TCP Programming

RES, Lecture 2 (second part)

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Code walkthrough

establish a connection with server

get streams to send and receive bytes

read bytes sent by the server until the connection is closed

```
public void sendWrongHttpRequest() {
     Socket clientSocket = null;
     OutputStream os = null;
     InputStream is = null;

     try {
          clientSocket = new Socket("www.lematin.ch", 80);
          os = clientSocket.getOutputStream();
          is = clientSocket.getInputStream();

          String malformedHttpRequest = "Hello, sorry, but I don't speak HTTP...\r\n\r\n";
          os.write(malformedHttpRequest.getBytes());

          ByteArrayOutputStream responseBuffer = new ByteArrayOutputStream();
          byte[] buffer = new byte[BUFFER_SIZE];
          int newBytes;
          while ((newBytes = is.read(buffer)) != -1) {
               responseBuffer.write(buffer, 0, newBytes);
          }

          LOG.log(Level.INFO, "Response sent by the server: ");
          LOG.log(Level.INFO, responseBuffer.toString());
     } catch (IOException ex) {
          LOG.log(Level.SEVERE, null, ex);
     } finally {
...
     }
}
```

Code walkthrough

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bind on TCP port

```
ServerSocket serverSocket = null;
Socket clientSocket = null;
BufferedReader reader = null;
PrintWriter writer = null;

try {
  serverSocket = new ServerSocket(listenPort);
  logServerSocketAddress(serverSocket);
  clientSocket = serverSocket.accept();

  logSocketAddress(clientSocket);
  reader = new BufferedReader(new InputStreamReader(clientSocket.getInputStream()));
  writer = new PrintWriter(clientSocket.getOutputStream());

 for (int i = 0; i < numberOfIterations; i++) {
    writer.println(String.format("{'time' : '%s'}", new Date()));
    writer.flush();
    LOG.log(Level.INFO, "Sent data to client, doing a pause...");
    Thread.sleep(pauseDuration);
  }
} catch (IOException | InterruptedException ex) {
  LOG.log(Level.SEVERE, ex.getMessage());
} finally {
   reader.close();
   writer.close();
   clientSocket.close();
   serverSocket.close();
}
```

block until a client makes a connection request

we want to exchange characters with the clients (we should specify the encoding!)

we make sure to flush the buffer, so that characters are actually sent!

Handling Concurrency

Concurrency in Network Programming

You don't want your server to talk to only one client at the time, do you?

Even for ***stateless*** *protocols...*

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blocking IO (synchronous)

n employee = n threads

employees are expensive

limited space for employees in the truck

few employees => long queue

non-blocking IO (asynchronous)

there is only 1 employee (1 thread)

customers are called back when the request is fulfilled

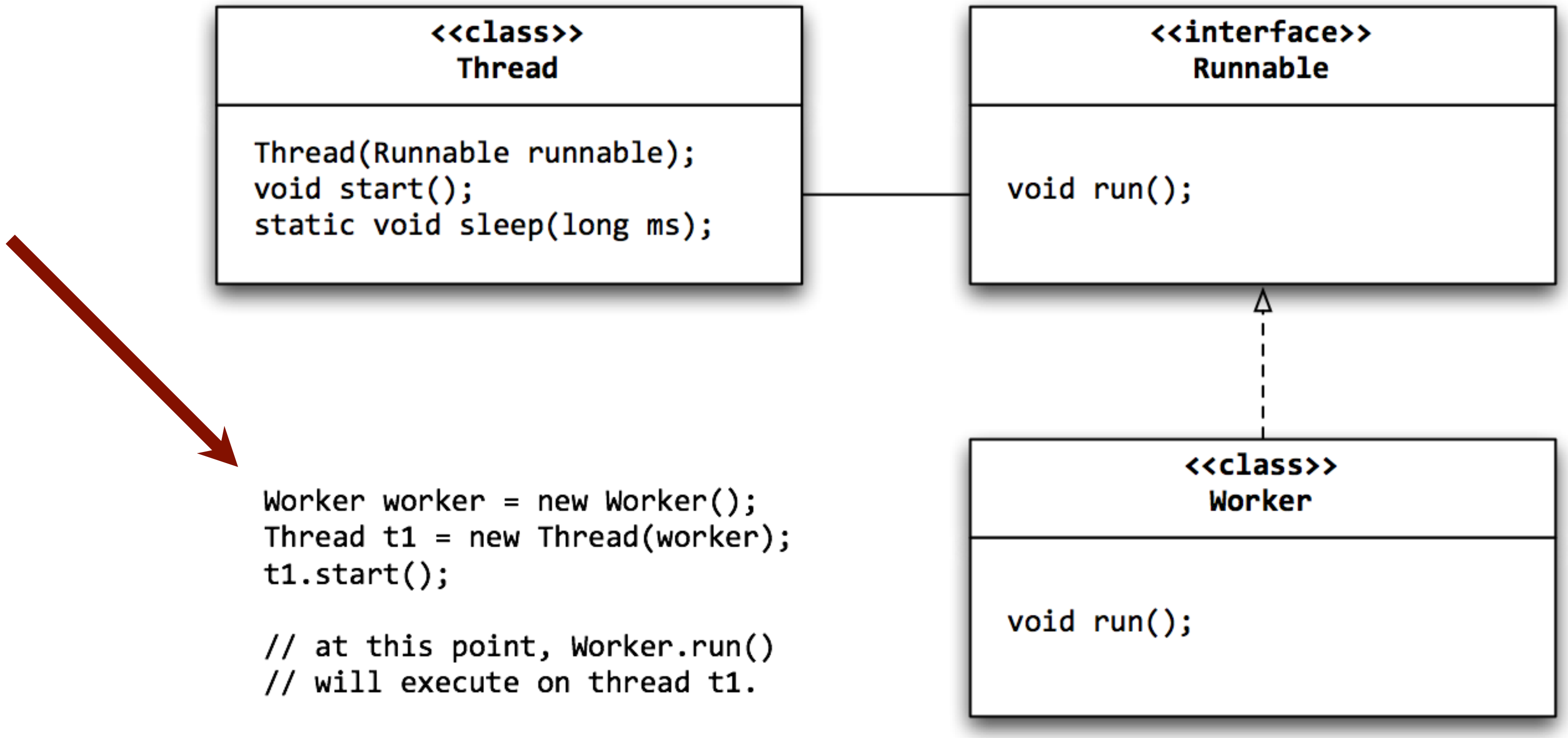
no queue

Concurrent Programming

- On top of the **operating system**, it is possible launch the Java Virtual Machine (**JVM**) several times (by invoking the java command). In this scenario, there is **one process (program) for every JVM instance**.
- If you don't do anything special, there is a **single execution thread** within each JVM. This means that all instructions in your code are executed **sequentially**.
- Very often, you write software where you want to **perform several tasks at the same time** (concurrently). For instance:
  - Manage a UI **while** fetching data from the network,
  - Talking to one HTTP client **while** talking to another HTTP client,
  - Have a worker do complex calculations on a subset of the data, **while** having another worker do the same calculations on another subset.
- You can use **threads** (also called **lightweight processes**) for this purpose.

Concurrent Programming in Java

- In Java, there are two main types
  - The **Thread class**, which *could be extended* to implement the behaviour you want to run in parallel.
  - The **Runnable interface**, which *is implemented* for the same purpose and is passed as an argument to the Thread constructor.



```
Worker worker = new Worker();
Thread t1 = new Thread(worker);
t1.start();

// at this point, Worker.run()
// will execute on thread t1.
```

Concurrent Programming in Java

- There are other classes related to threads, in the java.util.concurrent package. An important one is the **ExecutorService**, which makes it possible to use **thread pools**.
- A thread pool gives you a way to limit the number of threads spawned (by your server), so that you will not consume all resources. Others are queued.

```
package de.vogella.concurrency.threadpools;
import java.util.concurrent.ExecutorService;
import java.util.concurrent.Executors;
public class Main {
  private static final int NTHREDS = 10;

  public static void main(String[] args) {
    ExecutorService executor = Executors.newFixedThreadPool(NTHREDS);
    for (int i = 0; i < 500; i++) {
      Runnable worker = new MyRunnable(10000000L + i);
      executor.execute(worker);
    }
    // This will make the executor accept no new threads
    // and finish all existing threads in the queue
    executor.shutdown();
    // Wait until all threads are finish
    executor.awaitTermination();
    System.out.println("Finished all threads");
  }
}
```

http://www.vogella.com/tutorials/JavaConcurrency/article.html

Single Threaded
Single Process
Blocking

Not really an option...

The server implements a loop.

It waits for a client to arrive.
Then services the client until done.

Then only goes back to accept the next client.

Can only talk to 1 client at the time

It is only when we reach this line that a new client can connect

```
serverSocket = new ServerSocket(port);
while (true) {

   clientSocket = serverSocket.accept();

   in = new BufferedReader(new
InputStreamReader(clientSocket.getInputStream()));
   out = new PrintWriter(clientSocket.getOutputStream());
   String line;
   boolean shouldRun = true;

   LOG.info("Reading until client sends BYE");

   while ( (shouldRun) && (line = in.readLine()) != null ) {
      if (line.equalsIgnoreCase("bye")) {
         shouldRun = false;
      }
      out.println("> " + line.toUpperCase());
      out.flush();
   }
   clientSocket.close();
   in.close();
   out.close();
}
```

It takes a long time to serve each client

Single Threaded
Multi Process
Blocking

How apache httpd did it
(with pre-fork, kind of...)

The server implements a loop.
It waits for a client to arrive.
When the client arrives, the server forks a new process.

The child process serves the client while the server is immediately ready to serve the next client.

Forking a process is kind of heavy... and resource hungry

While the child process serves the client...

... the parent can immediately welcome the next client.

```
while(1) {  // main accept() loop
    sin_size = sizeof their_addr;
    new_fd = accept(sockfd, (struct sockaddr *)&their_addr,
&sin_size);
    if (new_fd == -1) {
        perror("accept");
        continue;
    }

    inet_ntop(their_addr.ss_family,
        get_in_addr((struct sockaddr *)&their_addr),
        s, sizeof s);
    printf("server: got connection from %s\n", s);

    if (!fork()) { // this is the child process
        close(sockfd); // child doesn't need the listener
        if (send(new_fd, "Hello, world!", 13, 0) == -1)
            perror("send");
        close(new_fd);
        exit(0);
    }
    close(new_fd);  // parent doesn't need this
}
```

http://www.beej.us/guide/bgnet/output/html/multipage/clientserver.html#simpleserver

Multi Threaded
Single Process
Blocking

The 'old' Java way

The server uses a first thread to wait for connection requests from clients.

Each time a client arrives, a new thread is created and used to serve the client.

Millions of clients, millions of threads?

Resource hungry.
Not scalable.

The ReceptionistWorker implements a run() method that will execute on its own thread.

```
private class ReceptionistWorker implements Runnable {

   @Override
   public void run() {
      ServerSocket serverSocket;

      try {
         serverSocket = new ServerSocket(port);
      } catch (IOException ex) {
         LOG.log(Level.SEVERE, null, ex);
         return;
      }

      while (true) {
         LOG.log(Level.INFO, "Waiting for a new client");
         try {
            Socket clientSocket = serverSocket.accept();
            LOG.info("A new client has arrived...");
            new Thread(new ServantWorker(clientSocket)).start();
         } catch (IOException ex) {
            LOG.log(Level.SEVERE, ex.getMessage(), ex);
         }
      }
   }
}
```

As soon as a client is connected, a new thread is created.
The code that manages the interaction with the client executes on this thread.

2 types of workers, n+1 threads

Example: **07-TcpServers**

Single Thread
Single Process
Asynchronous Programming

The 'à la Node.js' way

The server uses a single thread, but in a non-blocking, asynchronous way.

Callback functions have to be written, so that they can be invoked when clients arrive, when data is received, etc.

Different programming logic.
Scalable.

We are registering callback functions on the various types of events that can be notified by the server...

```
// let's create a TCP server
const server = net.createServer();

// it reacts to events: 'listening', 'connection', 'close', etc.
// register callback functions, to be invoked when the events
// occur (everything happens on the same thread)

server.on('listening', callbackFunctionToCallWhenSocketIsBound);
server.on('connection',
callbackFunctionToCallWhenNewClientHasArrived);

//Start listening on port 9907
server.listen(9907);

// This callback is called when the socket is bound and is in
// listening mode. We don't need to do anything special.
function callbackFunctionToCallWhenSocketIsBound() {
   console.log("The socket is bound and listening");
   console.log("Socket value: %j", server.address());
}

// This callback is called after a client has connected.
function callbackFunctionToCallWhenNewClientHasArrived(socket) {
   ...
}
```

... and we code these functions, implementing the behavior that is expected when the events occur.

Select is a blocking operation (with a possible timeout). It blocks until something has happened on one of the provided sets of file descriptors.

Single Thread
Single Process
IO Multiplexing

The 'select' way

Sockets are set in a non-blocking state, which means that read(), write() and other functions do not block.

System calls such as select() or poll() block, but work on multiple sockets. They return if data has arrived on at least one of the sockets.

Watch out for performance.

```
#include <stdio.h>
#include <sys/time.h>
#include <sys/types.h>
#include <unistd.h>

int main(void) {
    fd_set rfds;
    struct timeval tv;
    int retval;

    /* Watch stdin (fd 0) to see when it has input. */
    FD_ZERO(&rfds);
    FD_SET(0, &rfds);
    /* Wait up to five seconds. */
    tv.tv_sec = 5;
    tv.tv_usec = 0;

    retval = select(1, &rfds, NULL, NULL, &tv);
    /* Don't rely on the value of tv now! */

    if (retval == -1)
        perror("select()");
    else if (retval)
        printf("Data is available now.\n");
        /* FD_ISSET(0, &rfds) will be true. */
    else
        printf("No data within five seconds.\n");

    return 0;
}
```

Here, we know that something has happened on one of the sockets. We can iterate over the set of file descriptors and get the data.

Example: **06-PresenceApplication**

End of part 2
End of chapter