Workbook 4

Introduction

Last week you explored how to use the Java synchronized statement to acquire and release locks, and how to use the wait-notify paradigm to coordinate activities between threads. You then went on to build your own thread-safe implementation of the MessageQueue interface. This week you will write your own implementation of the Java chat server, using SafeMessageQueue as one of the core data structures.

Important

An on-line version of this guide is available at:

http://www.cl.cam.ac.uk/teaching/current/FJava

You should check this page regularly for announcements and errata. You might find it useful to refer to the on-line version of this guide in order to follow any provided web links or to cut 'n' paste example code.

A Java chat server

As you saw in Workbook 1 and 2, TCP communications often block the execution of a Java thread when data is read from a network socket. As a result, you used an additional Java Thread object to read data from the network socket and display it to the screen, allowing the main thread to read and parse user input. The Java chat server requires a more complex arrangement of Java Thread objects to handle messages coming from, and going to, multiple clients.

Figure 1, “The major Java objects and message flows in the Java chat server” provides an overview of the Java objects and messages passed between them when two clients are connected to the server; the Java objects which are part of the Java chat client you wrote for Workbook 2 are not shown in the diagram. The figure includes two instances of the ClientHandler class, each of which contains two Thread objects and a MessageQueue object. The figure also shows a single MultiQueue object and a single ChatServer object.

The flow of messages of type uk.ac.cam.cl.fjava.Message are represented in the Figure by solid black arrows. You probably recall from Workbook 2 that the first version of the Java chat client you wrote supported four message types. Table 1, “Message classes sent between the client and server” provides you with a summary of these message types. You will only be sending and receiving messages of these types in this Workbook. On the diagram, the messages flowing along the arrows shown as “from client” will be either ChatMessage or ChangeNickMessage types; all the other solid arrows on the diagram represent the flow of messages of type StatusMessage or RelayMessage.

<table>
<thead>
<tr>
<th>Message type (class)</th>
<th>Direction</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ChangeNickMessage</td>
<td>Client→Server</td>
<td>Update nickname of the client stored by the server.</td>
</tr>
<tr>
<td>ChatMessage</td>
<td>Client→Server</td>
<td>Message written by a user is sent to the server.</td>
</tr>
<tr>
<td>RelayMessage</td>
<td>Server→Client</td>
<td>User message sent from server to all clients.</td>
</tr>
<tr>
<td>StatusMessage</td>
<td>Server→Client</td>
<td>Message generated by the server, sent to all clients.</td>
</tr>
</tbody>
</table>

Table 1. Message classes sent between the client and server
Figure 1. The major Java objects and message flows in the Java chat server

The Figure only provides you with the objects and associated message flows when there are two clients connected to the Java chat server. In general, if there are N clients connected to the server, there are N instances of ClientHandler (and therefore 2N client threads in total) and one ChatServer. In addition, there are N queues of type MessageQueue (i.e. one associated with each ClientHandler) and one queue of type MultiQueue which all N instances of ClientHandler send messages to. Every queue is accessed by more than one thread and therefore must be thread-safe.

The following subsections of this workbook provides a description of each of the objects in turn and what you will need to do to implement them. Please read, and re-read, all the descriptions carefully before starting on the implementation work described at the end of the Workbook. Make use of the demonstrators and lecturers in the class if there are any points which are unclear.

SafeMessageQueue

A thread-safe FIFO queue. You implemented this as part of Workbook 3. Copy your implementation into the package uk.ac.cam.crsid.fjava.tick4 together with a copy of the interface MessageQueue.

MultiQueue

```java
public class MultiQueue<T> {
    private Set<MessageQueue<T>> outputs = //TODO
    public void register(MessageQueue<T> q) {
        //TODO: add "q" to "outputs"
    }
    public void deregister(MessageQueue<T> q) {
        //TODO: remove "q" from "outputs"
    }
    public void put(T message) {
        //TODO: copy "message" to all elements in "outputs"
    }
}
```
The server should contain a single instance of a `MultiQueue` object, regardless of the number of clients connected to the server. The instance should be specialised to process objects of type `Message`, although in practise there should only ever be `RelayMessage` or `StatusMessage` objects (i.e. server to client messages) and never any `ChatMessage` or `ChangeNickMessage` objects stored in the `MultiQueue` object. Internally, the `MultiQueue` object should store a list of active `SafeMessageQueue` objects associated with clients, and whenever a new message is added to the `MultiQueue` object through the `put` method, your implementation should copy the message to every registered `SafeMessageQueue` object.

To maintain a current list of active clients, the `MultiQueue` object must support `register` and `deregister` methods. All three methods (`put`, `register` and `deregister`) are, in general, invoked by multiple instances of `ClientHandler`, and as such you must ensure that `MultiQueue` is thread safe! You can do so by making appropriate use of the Java `synchronized` statement to prevent concurrent access to outputs by taking out a lock on this whenever the body of any method is invoked.

**ChatServer**

```java
class ChatServer {
    public static void main(String args[]) {
        //TODO
    }
}
```

This class should contain the special `main` method which is executed when the Java chat server is first started. Your implementation of the `main` method should expect an integer value representing the port number the server should start on as a single argument on the command line. If there are no arguments (or a malformatted argument) is found, your implementation should print out

Usage: java ChatServer <port>

and your implementation should then terminate.

If a port number was correctly provided by the user then the `main` method should create a single instance of `java.net.ServerSocket` by providing the port number entered by the user to the constructor of this class. If, for some reason, the Java chat server cannot use the provided port number (e.g. the port is already occupied by another server) your implementation should print out

Cannot use port number <port>

where `<port>` is the port number entered by the user and then terminate.

In addition to creating an instance of `ServerSocket`, your implementation of the `main` method should also create a single instance of the `MultiQueue` class. After the initialisation of an instance of `ServerSocket` and `MultiQueue` your implementation should sit in a loop forever doing the following things:

1. call the method `accept` on the `ServerSocket` object;

2. The `accept` method will block execution of the `main` method until a new client connects to the port; when this happens create a new instance of the `ClientHandler` object, passing in a reference to the `MultiQueue` you created earlier together with the instance of `Socket` as returned by `accept`;

3. Go to (1) above.
ClientHandler

public class ClientHandler {
    private Socket socket;
    private MultiQueue<Message> multiQueue;
    private String nickname;
    private MessageQueue<Message> clientMessages;
    //TODO: possibly other fields here
    public ClientHandler(Socket s, MultiQueue<Message> q) {
        //TODO
    }
    //TODO: Other code here as necessary
}

This class handles the interaction between the Java chat client and the MultiQueue object. This class should provide a single constructor which takes two arguments: a reference to the Socket object associated with the Java chat client and a reference to a MultiQueue object. The constructor should do the following:

1. Update the fields socket and multiQueue to reference s and q respectively.

2. Update clientMessages to reference a new instance of SafeMessageQueue and call the register method on multiQueue to make multiQueue aware of the new client (more details on this in the MultiQueue Section above).

3. Create a default nickname and store it in the private field nickname by concatenating a random five digit number onto the string Anonymous. (Hint: you might like to use java.util.Random.)

4. Create a new StatusMessage object to record the fact that a new client has connected to the Java chat server and add this to multiQueue. The example chat session you saw first in Workbook 2 requires the server to print the machine name (not the IP address) the client connected from; to do so take a close look at the type of object returned by the method socket.getInetAddress().

5. Define and instantiate a Thread object to handle incoming serialised objects which are sent by the client and received by ClientHandler on the input stream associated with the Socket object provided to the constructor. When the incoming thread receives a serialised ChangeNickMessage object, then update the private field nickname and create and send a StatusMessage object to all clients by calling put on the MultiQueue object; when the incoming thread receives a serialised ChatMessage from the client, create a RelayMessage object and call put on the MultiQueue object to send the message to all clients. If the incoming thread receives a message of any other type from the client the message should be ignored.

6. Define and instantiate a Thread object to handle outgoing messages found on the SafeMessageQueue. The thread should serialise and send any message objects on the queue to the Java chat client by making use of the output stream of the Socket object.

When the Java chat client disconnects, the Java chat server will receive an IOException. Handle this exception in the ClientHandler by calling the deregister method on multiQueue appropriately and create and send a StatusMessage object to all the remaining clients. When the Java chat client disconnects, you must ensure that both the threads used to handle incoming and outgoing threads terminate. (If you don’t, your Java chat server will eventually fail, since every new Java chat client which connects creates a new instance of ClientHandler, and when they disconnect the incoming and outgoing threads don’t finish and so continue to consume memory on the server.)

Testing

Testing an implementation of your server is going to be hard since it will create quite a lot of threads. Here are some suggestions which should help:
1. Never leave the body of a `catch` block empty unless you really know what you're doing! If you do nothing else, catch the exception as a variable called `e` and then call `e.printStackTrace()` in the body of the catch block so you see some useful debugging output when your server fails.

2. Package up a copy of the client you wrote for Tick 2 into a jar file and set the jar manifest so you can run it from the command line as follows:

   ```
   java -jar ChatClient.jar localhost 1234
   ```

   Assuming, of course, that you're running your Java chat server on port 1234. You can then run multiple Java chat clients easily in multiple terminals on your own PWF workstation and use the Eclipse "Run As..." feature to run the actual server.

3. When you think your server is running correctly, enter in the dialog as shown in Figure 2, “A chat session between Dave and Hal” and make sure your server responds in precisely the same manner.

4. Beware when offering to test a server written by your friend using your Java chat client—unless you have implemented Tick 2*, your existing implementation will execute any method sent to you which is annotated with `@Execute`. You should modify your Java chat client to remove this feature before testing other servers. Even if you have implemented Tick 2*, you might want to reconsider the permissions you've given to any classes you load dynamically. You have been warned!

   ```
   crsid@machine:~> java -jar crisd-tick2.jar
   14:23:27 [Client] Connected to java-lb.cl.cam.ac.uk on port 15003.
   nick Dave
   14:23:29 [Server] Anonymous15983 is now known as Dave.
   14:23:17 [Server] Anonymous82791 is now known as Hal.
   Hello, Hal. Do you read me, Hal?
   14:23:22 [Dave] Hello, Hal. Do you read me, Hal?
   Open the pod bay doors, Hal.
   14:23:31 [Dave] Open the pod bay doors, Hal.
   14:23:36 [Hal] I'm sorry, Dave. I'm afraid I can't do that.
   Why not, Hal? What's the problem?
   14:23:43 [Hal] I think you know what the problem is just as well as I do.
   What are you talking about, Hal?
   14:23:50 [Dave] What are you talking about, Hal?
   14:23:53 [Hal] This mission is too important for me to allow you to jeopardise it. I don't know what you're talking about.
   14:23:59 [Dave] I don't know what you're talking about.
   destroy Hal
   14:24:02 [Client] Unknown command "destroy"
   14:24:06 [Hal] I know you and Frank were planning to disconnect me.
   14:24:08 [Hal] And that's something I cannot allow to happen.
   14:24:12 [Server] Hal has disconnected.
   quit
   crsid@machine:~>
   ```

**Figure 2. A chat session between Dave and Hal**

---

Ticklet 4

You have now completed all the necessary code to gain your fourth ticklet. Please generate a jar file which contains all the code you have written for package `uk.ac.cam.crsid.fjava.tick4` together with the code you downloaded and imported in package `uk.ac.cam.cl.fjava.messages`. Please use Eclipse to export both the class files and the source files into a jar file called `crsid-tick4.jar`. Once you have generated your jar file, check that it contains at least the following classes:

```
crsid@machine~:> jar tf crsid-tick4.jar
META-INF/MANIFEST.MF
uk/ac/cam/crsid/fjava/tick4/ChatServer.java
uk/ac/cam/crsid/fjava/tick4/ChatServer.class
uk/ac/cam/crsid/fjava/tick4/MessageQueue.java
uk/ac/cam/crsid/fjava/tick4/MessageQueue.class
uk/ac/cam/crsid/fjava/tick4/SafeMessageQueue.java
uk/ac/cam/crsid/fjava/tick4/SafeMessageQueue.class
uk/ac/cam/crsid/fjava/tick4/MultiQueue.java
uk/ac/cam/crsid/fjava/tick4/MultiQueue.class
uk/ac/cam/crsid/fjava/tick4/ClientHandler.java
uk/ac/cam/crsid/fjava/tick4/ClientHandler.class
uk/ac/cam/cl/fjava/messages/ChangeNickMessage.class
uk/ac/cam/cl/fjava/messages/ChangeNickMessage.java
uk/ac/cam/cl/fjava/messages/NewMessageType.class
uk/ac/cam/cl/fjava/messages/NewMessageType.java
uk/ac/cam/cl/fjava/messages/RelayMessage.class
uk/ac/cam/cl/fjava/messages/RelayMessage.java
uk/ac/cam/cl/fjava/messages/StatusMessage.class
uk/ac/cam/cl/fjava/messages/StatusMessage.java
uk/ac/cam/cl/fjava/messages/ChatMessage.class
uk/ac/cam/cl/fjava/messages/ChatMessage.java
uk/ac/cam/cl/fjava/messages/Message.class
uk/ac/cam/cl/fjava/messages/Message.java
crsid@machine~:>
```

When you are satisfied you have built the jar correctly, you should submit your jar file as an email attachment to `ticks1b-java@cl.cam.ac.uk`.

You should receive an email in response to your submission. The contents of the email will contain the output from a program (written in Java!) which checks whether your jar file contains all the relevant files, and whether your program has run successfully or not. If your jar file does not pass the automated checks, then the response email will tell you what has gone wrong; in this case you should correct any errors in your work and resubmit your jar file. You can resubmit as many times as you like and there is no penalty for re-submission. If, after waiting one hour, you have not received any response you should notify `ticks1b-admin@cl.cam.ac.uk` of the problem. You should submit a jar file which successfully passes the automated checks by the deadline, so don’t leave it to the last minute!