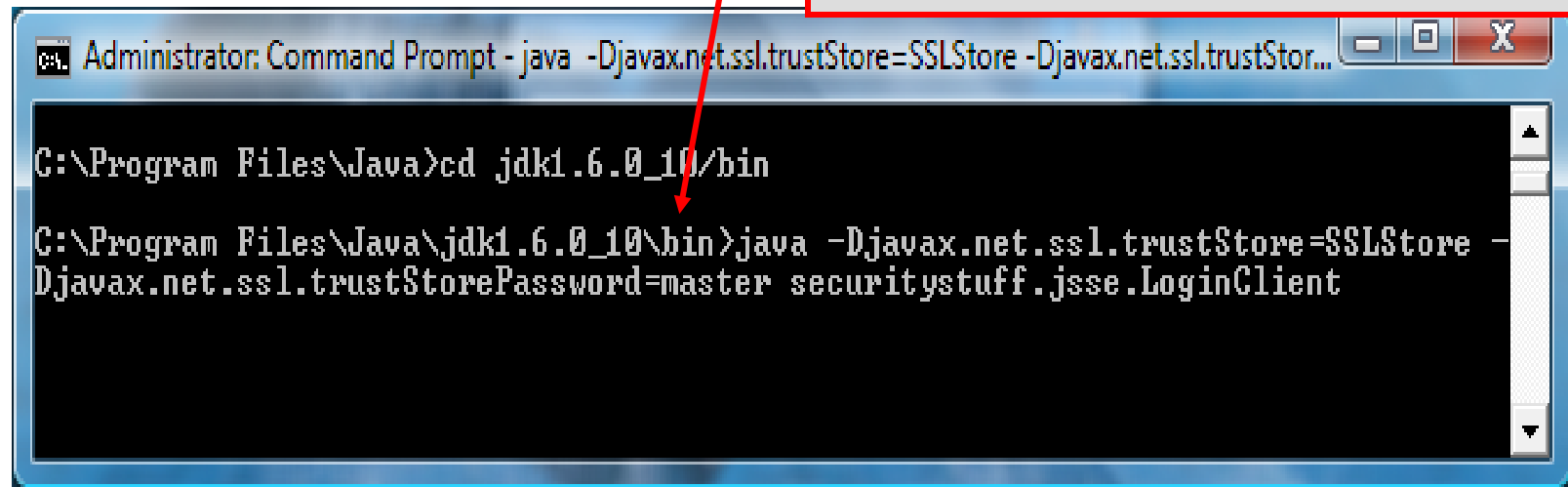
Start the SSL Server executing with this command where you replace this password with the password you used when you set-up the keystore.



Launching the SSL Client

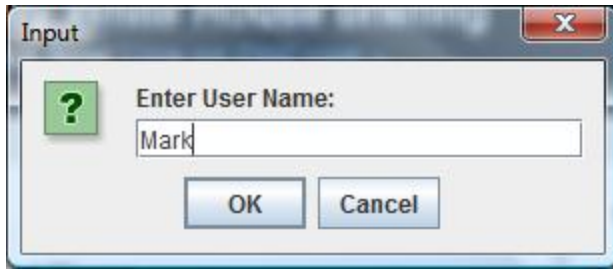
- Start a client application executing from a new command window...
- Once the client establishes communication with the server, the authentication process begins.

Start the SSL Client application executing with this command where you replace this password with the password you used when you set-up the keystore. Since we are using the same keystore for the server and the client...these will be the same.

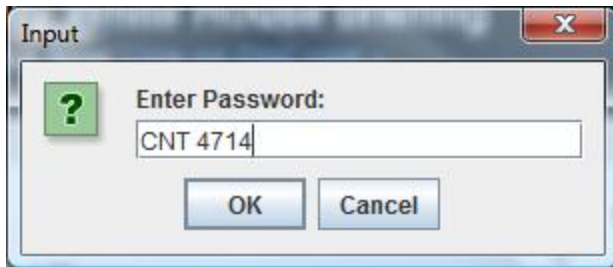


```
Administrator: Command Prompt - java -Djavax.net.ssl.trustStore=SSLStore -Djavax.net.ssl.trustStor...  
C:\Program Files\Java>cd jdk1.6.0_10/bin  
C:\Program Files\Java\jdk1.6.0_10\bin>java -Djavax.net.ssl.trustStore=SSLStore -  
Djavax.net.ssl.trustStorePassword=master securitystuff.jsse.LoginClient
```

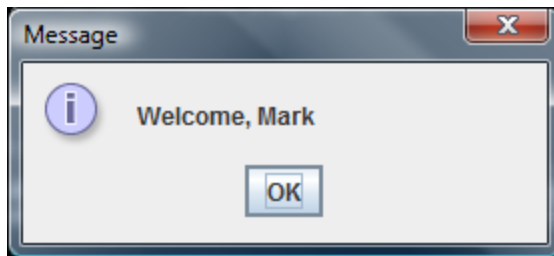


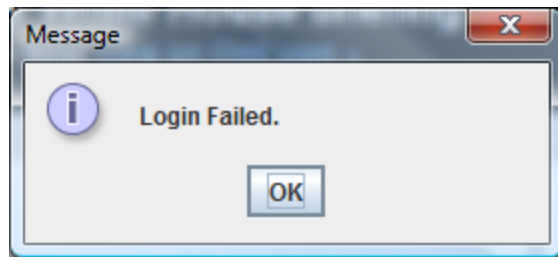
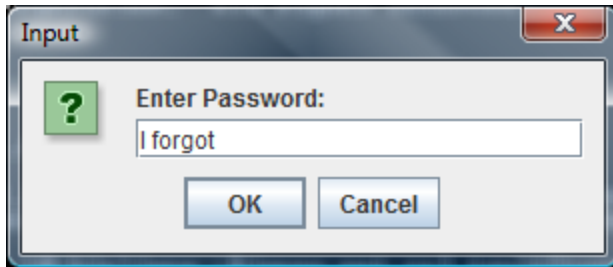
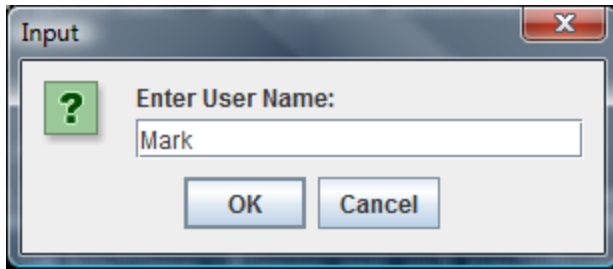


User enters username and password which are sent to the server.



Authentication successful – user is logged on.





User enters username and password which are sent to the server. In this case the user enters an incorrect password.

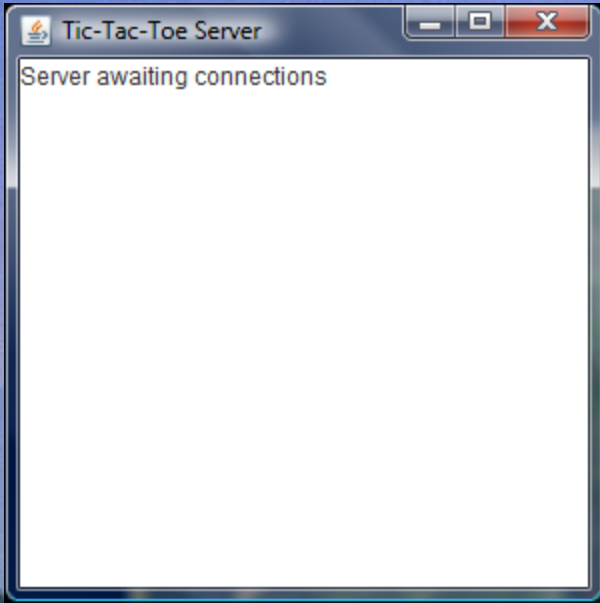
Authentication not successful – user is not logged on.



Multithreaded Socket Client/Server Example

- As a culminating example of networking and multi-threading, I've put together a rudimentary multi-threaded socket-based TicTacToe client/server application. The code is rather lengthy and there isn't really anything in it that we haven't already seen in the earlier sections of the notes. However, I did want you to see a somewhat larger example that utilizes both sockets and threading in Java. The code is on the course web page so try it out.
- This application is a multithreaded server that will allow two client's to play a game of TicTacToe run on the server.
- To execute, open three command windows, start one server and two clients (in separate windows).
- The following few pages contain screen shots of what you should see when executing this code.





Start server running...



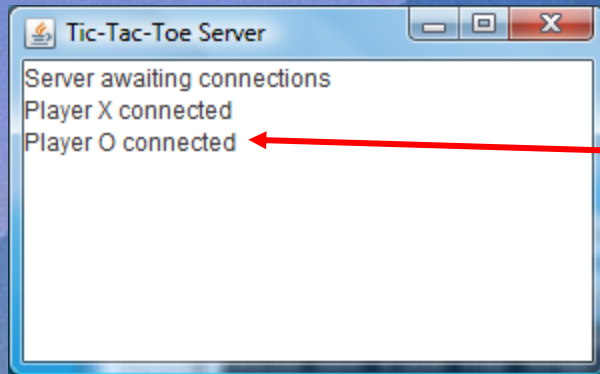
```
Tic-Tac-Toe Server
Server awaiting connections
Player X connected
```

Indicate to first player that server is waiting for another player thread to connect.

```
Tic Tac Toe Client/Player
You are player "X"
[3x3 Grid]
Player X connected
Waiting for another player
```

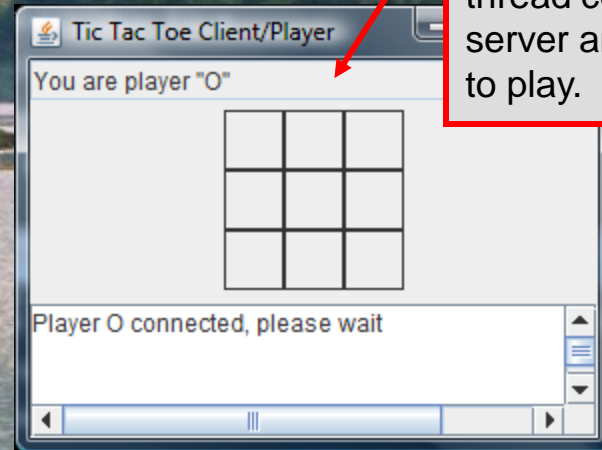
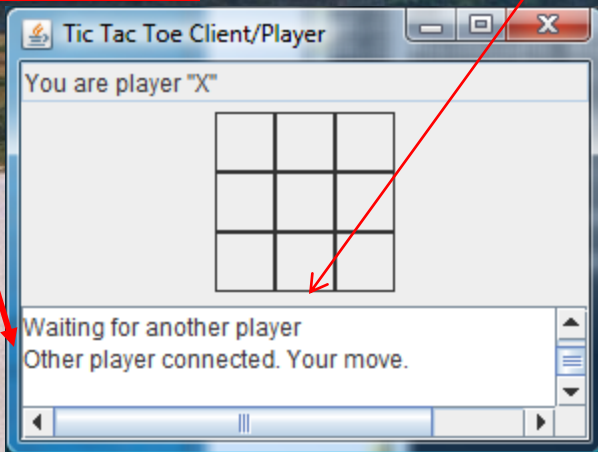
Start first player thread





Server completes connection for second player. Notifies Player X that they can make their move.

Player X is notified by server that another player has connected and they can make their move.



Second player thread connects to server and is ready to play.



Server validates move made by Player X, records board configuration and notifies Player O that they can move and redraws the board for Player O.

```
Tic-Tac-Toe Server
Server awaiting connections
Player X connected
Player O connected

X in location: 4|
```

Player O sees the move made by Player X and is now ready to make a move.

```
Tic Tac Toe Client/Player
You are player "X"

  | | |
  | | |
  | | |
  | | |

Other player connected. Your move.
Valid move, please wait.
```

Player X makes a move by placing an "X" marker in location 4 of the game board.

```
Tic Tac Toe Client/Player
You are player "O"

  | | |
  | | |
  | | |
  | | |

Player O connected, please wait
Opponent moved. Your turn.
```




```
Tic-Tac-Toe Server
Server awaiting connections
Player X connected
Player O connected

X in location: 4
O in location: 5
X in location: 2
O in location: 6
X in location: 0
O in location: 7
X in location: 8
```

Player O is notified that Player X has made a move and is graphically shown the updated board layout. Server indicates Player O is now able to make their move. No indication is given that the game is technically over.

```
Tic Tac Toe Client/Player
You are player "X"

| X |   | X |
|   | X | O |
| O | O | X |

Opponent moved. Your turn.
Valid move, please wait.
```

Although Player X has won the game, this server is too dumb to know this and allows the game to continue

```
Tic Tac Toe Client/Player
You are player "O"

| X |   | X |
|   | X | O |
| O | O | X |

Valid move, please wait.
Opponent moved. Your turn.
```

