FACULTY OF ENGINEERING TECHNOLOGY

ELECTRIC & COMPUTER ENGINEERING DEPARTMENT

Computer Networks (ENCS336)

Report Project: Socket Programming,

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Outline

Abstract

This project explains the application of core networking principles and socket programming techniques through a series of practical exercises. It begins with the exploration of essential networking commands such as ping, tracert, nslookup, and telnet, which are utilized to diagnose and understand network behavior. Wireshark is employed to capture and analyze DNS traffic, providing insights into packet-level communication. The project advances into the development of TCP and UDP client-server applications, where custom protocols are implemented to achieve specific tasks like message exchange and data manipulation. Finally, the project involves the creation of a simple yet functional web server using socket programming, capable of handling HTTP requests and serving web content. Throughout the project, I have gained experience in networking, enhanced my understanding of socket programming, and developed a working knowledge of web server implementation, all of which are crucial skills for a career in computer science and network engineering.

Task1: Commands & Wireshark

In this task, I will explore some key network commands and use Wireshark to capture and analyze DNS messages. Before starting, I'll list the definitions of each concept to ensure a clear understanding before applying them practically.

1. **Definitions of ping, tracert, nslookup, and telnet:**

    a) **Ping** is the time it takes for a small data set to be transmitted from your device to a server on the Internet and back to your device again and is measured in milliseconds. For example, when playing an online game, a higher ping indicates that it takes longer for data packets to travel between your computer and the game server (or other players' computers). This increased delay can result in lag, leading to poor gameplay performance.

    b) **Tracert** is a network tool that tracks the path data takes from your computer to a destination, like a website. It shows each step (hop) the data takes through network devices (like routers) and how long each step takes. It's used to diagnose network problems and understand the route data travels across the internet.

    c) **nslookup** is a network tool used to find the IP address associated with a domain name (like "something.com") or vice versa. It queries DNS (Domain Name System) servers to get this information, helping you troubleshoot domain-related issues or understand where a domain is hosted.

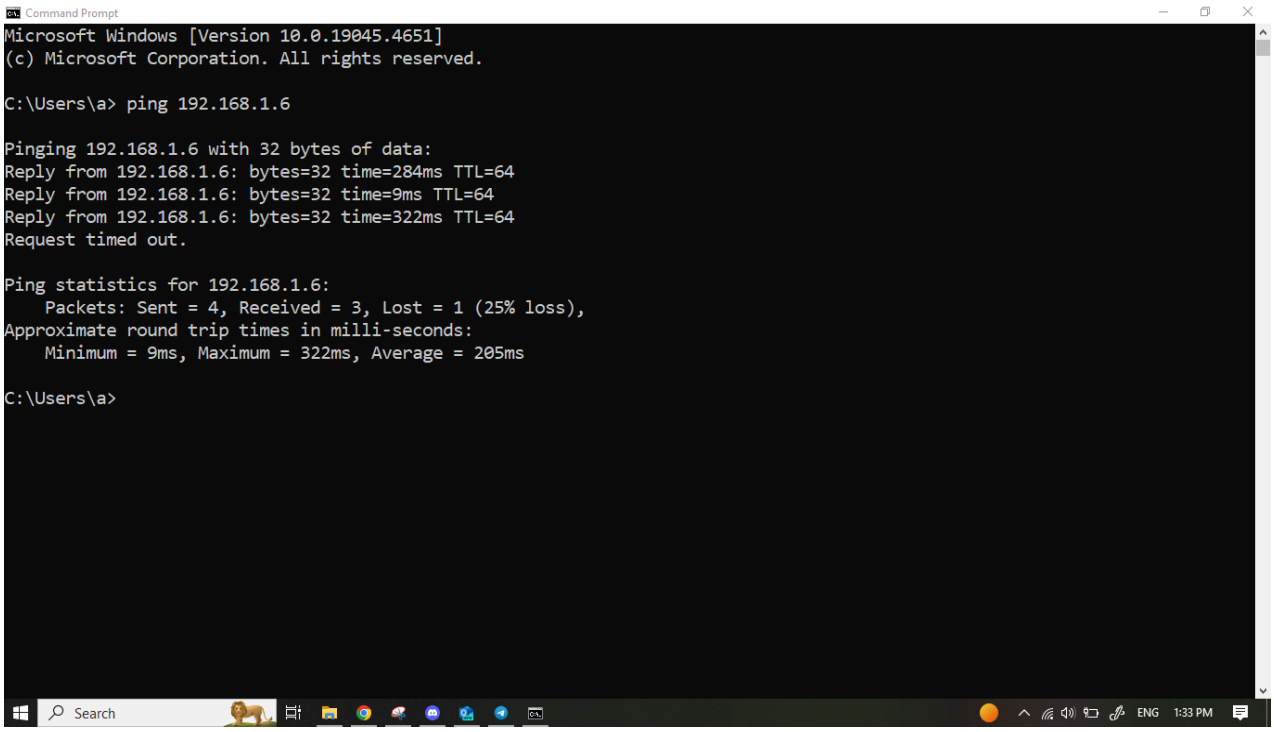
    d) **Telnet** is a network protocol and tool used to connect to remote servers or devices over a network. It allows you to interact with the server through a command-line interface, often used for testing and managing services on remote systems.

After defining these concepts, I'll ensure my computer is connected to the internet and then process to run these commands. I'll start by pinging a device on my local

network (I chose my mobile phone) and a public website to observe the differences in response times and connectivity.

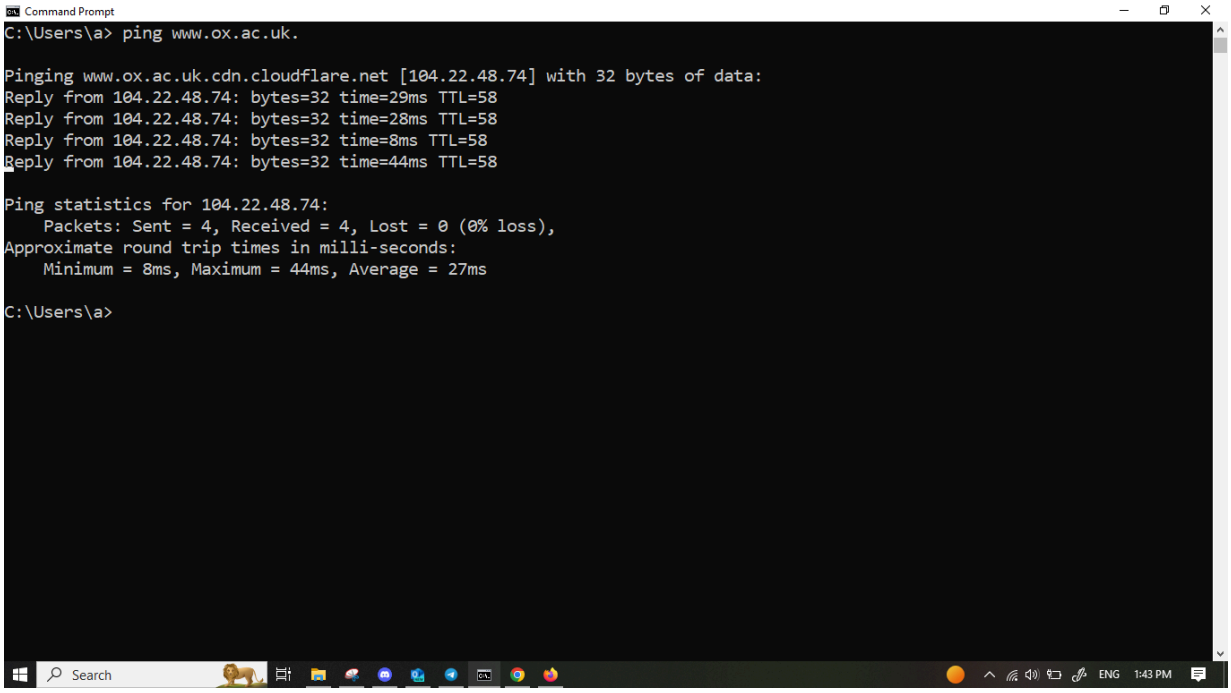
2. Running commands on cmd:

a) Ping for device in the same network (Mobile phone):



The screenshot shows the result of a ping command to the IP address of my phone 192.168.1.6. Out of four packets sent, three were successfully received, and one was lost, resulting in a 25% packet loss. The round trip times for the successful pings varied significantly, ranging from 9 ms to 322 ms, with an average of 205 ms. This indicates some instability or network issues affecting the connection to that IP address.

b) Ping for the url www.ox.ac.uk :

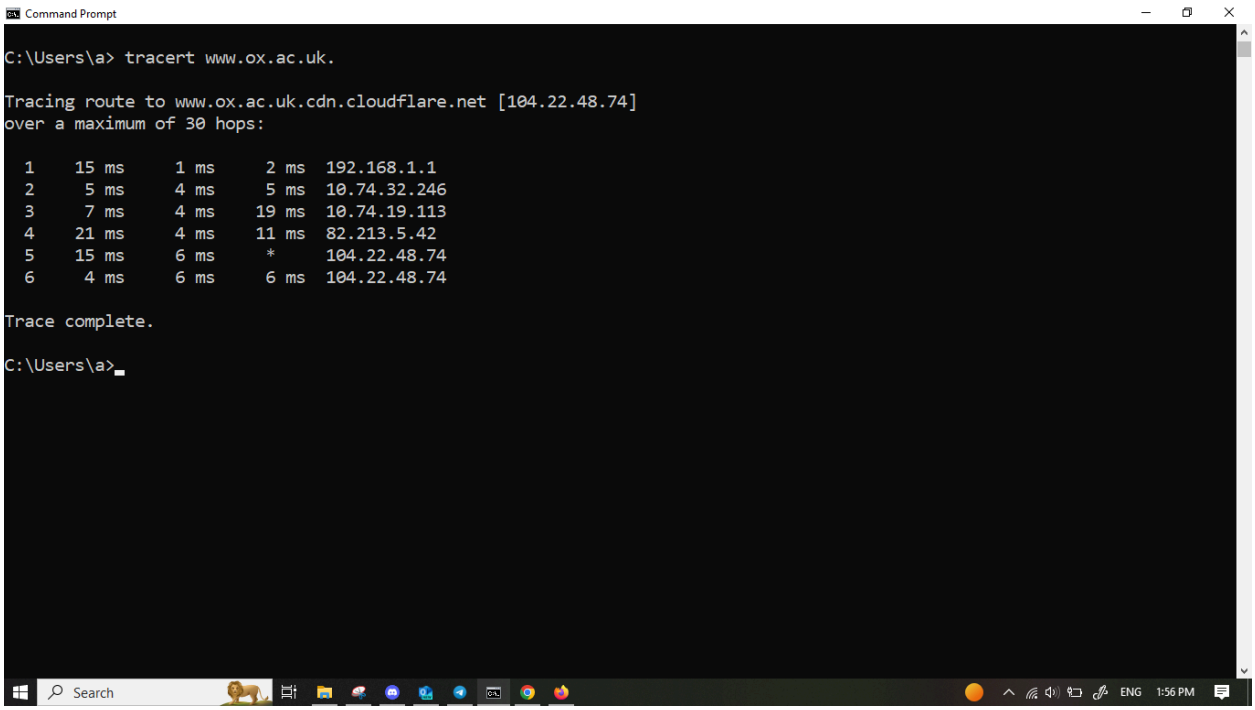


The screenshot shows the result of a ping command to the domain www.ox.ac.uk, resolving to the IP address 104.22.48.74. All four packets sent were successfully received, resulting in 0% packet loss. The round trip times for these pings were consistent and low, with a minimum of 8 ms, a maximum of 44 ms, and an average of 27 ms. This indicates a stable and reliable connection to the domain.

c) specifying the location of the server from where i got the response:

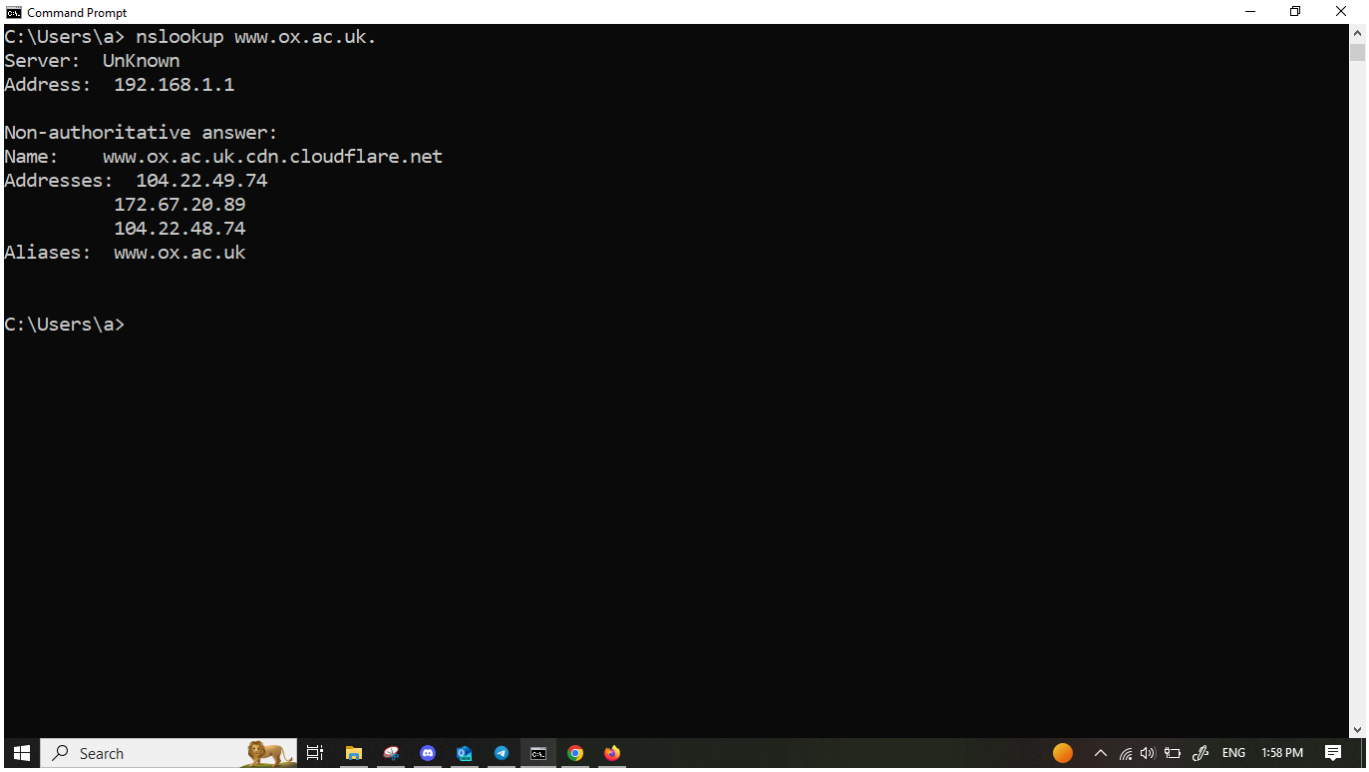
The IP address 104.22.48.74 is the identifier of the server that responded to my ping.The server is part of Cloudflare's Content Delivery Network (CDN), which means that the physical server i applied the ping command on could be in a data center near my location, since Cloudflare has data centers all over the world, so while the IP address belongs to Cloudflare, the actual physical server could be in a different country or region.

d) Tracert for www.ox.ac.uk. :



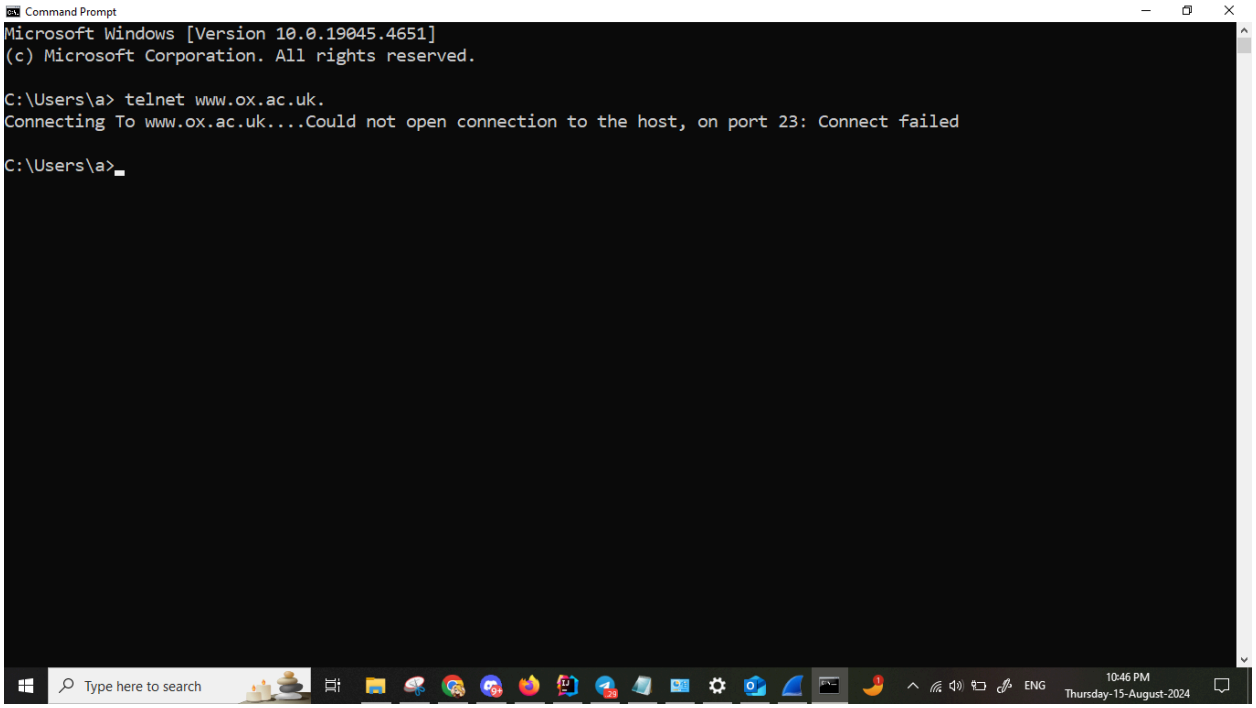
The screenshot shows the result of a tracert (traceroute) command to the domain www.ox.ac.uk, resolving to the IP address 104.22.48.74. The trace completed in 6 hops, with the times for each hop ranging from 1 ms to 21 ms. The first hop is to the local gateway (192.168.1.1), followed by a few internal network hops before reaching external IP addresses, including one at 82.213.5.42 and the final destination at 104.22.48.74. There is one instance of a missing response (indicated by the asterisk), which is common and not necessarily indicative of a problem. Overall, the trace shows a relatively quick and direct route to the destination.

e) nslookup for www.ox.ac.uk. :



The screenshot shows the result of promoting an nslookup query for the domain "www.ox.ac.uk." The results indicate that the DNS lookup returned IP addresses associated with Cloudflare's content delivery network (CDN), suggesting that the Oxford University website is utilizing Cloudflare for DNS services and possibly for enhanced security and performance. The local DNS server's address is shown as "192.168.1.1," but it is marked as "Unknown," which may indicate a local network configuration detail.

f) telnet www.ox.ac.uk.



Connection to port 23 failed, this problem is mentioned in the **Alternatives Solutions, Issues and Limitations** part of the report.

3. Some details about autonomous system (AS) number, number of IPs, prefixes, peers, name of Tier1-ISP of www.ox.ac.uk. :

ox.ac.uk

DNS Info | Website Info | IP Info

151.101.2.216 > 151.101.0.0/22 > AS54113 > Fastly, Inc.
151.101.2.216 > 151.101.0.0/16 > AS54113 > Fastly, Inc.
151.101.130.216 > 151.101.128.0/22 > AS54113 > Fastly, Inc.
151.101.130.216 > 151.101.0.0/16 > AS54113 > Fastly, Inc.
151.101.66.216 > 151.101.64.0/22 > AS54113 > Fastly, Inc.
151.101.66.216 > 151.101.0.0/16 > AS54113 > Fastly, Inc.
151.101.194.216 > 151.101.192.0/22 > AS54113 > Fastly, Inc.
151.101.194.216 > 151.101.0.0/16 > AS54113 > Fastly, Inc.

This screenshot maps specific IP addresses to the larger IP blocks and the autonomous system (Fastly's AS54113) that manages them. This is crucial for understanding how internet traffic is routed through Fastly's network.

Breakdown of the Information:

IP Addresses:

- **151.101.2.216**
- **151.101.130.216**
- **151.101.66.216**
- **151.101.194.216**

  These are individual IP addresses that belong to the same larger IP block managed by the same organization, which is Fastly, Inc.

IP Prefixes:

- **151.101.0.0/22**
- **151.101.0.0/16**
- **151.101.128.0/22**
- **151.101.64.0/22**
- **151.101.192.0/22**

These represent the IP address ranges (prefixes) that include the specific IP addresses listed. The /22 and /16 are CIDR (Classless Inter-Domain Routing) notations that define the size of the IP address block. A /22 prefix contains 1,024 IP addresses, while a /16 prefix contains 65,536 IP addresses.

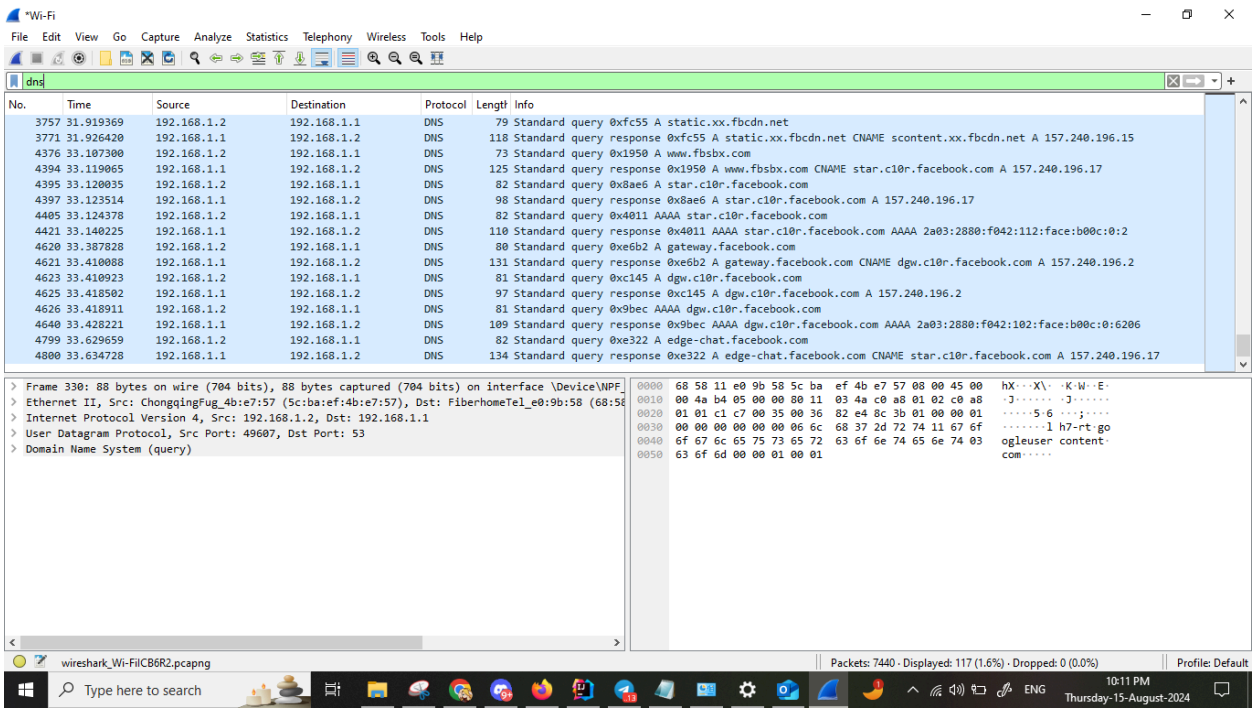
Autonomous System (AS) Number:

- **AS54113**

This is the Autonomous System Number associated with these IP address ranges. AS54113 is assigned to Fastly, Inc.

Oxford is not a Tier 1 ISP, meaning it does not have settlement-free peering relationships with every other network on the Internet. Instead, it relies on JANET and other Tier 2 ISPs for transit services.

4. Capturing some DNS messages from WireShark:



The screenshot shows a Wireshark capture focused on DNS traffic between a local machine (192.168.1.2) and a router (192.168.1.1). The DNS queries are related to Facebook domains, such as static.xx.fbcdn.net, star.c10r.facebook.com, and gateway.facebook.com, with responses indicating successful resolution to both IPv4 and IPv6 addresses. The capture highlights multiple standard DNS queries and their corresponding responses, illustrating typical DNS resolution for accessing Facebook services.

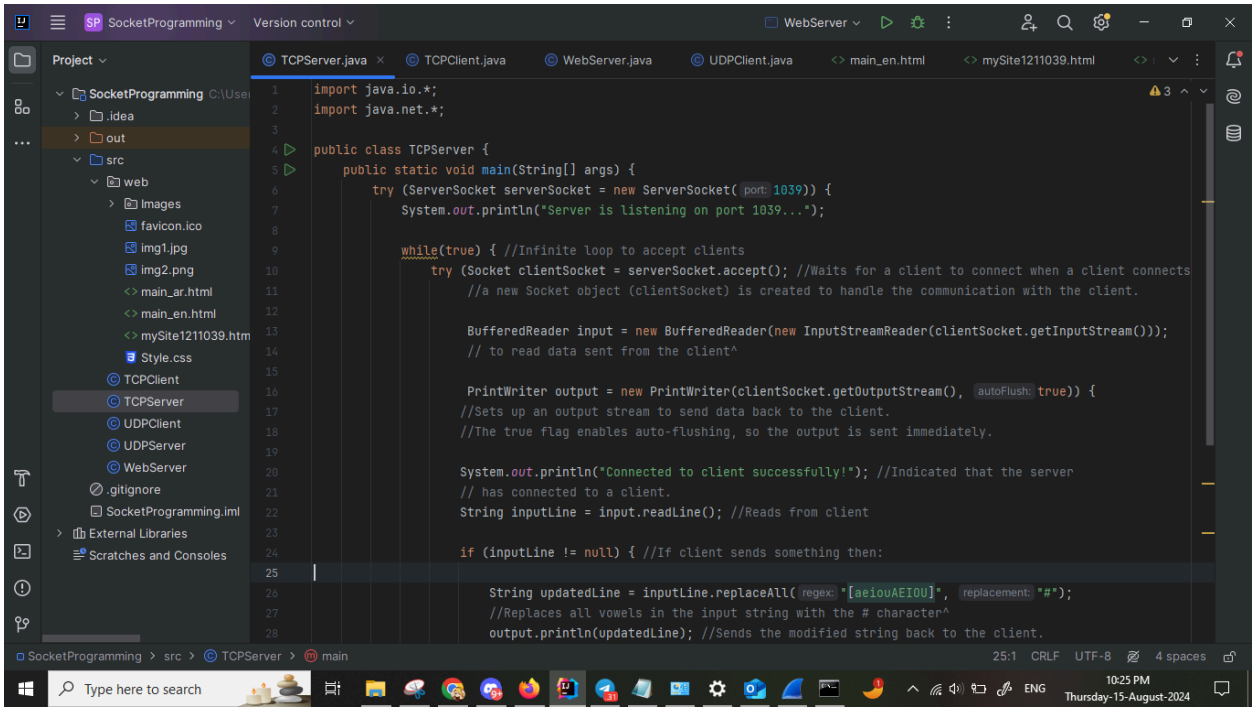
Task2: Socket Programming (TCP and UDP)

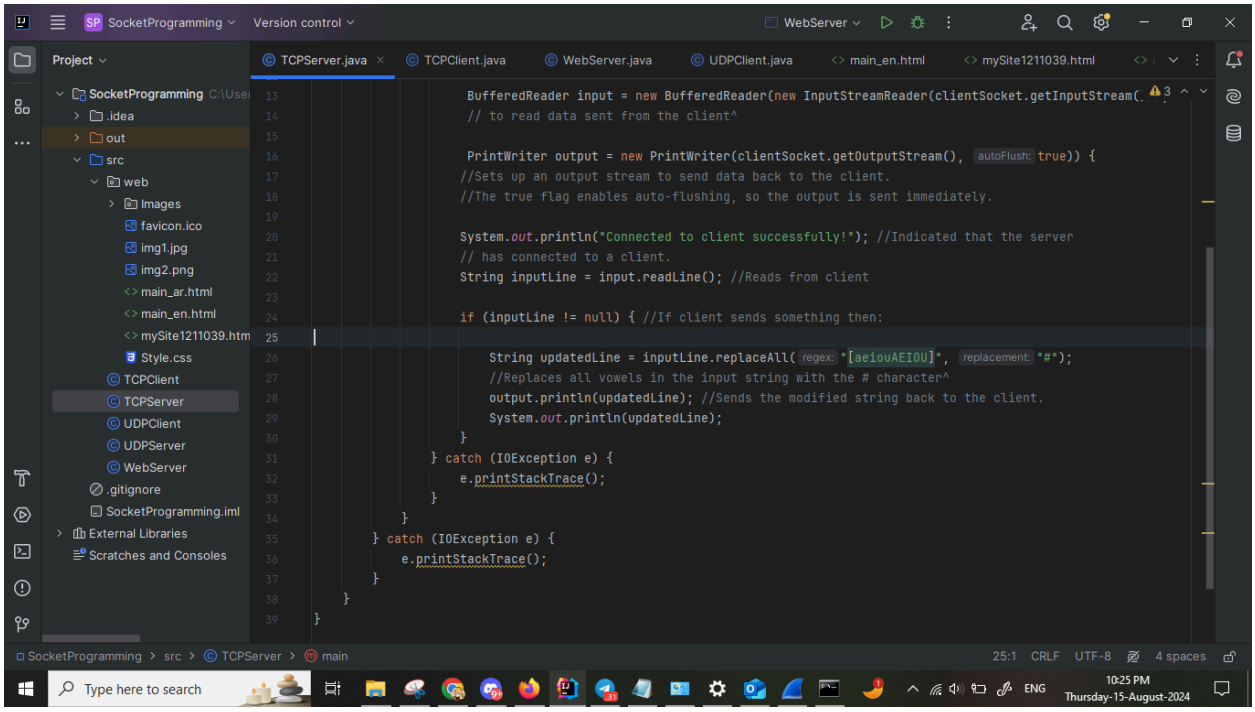
In this task, I implemented socket programming for both TCP and UDP communications. For the TCP part, I developed a client-server application in Java where the client sends a string to the server. The server processes the string by replacing all vowels with '#' and returns the modified string to the client for display. The communication uses a port number 1039 derived from my ID. For the UDP part, I created client and server applications where the server listens on the same port. Clients and the server exchange messages, with the server displaying messages received from all peers. Each client only shows messages exchanged with the server. This setup allows for testing and demonstrating peer-to-peer communication and message handling.

TCP part

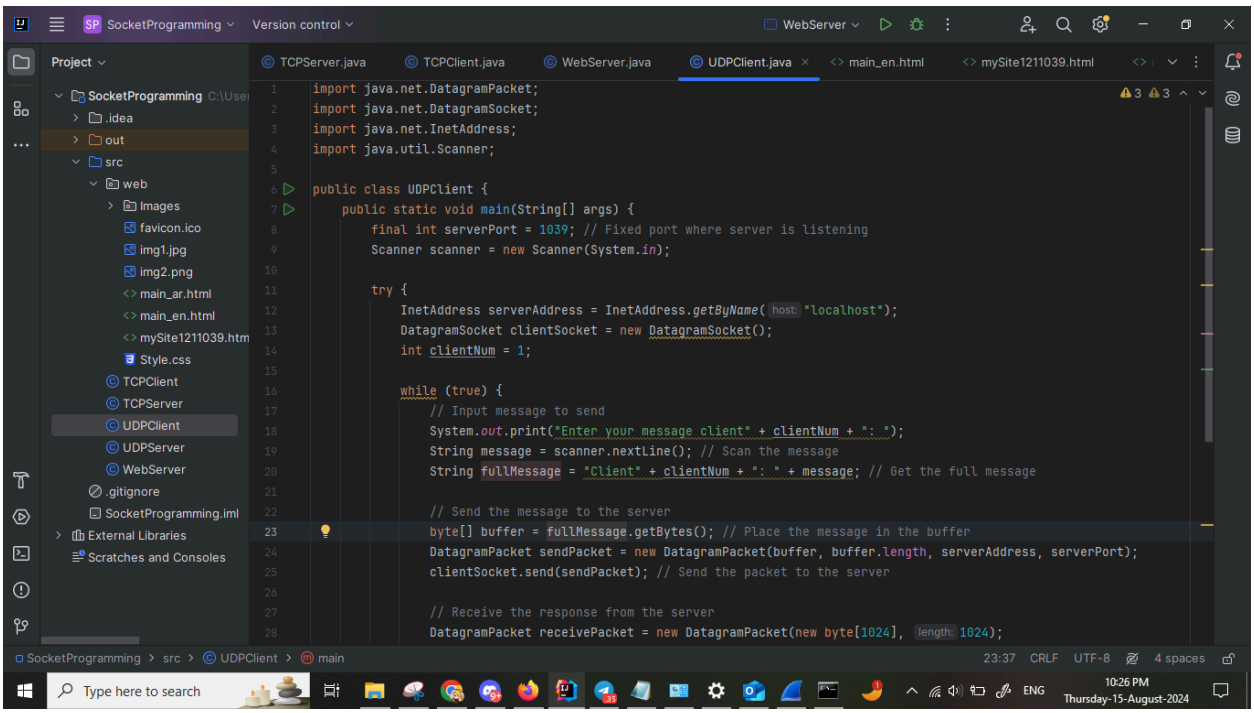
Codes:

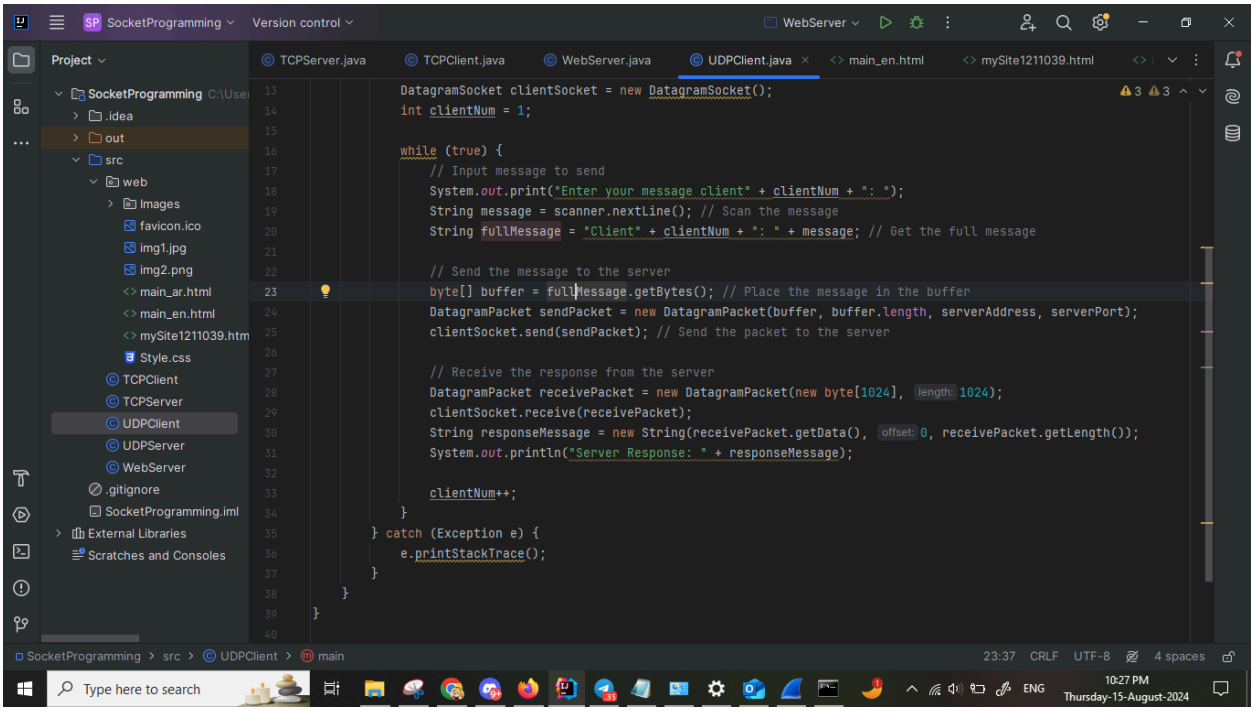
- TCP Server code:





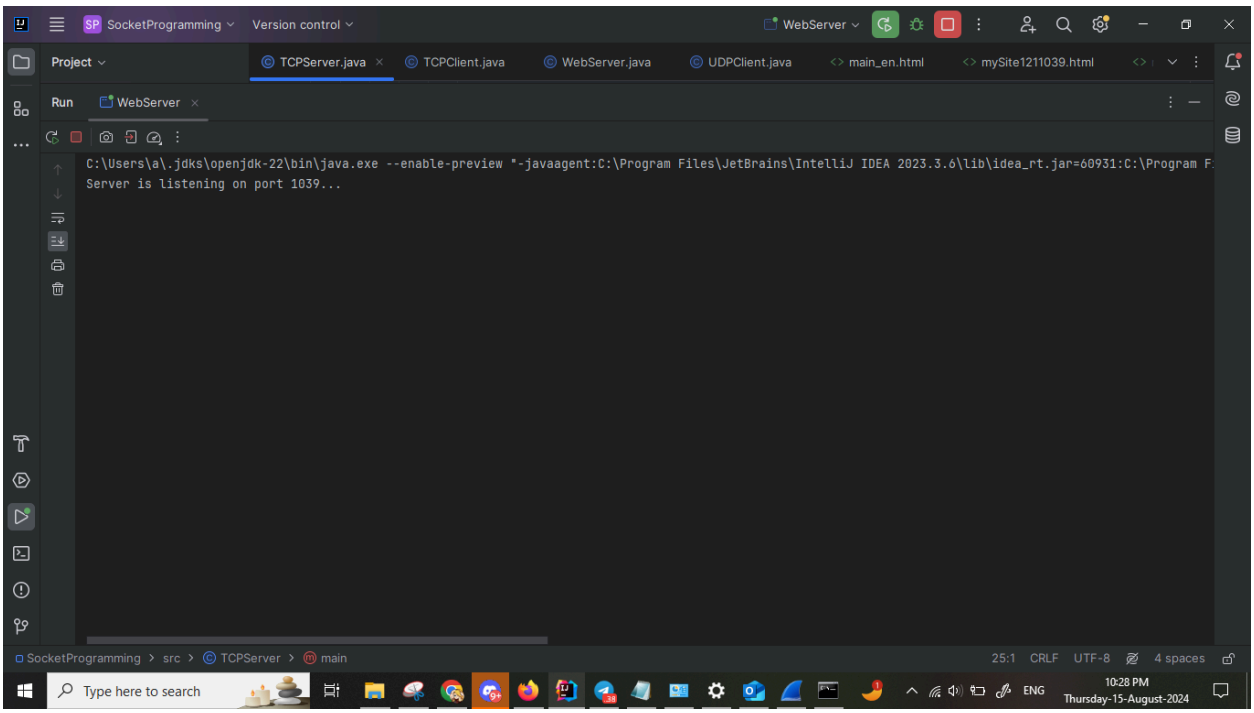
- TCP Client code:





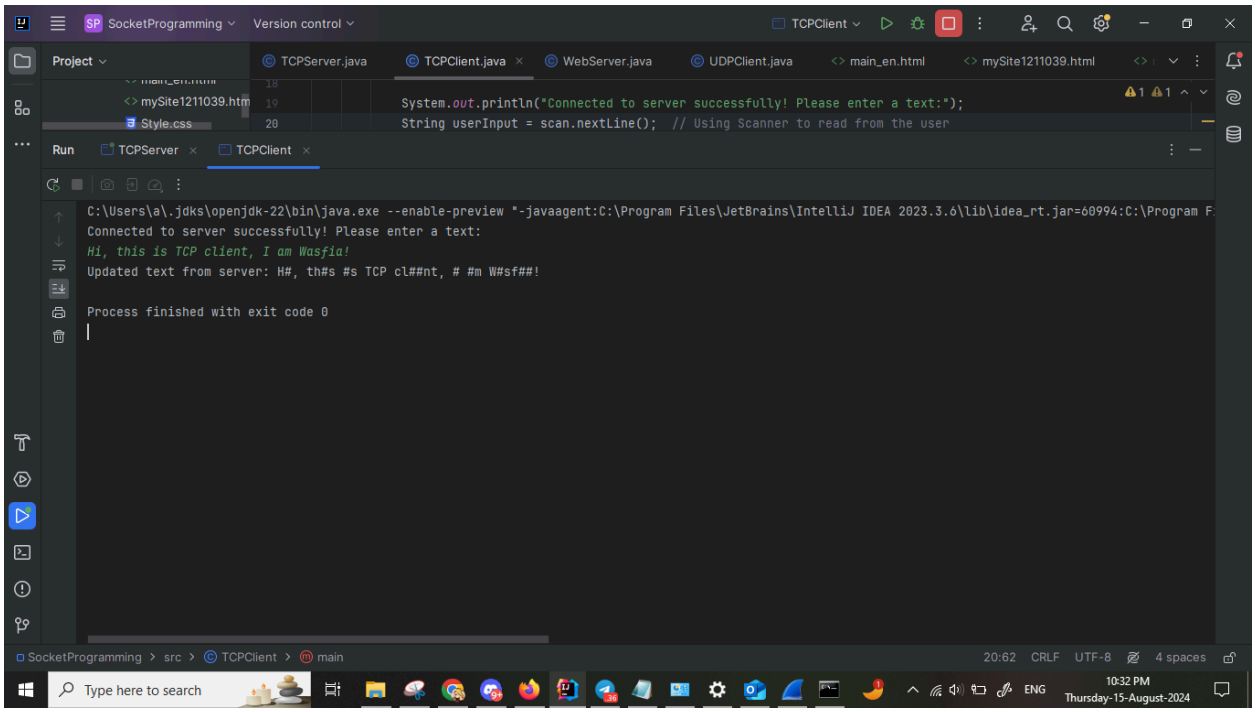
Runs:

Beginning with running the TCP server:

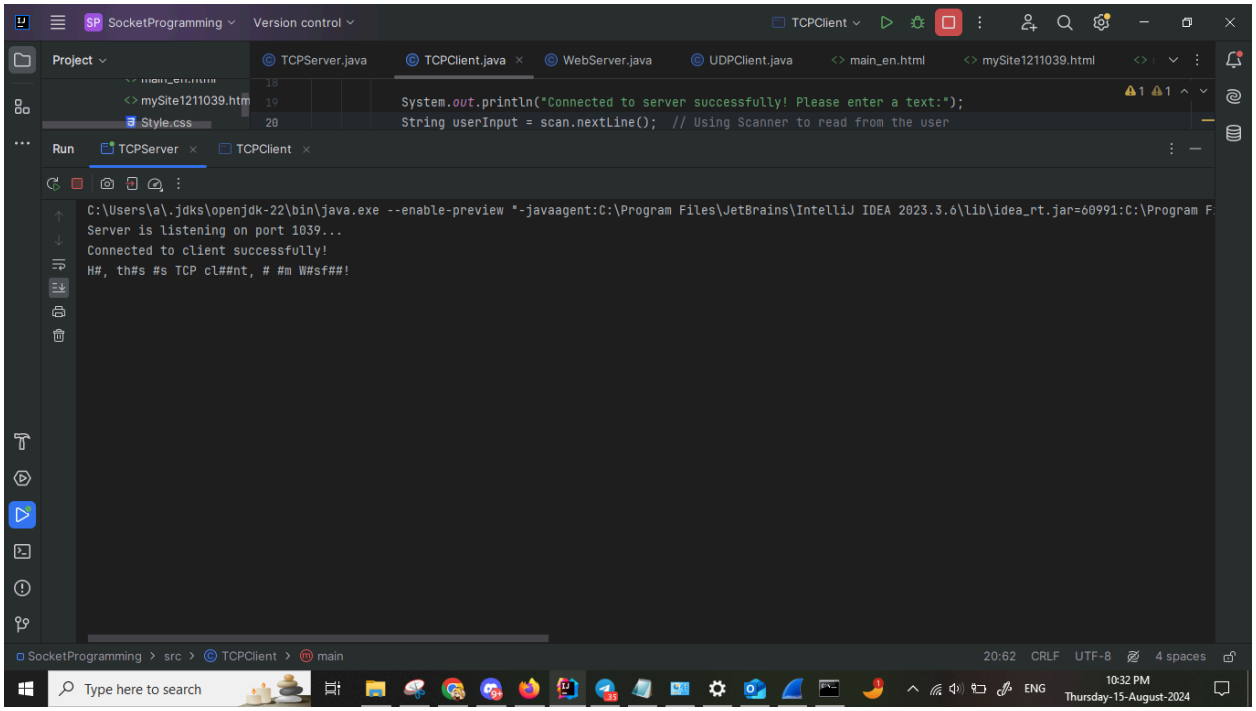


This message on the terminal indicates that the server has successfully started and is now listening for incoming client connections on port 1039.

Secondly, we run the TCPClient:



This screenshot shows what happens after running the TCP client, we can see that the client successfully connects to the server, and the server prompts the user to enter text, displaying .The client inputs "Hi, this is TCP client, I am Wasfia!" which is sent to the server. The server receives this input, processes it by replacing all vowels with the “#” character, and sends back the modified string. The TCPClient program then prints the received modified string and the program terminates with "Process finished with exit code 0," indicating successful execution and communication between the client and server.

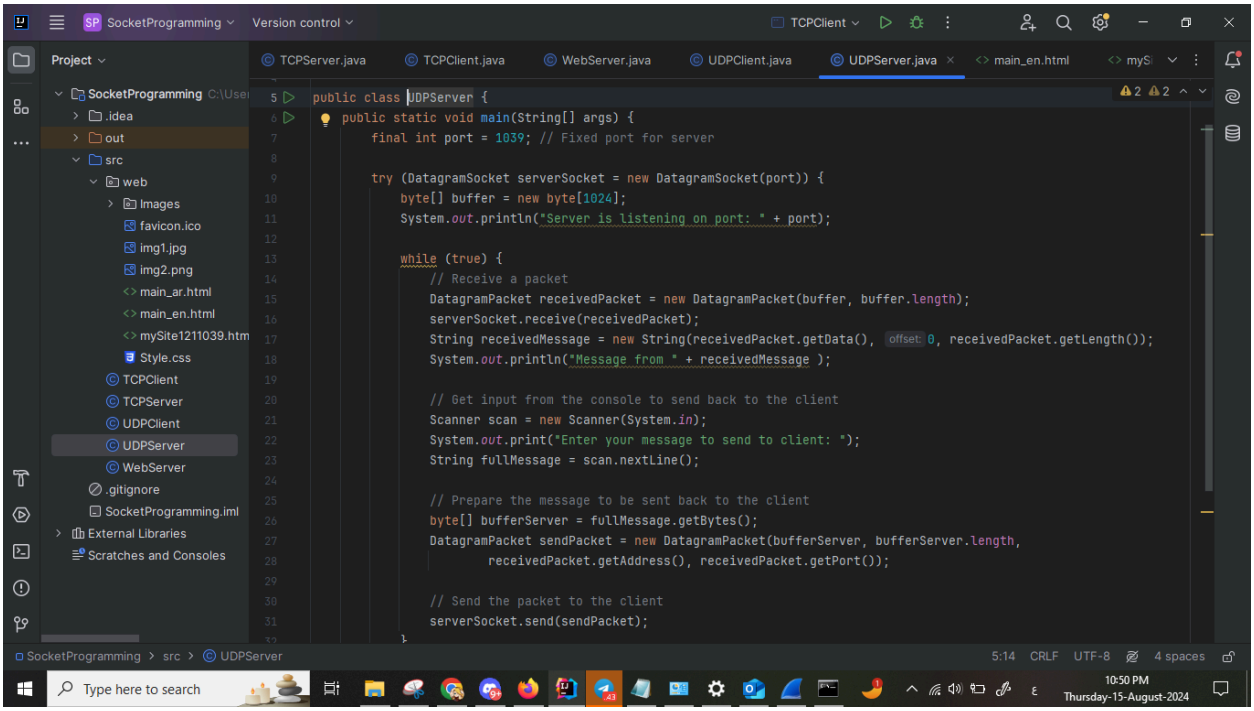


And this screenshot from the TCPServer shows the modified message.

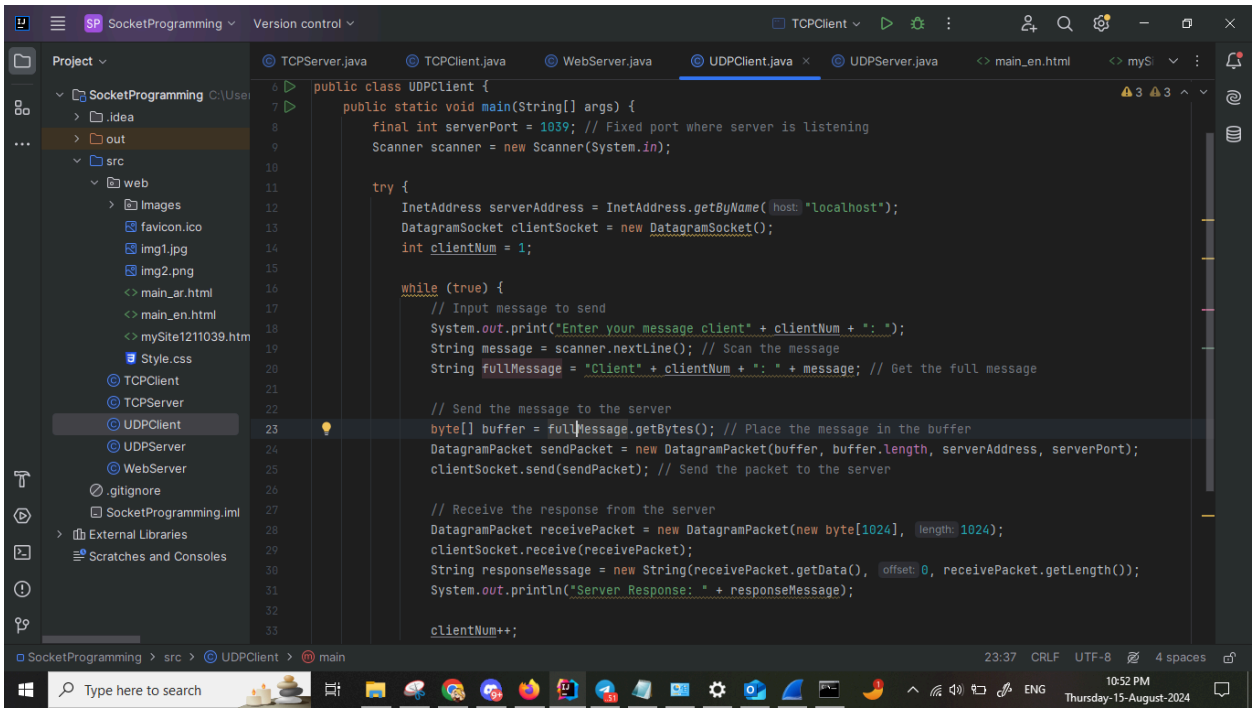
UDP Part

Codes:

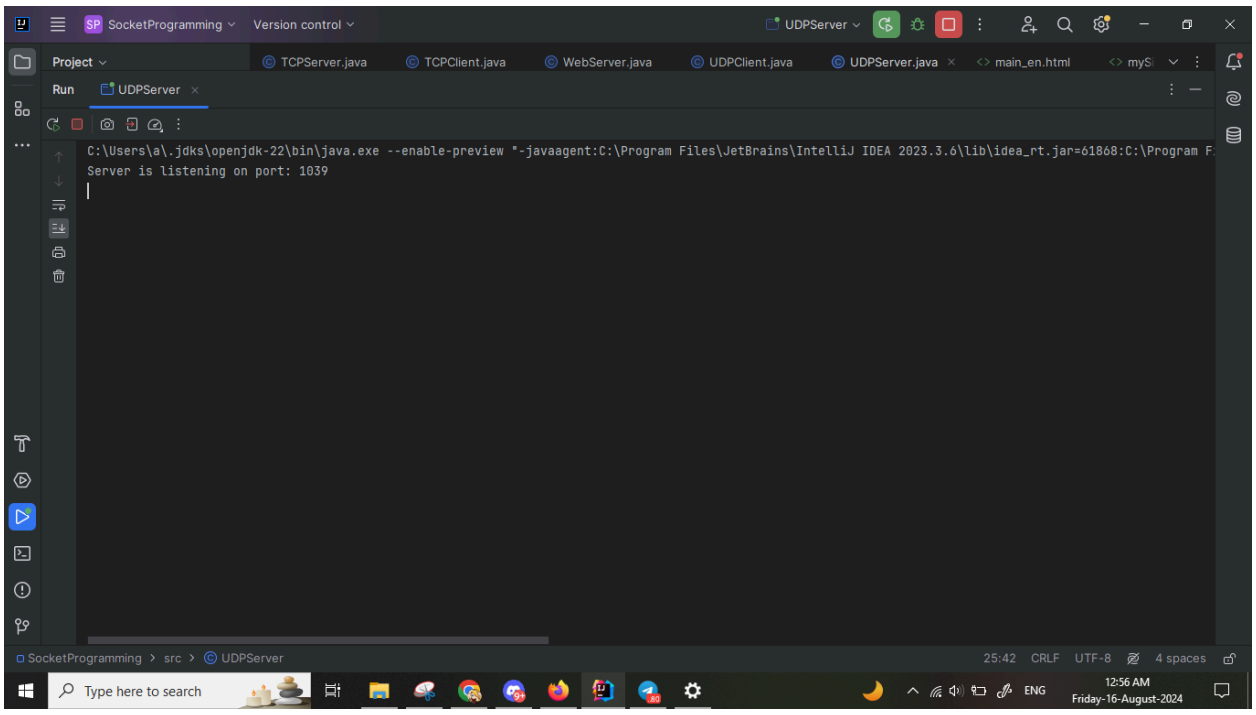
- UDPServer code



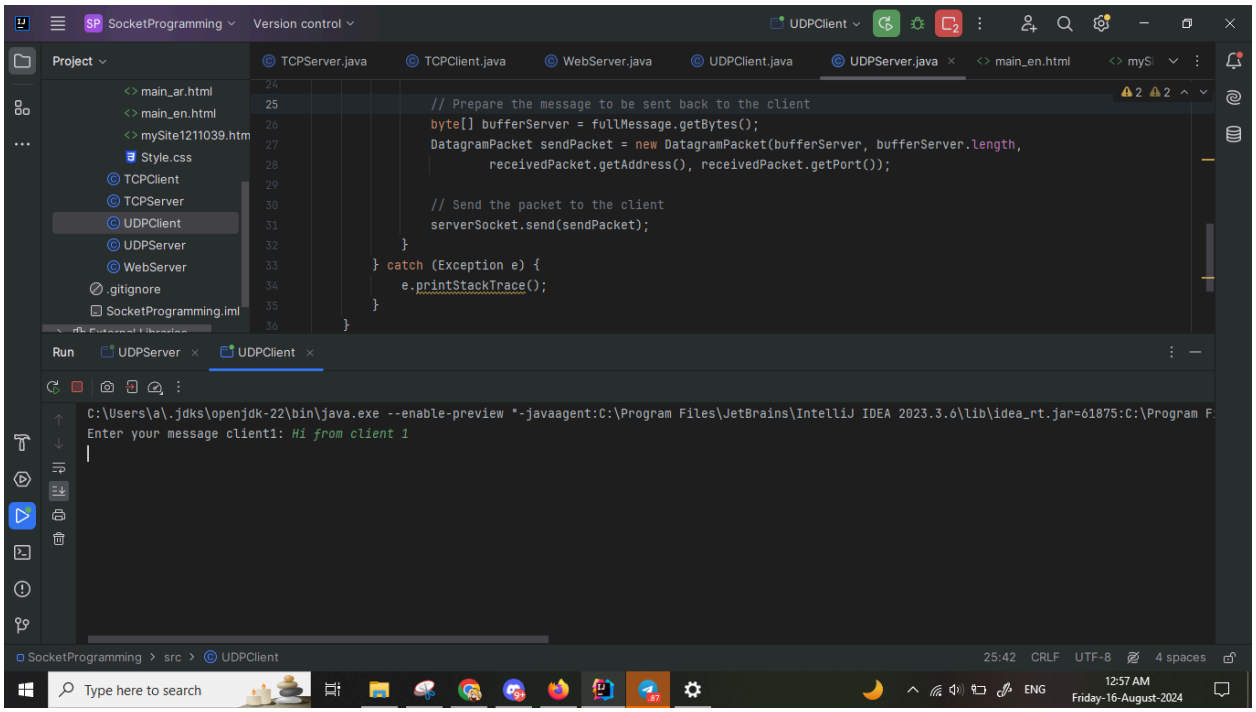
- UDPClient Code:



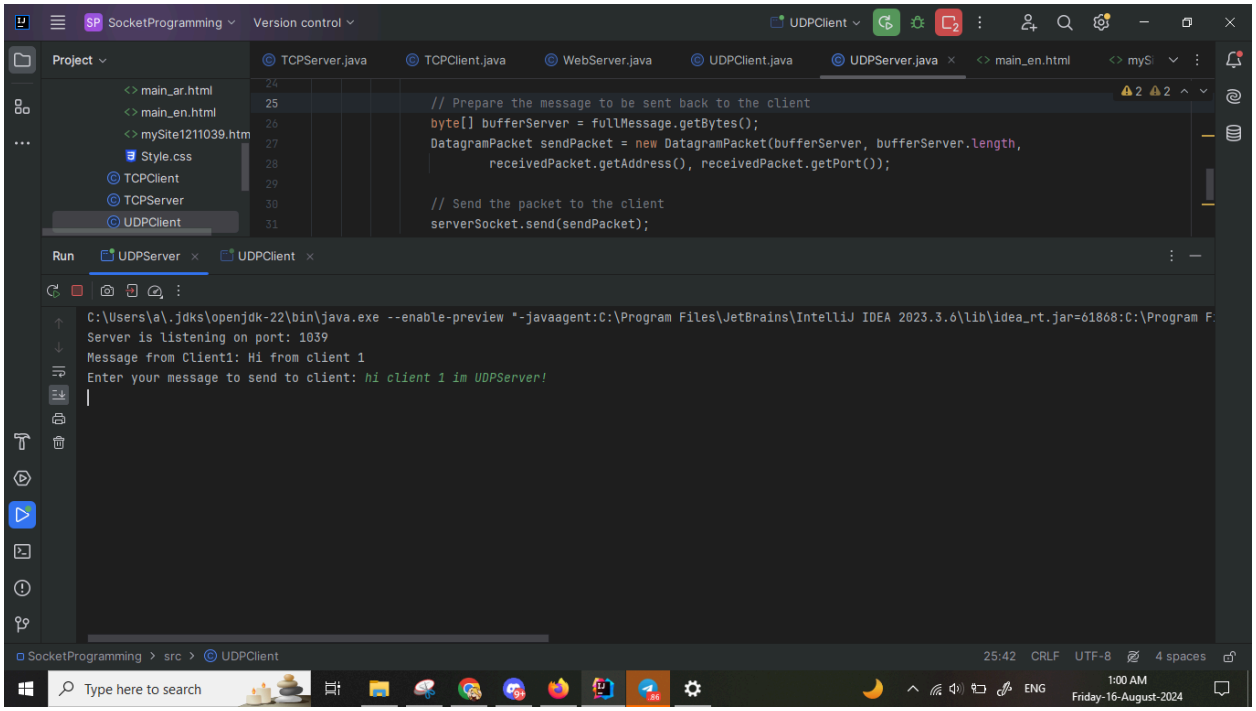
Runs:



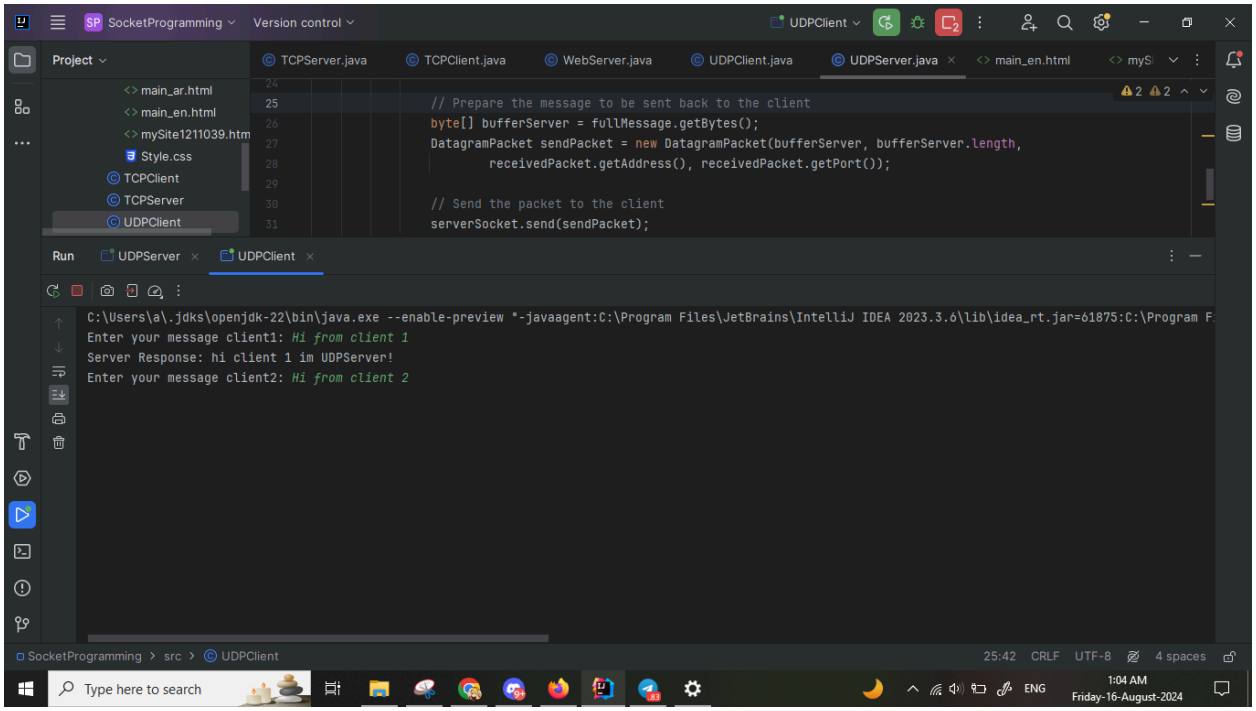
This screenshot shows the result of running UDPServer. This message on the terminal indicates that the server has successfully started and is now listening for incoming client connections on port 1039.



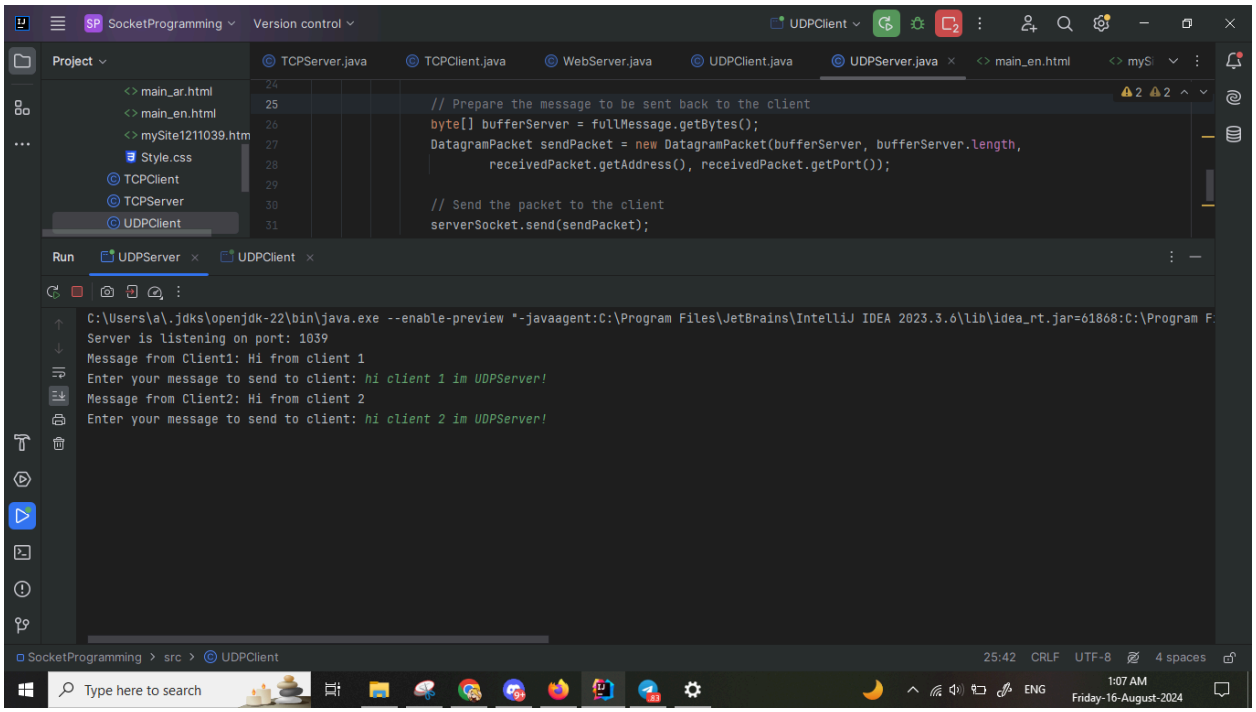
This screenshot shows the result of running UDPClient. Client number 1 was successfully connected to the server and ready to type a message, and typed “Hi from client 1” as shown in the screenshot.



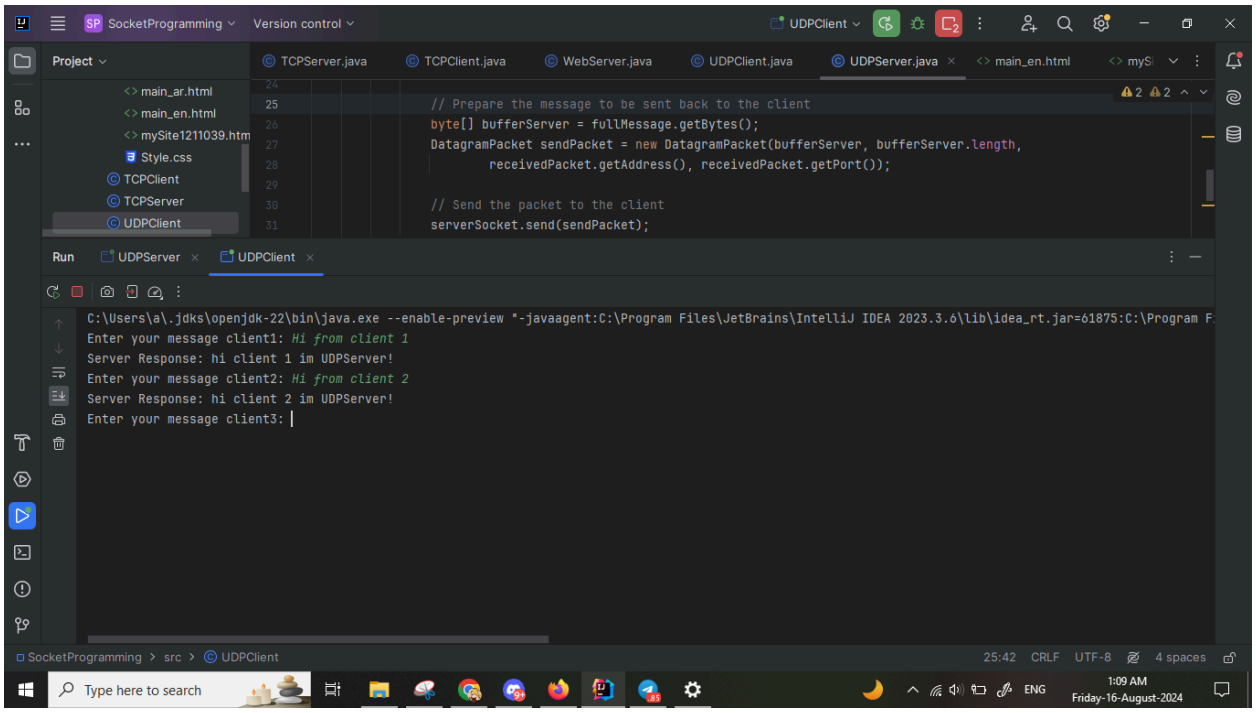
This screenshot shows the UDPServer terminal after receiving client 1 message, server can reply back to this message, it replied back with “hi client 1 I’m UDPServer” as shown in the screenshot.



This screenshot shows the UDPClient terminal, client 1 received the server's message successfully, now client 2 can go ahead and message the server, as shown in the screenshot client 2 sends a message saying "Hi from client 2".



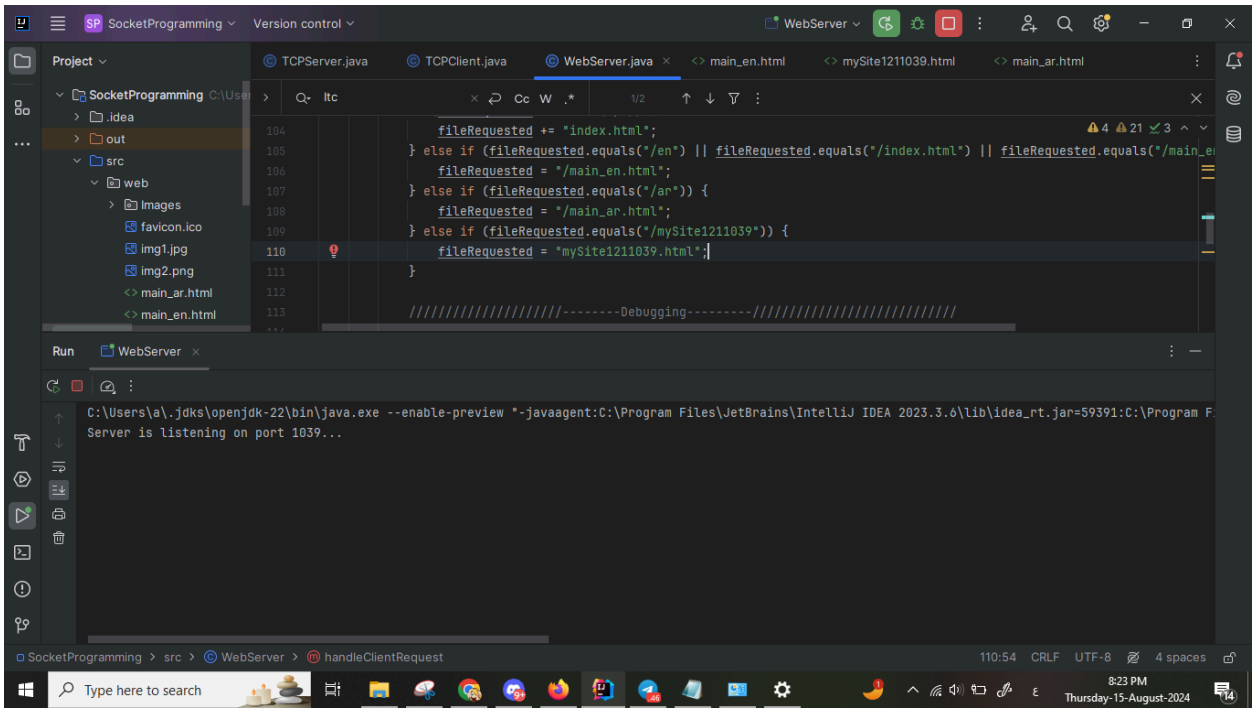
This screenshot shows the UDPServer terminal, the server has successfully received the message from client 2, and can reply back to client 2, it replied bcak with “hi client 2 im UDPServer!”.



This screenshot displays the terminal for UDPClient. Client 2 has successfully received a message from the server, and Client 3 is now ready to send its message to the server.

Task3: Web Server

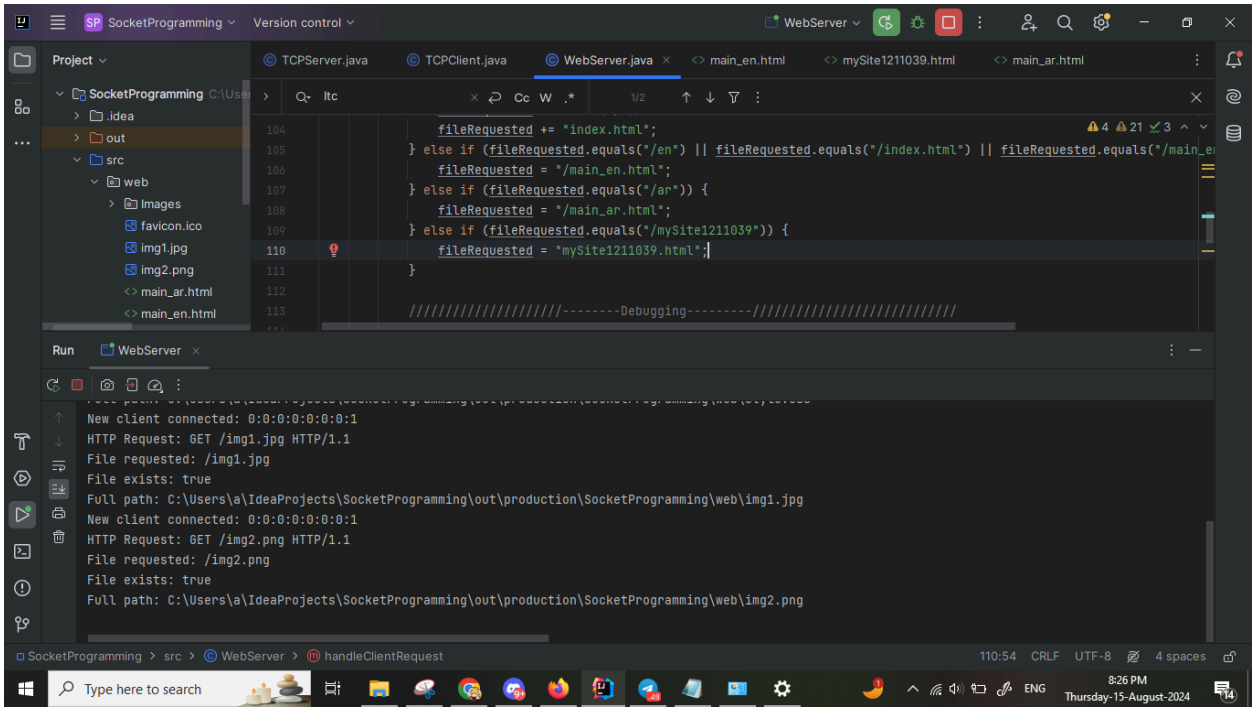
As part of my assignment, I implemented a simple web server using Java socket programming, listening on port 1039. The server handles requests for various paths, serving HTML and CSS files, as well as images in .jpg and .png formats. For specific requests, it serves main_en.html for English content and main_ar.html for Arabic content. Additionally, the server provides information about me, including my bio, showcases my art projects, and allows clients to search for images within a folder containing my drawings. It also includes redirections and custom 404 error handling, and it logs all HTTP requests in the terminal.



I ran the webServer in this screenshot

Next i'm attaching screenshots for opening the required URLs from my computer and the WebServer terminal output when opening each URL:

- http://localhost:1039/index.html



Clearing the output:

Client Connection:

New client connected: 0:0:0:0:0:0:0:1: This means the server accepted a connection from your browser. The IP address 0:0:0:0:0:0:0:1 is the IPv6 loopback address, equivalent to 127.0.0.1 in IPv4.

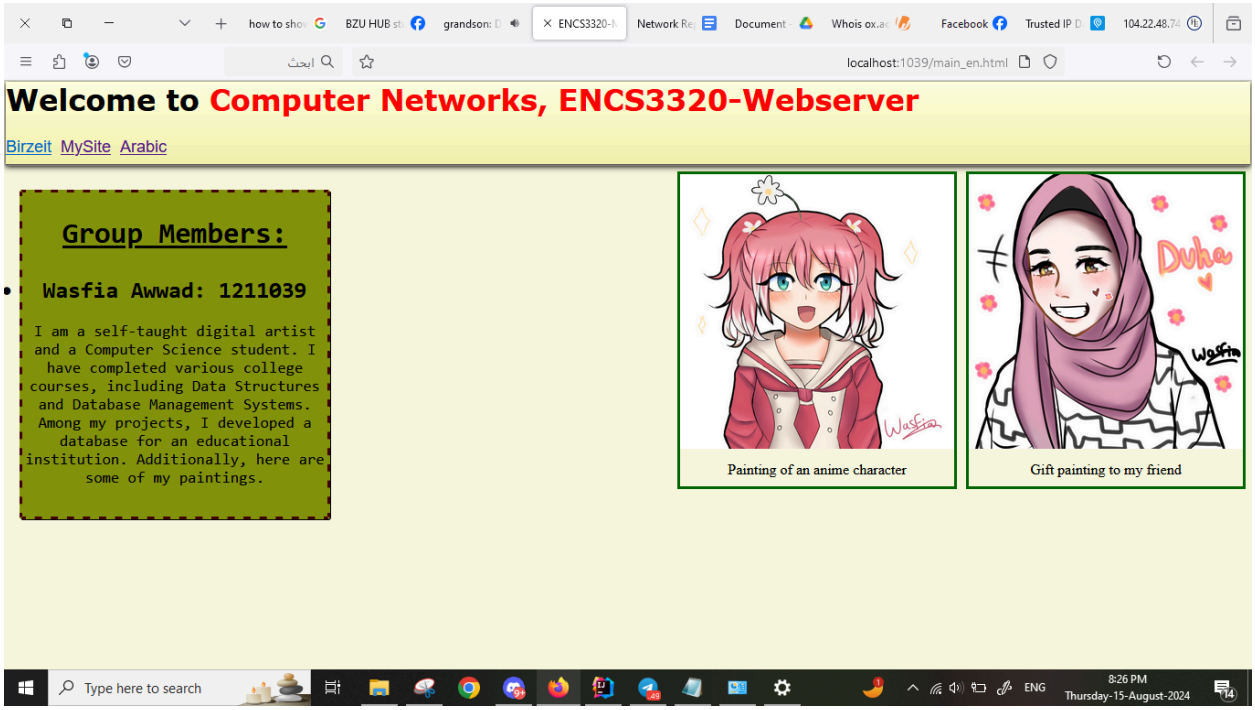
HTTP Request Handling:

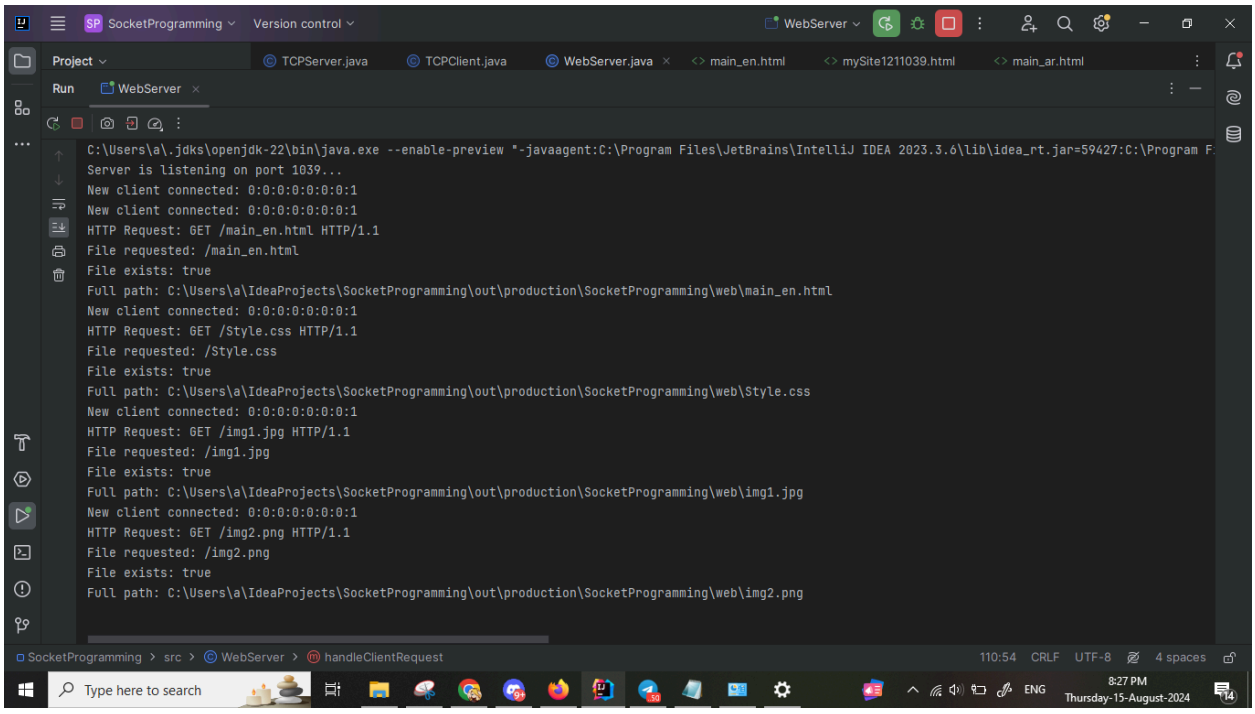
The server received a request for img1.jpg and img2.png, both of which were found in the ROOT_IMG directory (File exists: true).

File Serving:

The server successfully served the images (img1.jpg and img2.png) from the ROOT_IMG directory. It logged the full paths to these images.

- http://localhost:1039/main_en.html





Clearing the output:

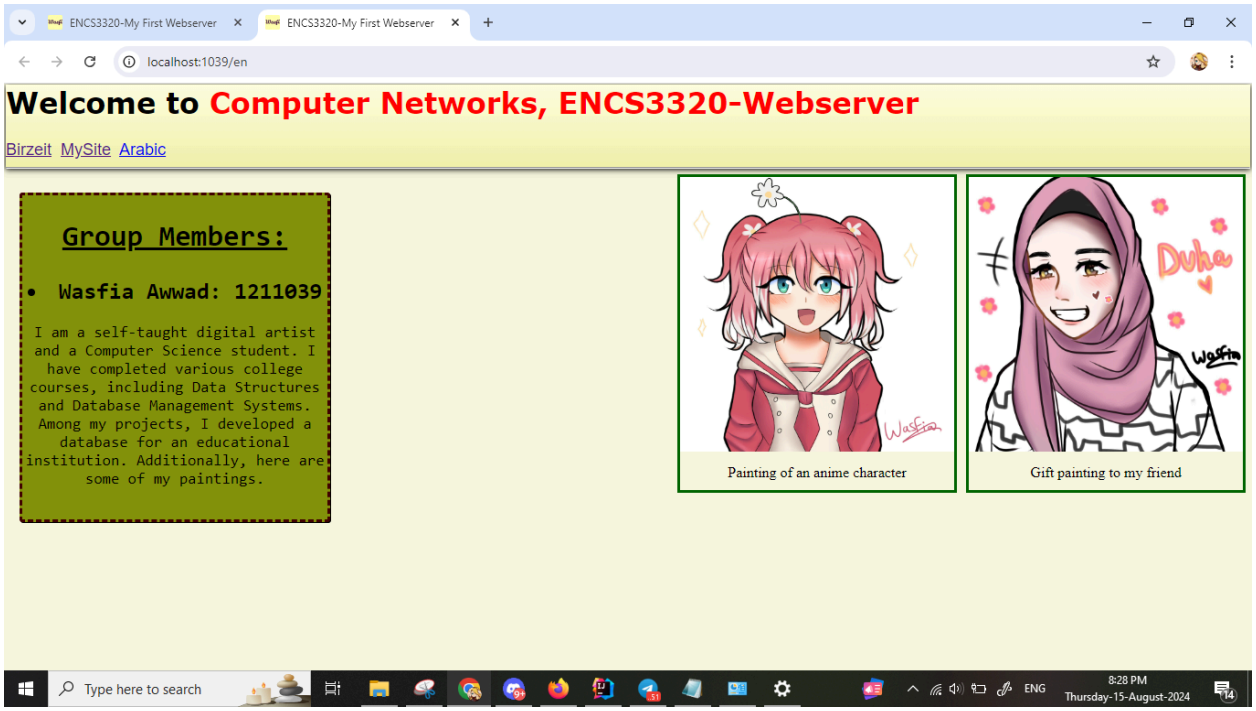
Server Start:
The server successfully starts and begins listening on port 1039.

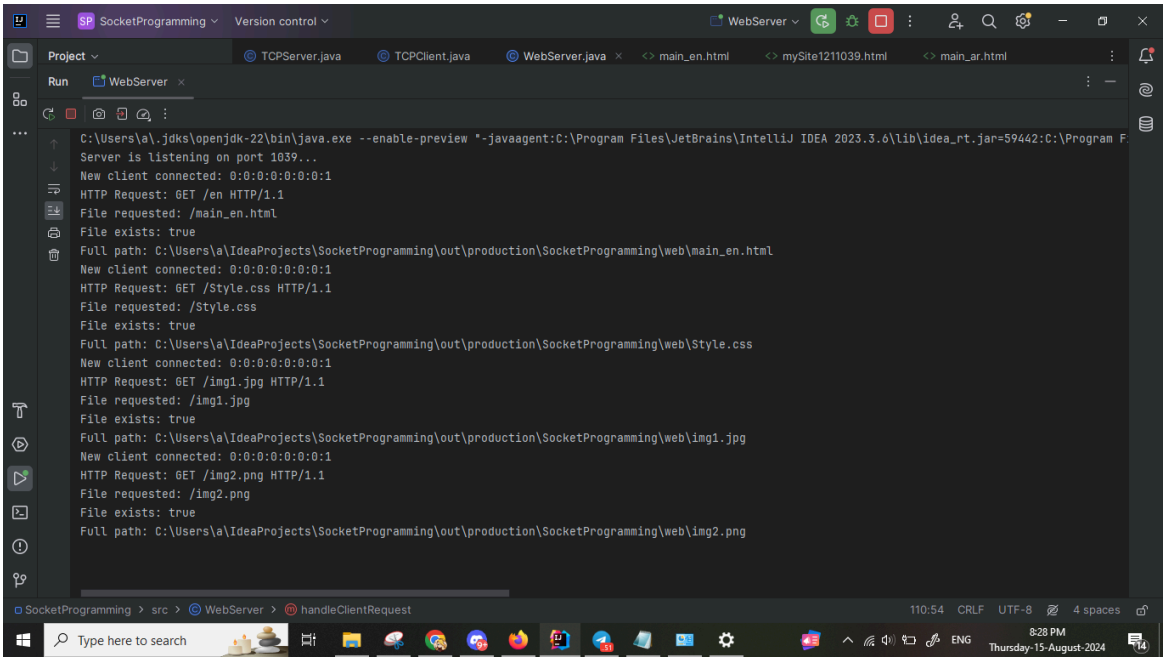
Client Connections:
New client connected: 0:0:0:0:0:0:0:1: This indicates that a new client has connected to the server. The IP address shown (0:0:0:0:0:0:0:1) is the IPv6 loopback address, equivalent to 127.0.0.1 in IPv4, meaning the client is on the same machine as the server.

HTTP Requests:
HTTP Request: GET /main_en.html HTTP/1.1: The client is asking for the main_en.html file.
File exists: true: The server found the requested file and is ready to serve it.
Full path: ...\main_en.html: The complete file path on the server's machine where the file is located.

Serving Files:
The server logs show that it successfully served several files, including main_en.html, style.css, img1.jpg, and img2.png.

- http://localhost:1039/en





Clearing the output:

Server Initialization:

The server is up and running on port 1039, just like before.

Client Request (for /en):

HTTP Request: GET /en HTTP/1.1

> The server received a request for the /en endpoint. It appears that the server mapped this to main_en.html.

File Handling for main_en.html:

The file main_en.html is found in the root directory and is served to the client (your browser).

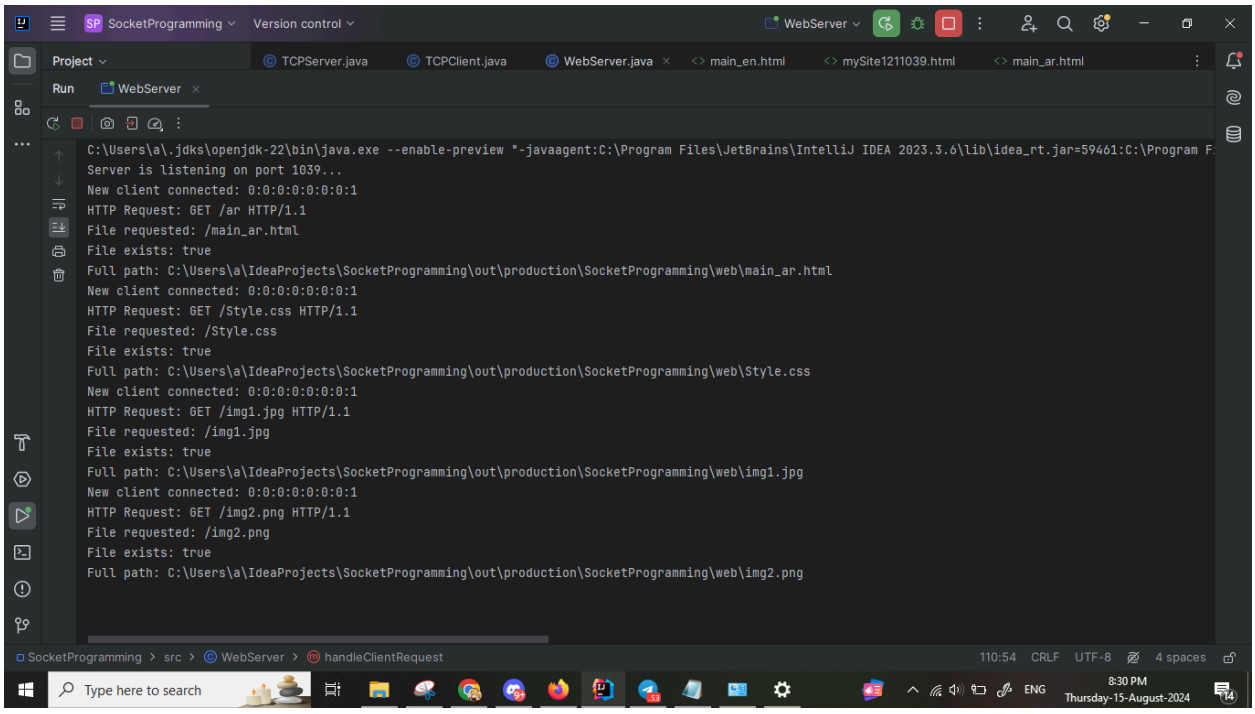
Full path:
C:\Users\a\IdeaProjects\SocketProgramming\out\production\SocketProgramming\web\main_en.html

> The file was successfully found and served.

Additional Requests:

After serving main_en.html, the browser made additional requests for resources like style.css, img1.jpg, and img2.png. These resources were likely linked within main_en.html:

- http://localhost:1039/ar



Clearing the output:

Server Initialization:

The server is listening on port 1039, which is the same as before.

First Client Request (for /ar):

HTTP Request: GET /ar HTTP/1.1

The server received a request for the /ar endpoint. The server likely interprets this request as a file or directory.

The server checks if /ar exists. Since it doesn't seem to be logged in the output directly, it likely maps /ar to main_ar.html (as seen in the output).

File Handling for main_ar.html:

The file main_ar.html is found in the root directory, so the server sends this file back to the client (your browser).

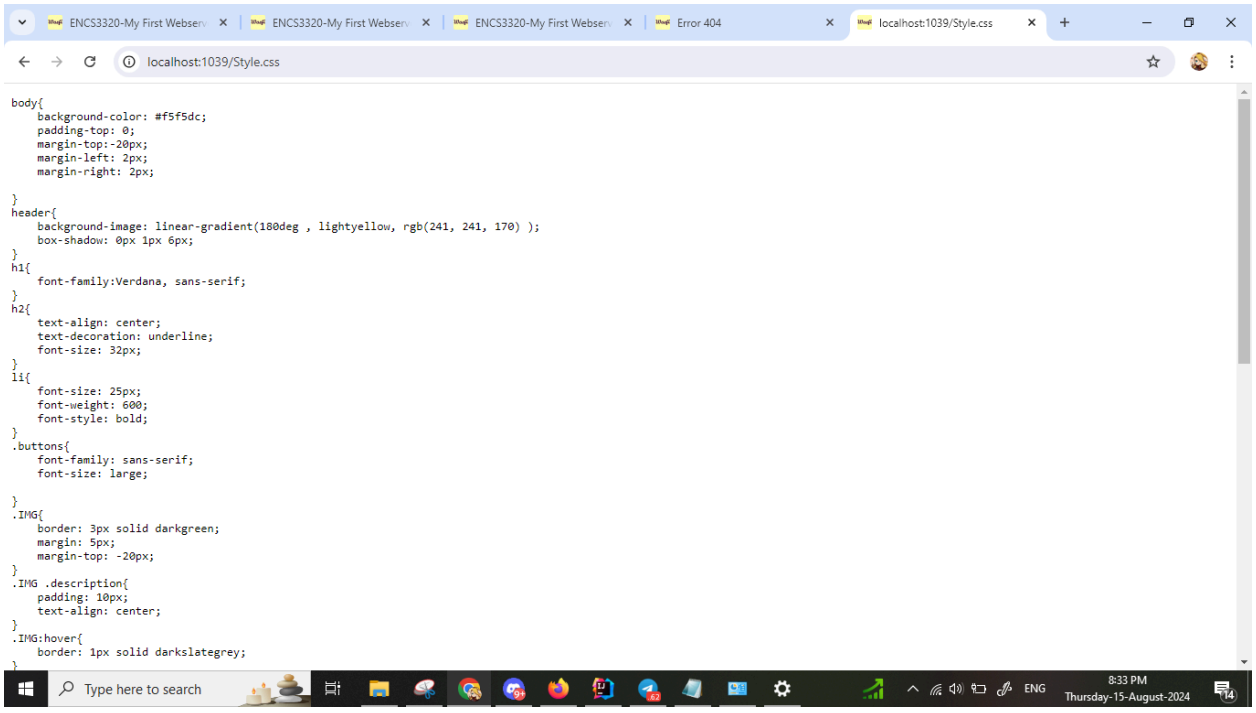
Full path:
C:\Users\a\IdeaProjects\SocketProgramming\out\production\SocketProgramming\web\main_ar.html

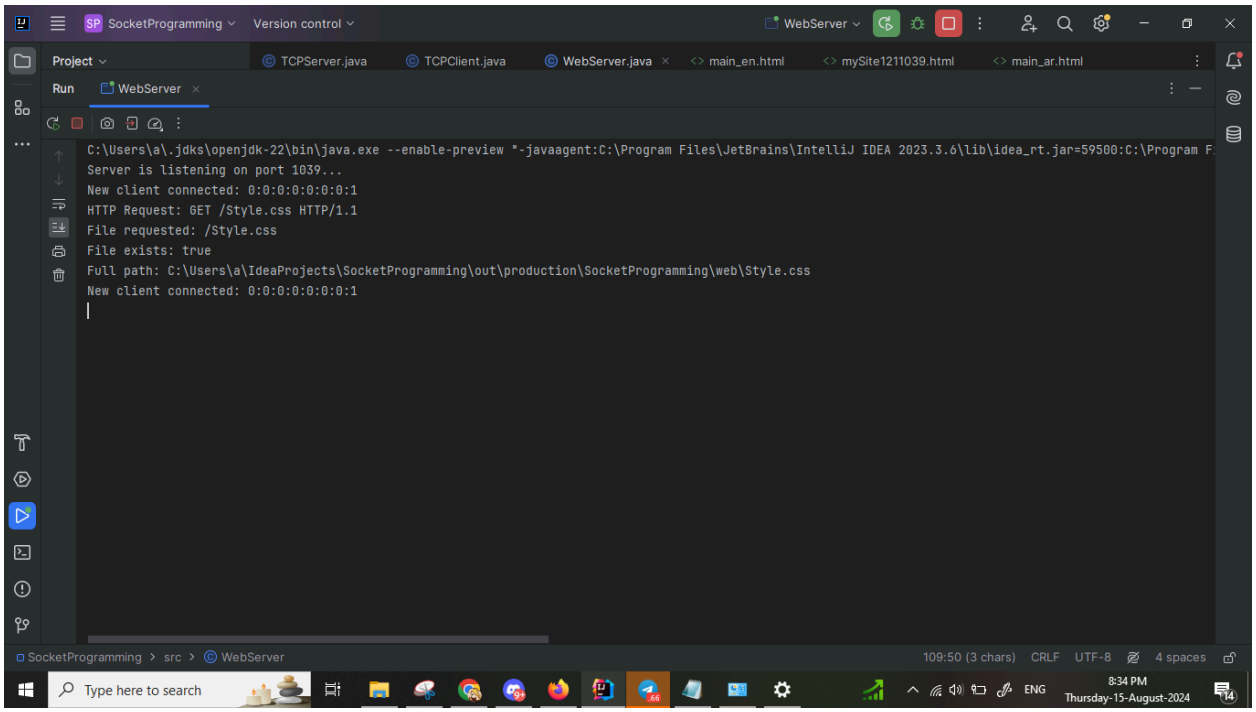
The file was successfully found and served.

Additional Requests:

After serving main_ar.html, the browser made additional requests for resources like style.css, img1.jpg, and img2.png. These are likely referenced within main_ar.html:

- http://localhost:1039/Style.css





Clearing the Output:

Server Initialization:

The server is listening on port 1039, indicating that it has successfully started and is ready to handle incoming requests.

First Client Request (for /index.html):

HTTP Request: GET /Style.css HTTP/1.1

The server received a request for the /Style.css file. This request likely came as part of the process of rendering index.html, where the browser requests associated CSS files to style the HTML content.

File Handling for Style.css:

File Requested: /style.css

The server identifies that the requested file is /style.css.

Full Path:
C:\Users\a\IdeaProjects\SocketProgramming\out\production\SocketProgramming\web\Style.css

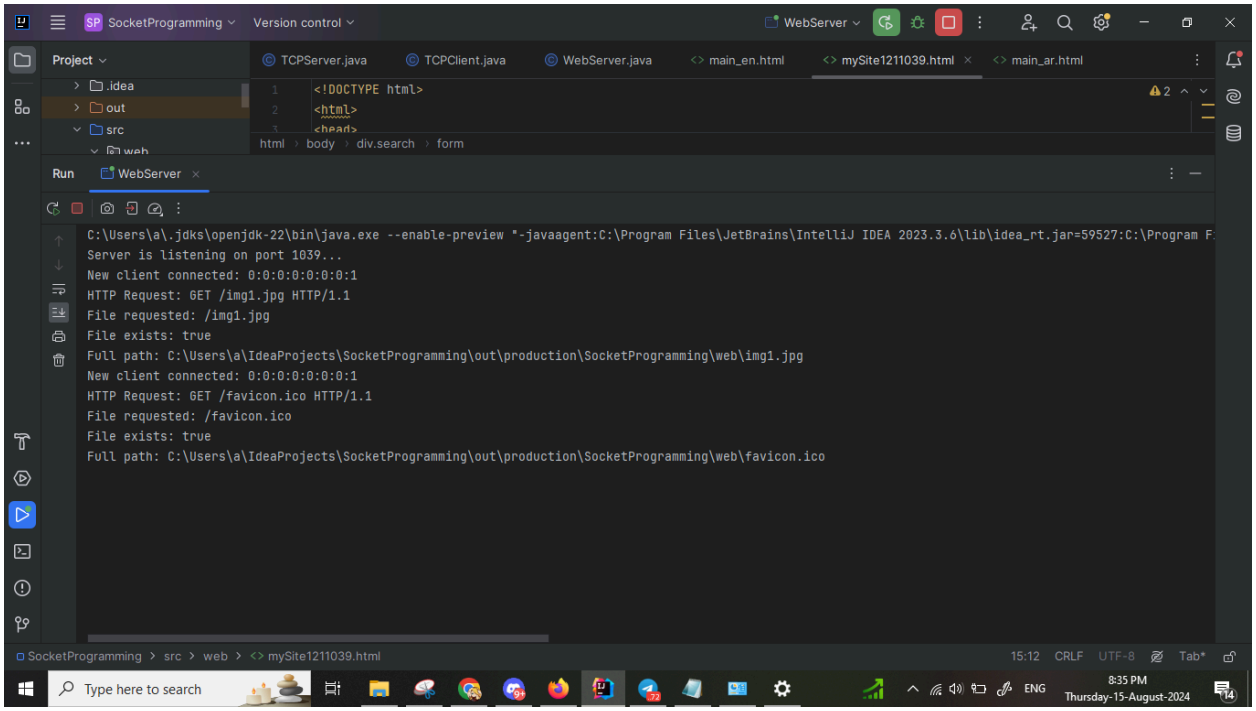
The full path of the requested file is displayed, indicating where the server found the file on the filesystem.

Additional Client Connections:

New Client Connected: 0:0:0:0:0:0:0:1

Another client connection was established,due to the browser making additional requests for resources needed to render the page, such as images, scripts, or other assets.

- http://localhost:1039/img1.jpg



Clearing the Output:

Server Initialization:

- The server is listening on port 1839, which indicates it has started successfully.

First Client Request (for /img1.jpg):

- **HTTP Request:** GET /img1.jpg HTTP/1.1

  The server received a request for the image file /img1.jpg.

- **File Handling for img1.jpg:**

  File Requested: /img1.jpg

  The server identifies the requested file as /img1.jpg.

  File Exists: true

The server confirms that the file /img1.jpg exists.

Full Path:
C:\Users\a\IdeaProjects\SocketProgramming\out\production\SocketProgramming\web\img1.jpg

The full path shows where the server found the file on the filesystem.

Additional Client Request (for /favicon.ico):

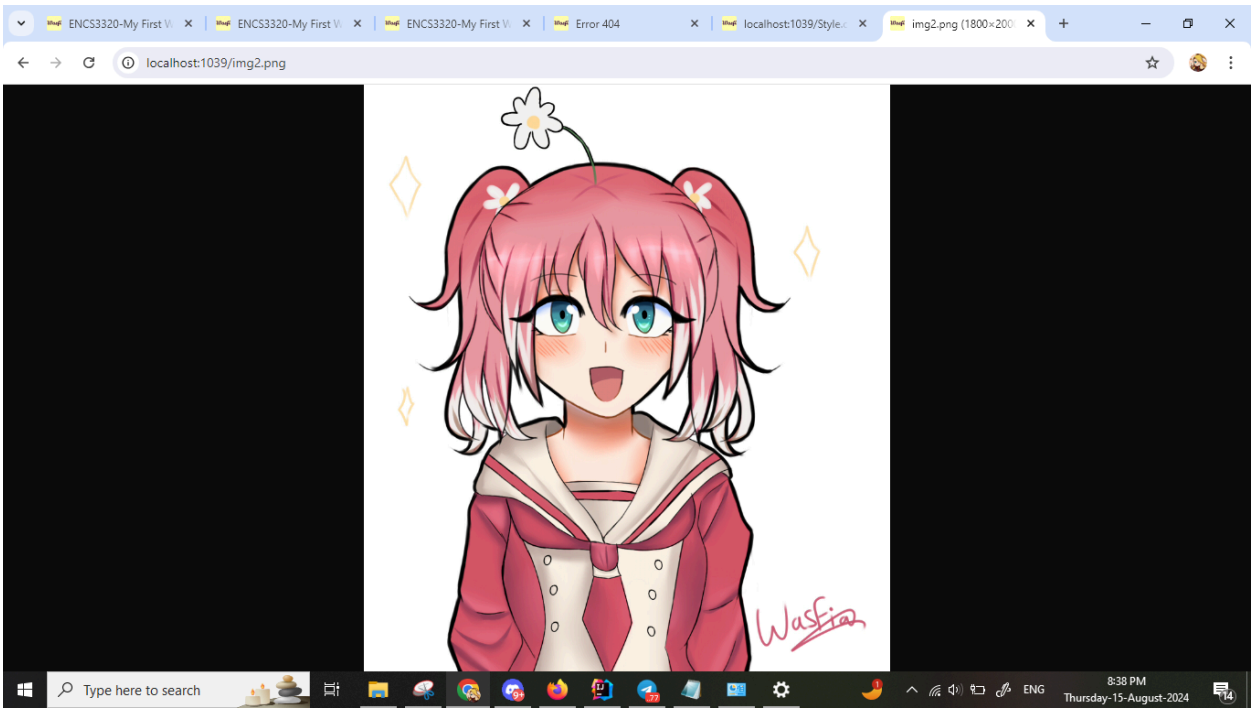
New Client Connected: 0:0:0:0:0:0:0:1

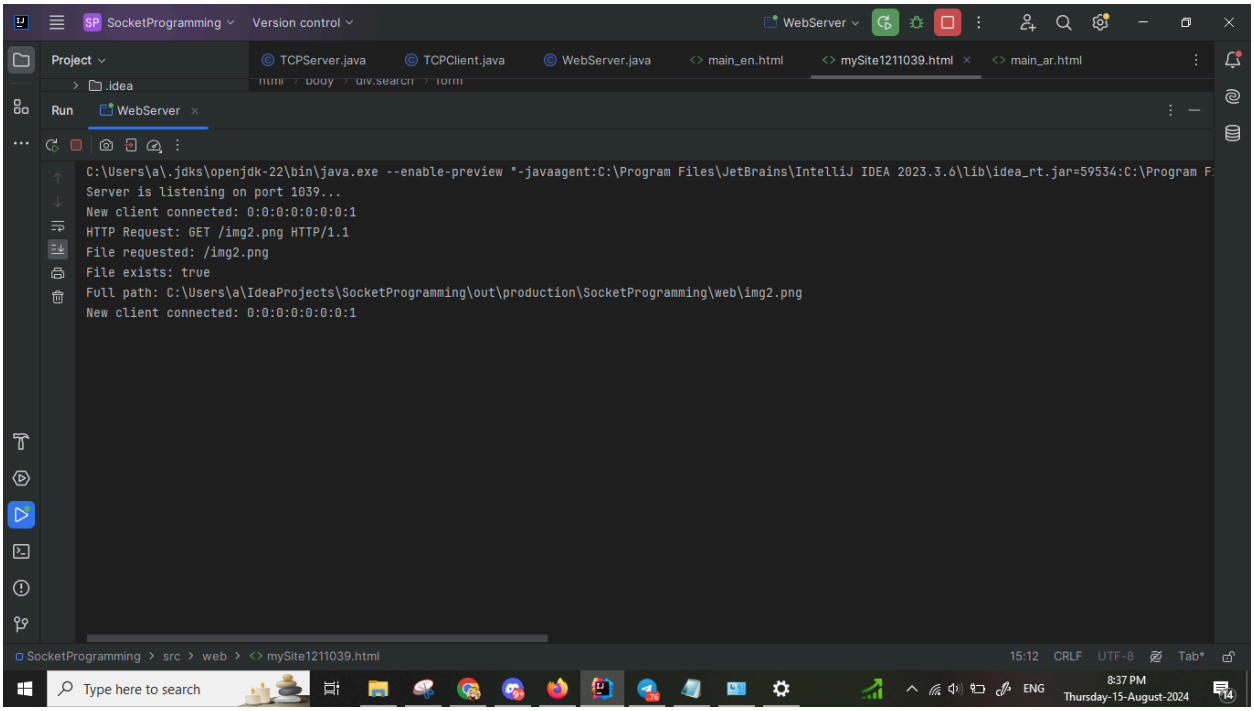
A new client connection was established, likely the browser automatically requesting the favicon.

HTTP Request: GET /favicon.ico HTTP/1.1

The server received a request for /favicon.ico, which is the default small icon that browsers often request.

- http://localhost:1039/img2.png





Server Initialization:

The server is listening on port 1039, which indicates it has started successfully.

First Client Request (for /img2.png):

HTTP Request: GET /img2.png HTTP/1.1

The server received a request for the image file /img2.png.

File Handling for img2.png:

File Requested: /img2.png

The server identifies the requested file as /img2.png.

File Exists: true

The server confirms that the file /img2.png exists.

Full Path:
C:\Users\a\IdeaProjects\SocketProgramming\out\production\SocketProgramming\web\img2.png

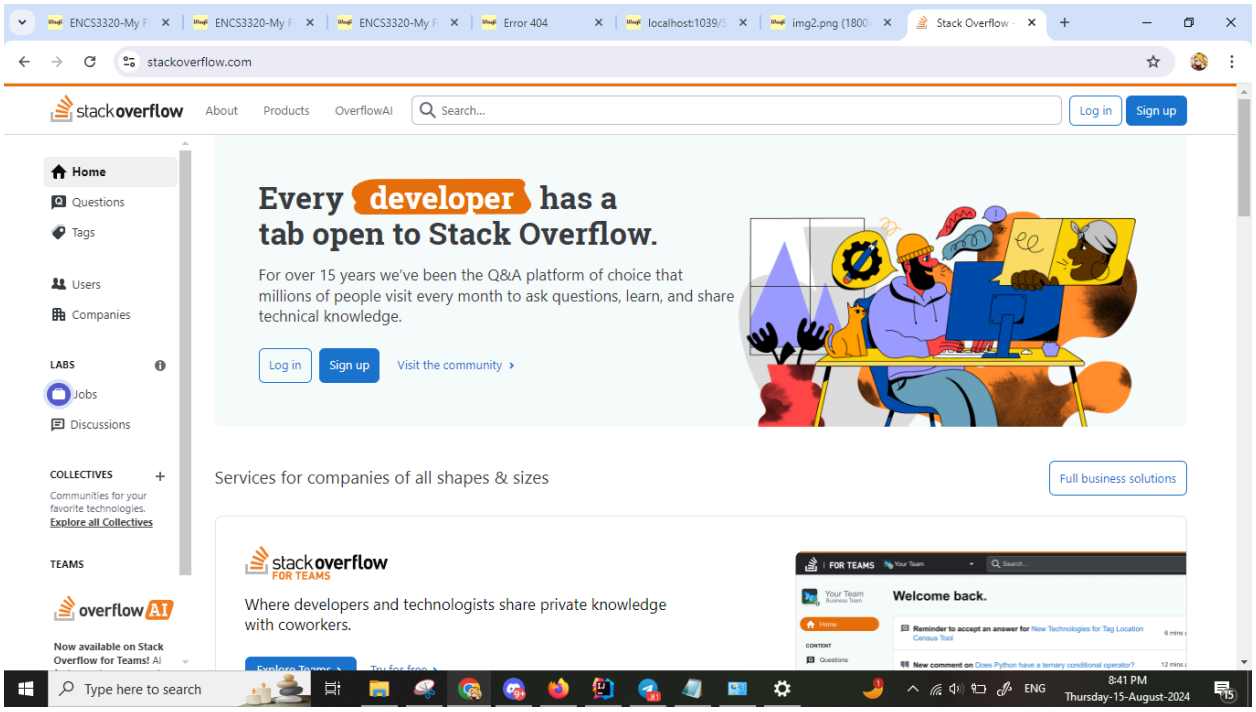
The full path shows where the server found the file on the filesystem.

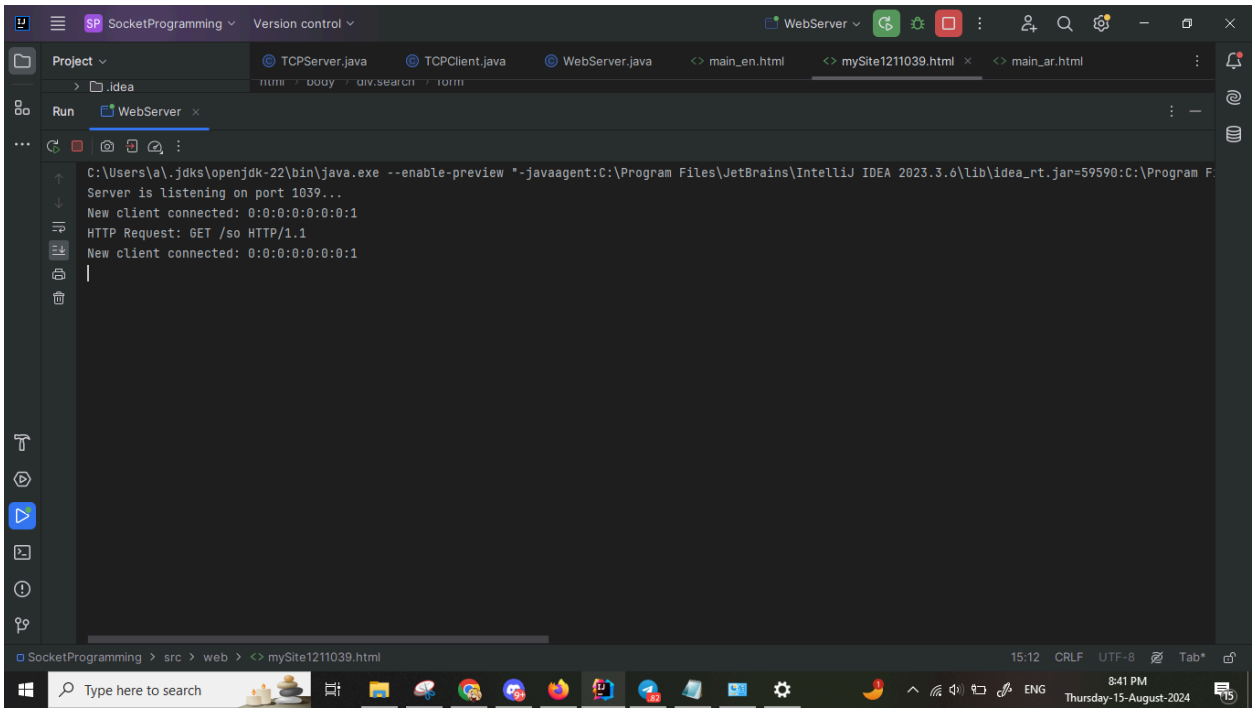
Additional Client Connection:

New Client Connected: 0:0:0:0:0:0:0:1

Another client connection was established, which might be due to the browser making additional requests or refreshing the connection.

- http://localhost:1039/so





Clearing the Output:

Server Initialization:

The server is listening on port 1039, indicating that it has started successfully.

First Client Request (for /so):

HTTP Request: GET /so HTTP/1.1

The server received a request for the /so endpoint. This request seems to be for a file or directory that might not exist on the server.

No File Handling Logged:

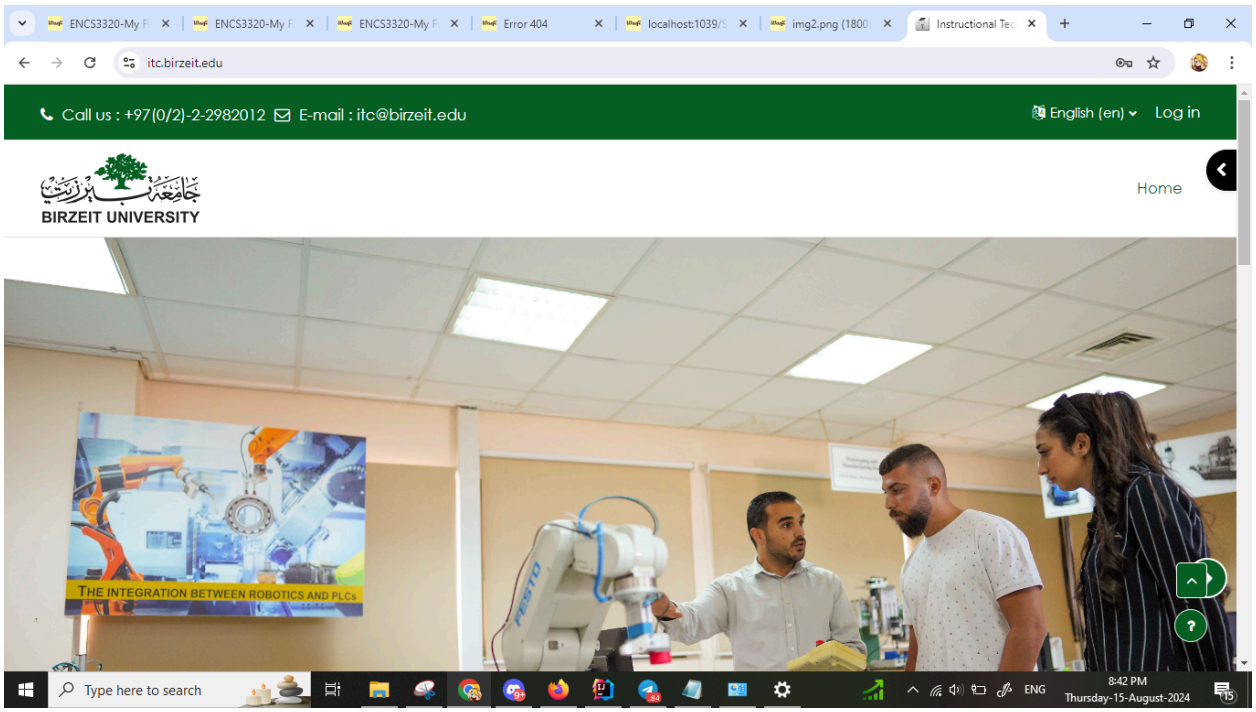
There is no log indicating whether the file /so exists or not. This could suggest that the server either did not find the file or did not log the result.

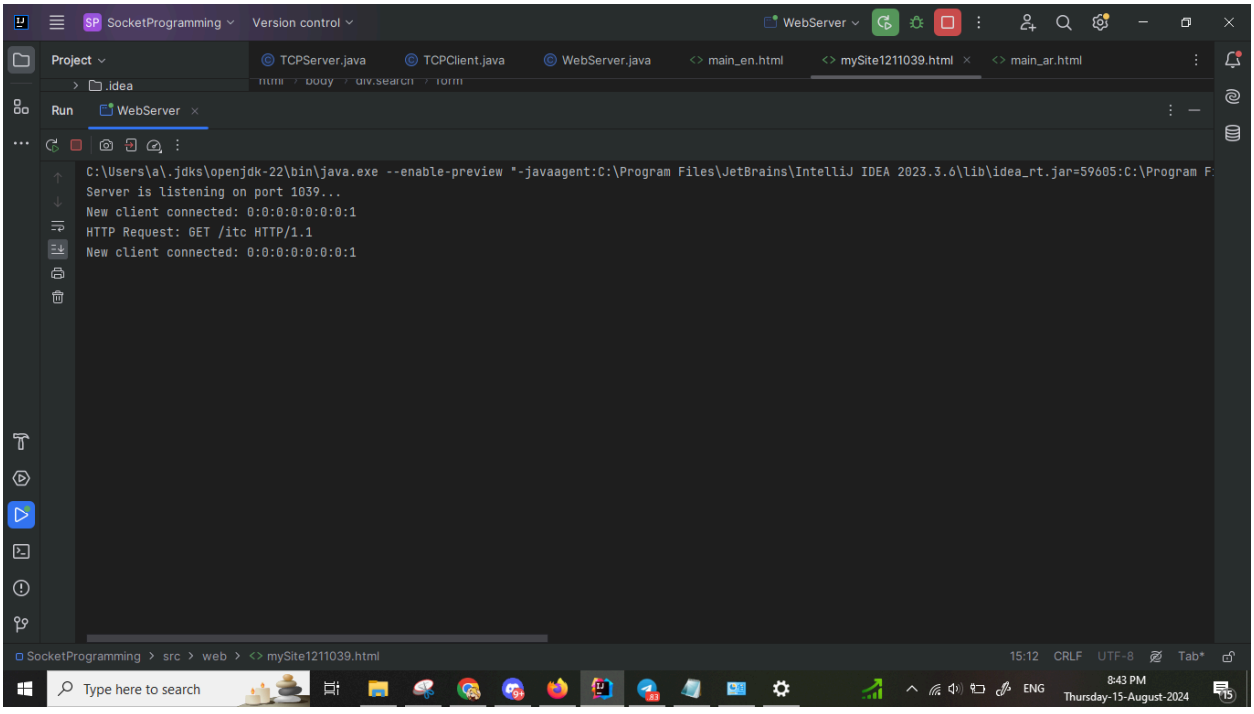
Additional Client Connection:

New Client Connected: 0:0:0:0:0:0:0:1

Another client connection was established, possibly due to the browser retrying the request or making another request after receiving an incomplete response.

- http://localhost:1039/itc





Clearing the Output:

Server Initialization:

The server is listening on port 1039, indicating that it has started successfully.

First Client Request (for /itc):

HTTP Request: GET /itc HTTP/1.1

The server received a request for the /itc endpoint. This appears to be a request for a file or directory that may not exist on the server.

No File Handling Logged:

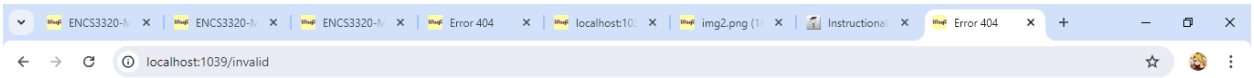
Similar to the previous request for /so, there is no log indicating whether the file /itc exists or not. This suggests that the server did not find the file or did not log the result.

Additional Client Connection:

New Client Connected: 0:0:0:0:0:0:0:1

Another client connection was established, likely due to the browser retrying the request or making another request after the initial one.

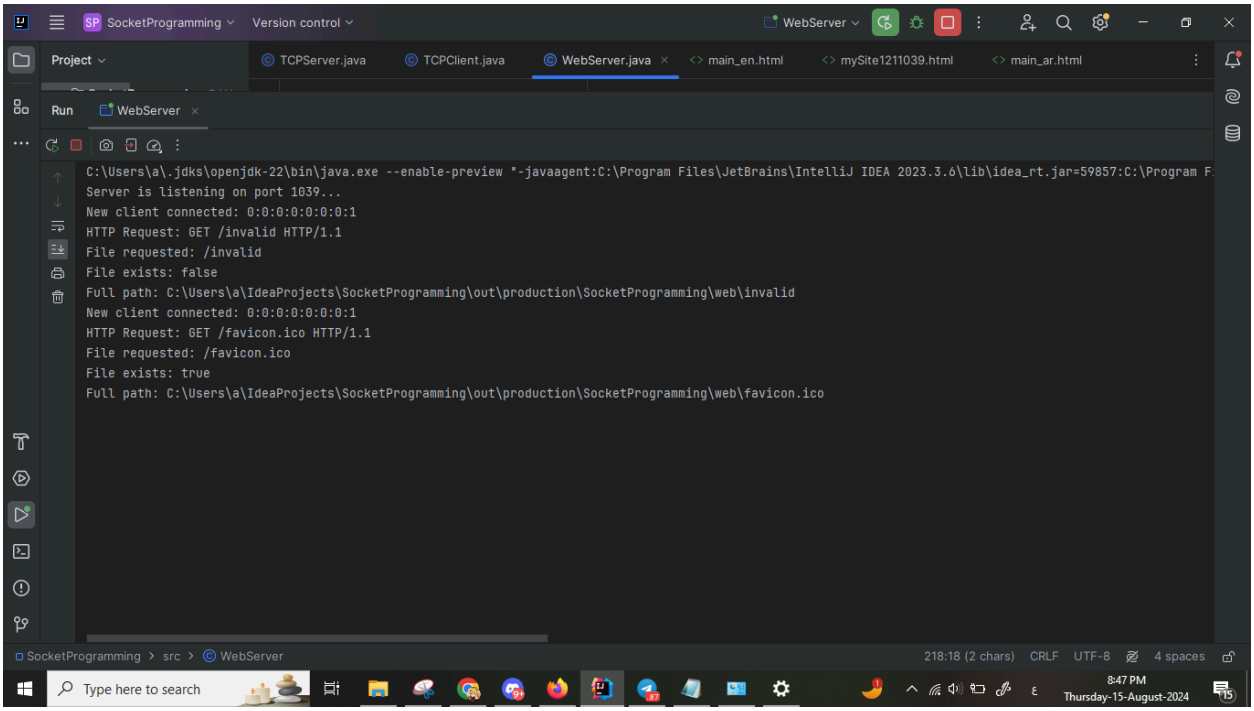
- Invalid Requests:



The file is not found

Name: Wasfia Awwad
ID: 1211039

Client IP: 0:0:0:0:0:0:0:1
Port: 1039



Clearing the Output:

Server Initialization:

The server is listening on port 1039, indicating that it has started successfully.

First Client Request (for /invalid):

HTTP Request: GET /invalid HTTP/1.1

The server received a request for the /invalid endpoint.

File Handling for invalid:

File Requested: /invalid

The server identifies the requested file as /invalid.

File Exists: false

The server confirms that the file /invalid does not exist in the specified directory.

Full Path:
C:\Users\a\IdeaProjects\SocketProgramming\out\production\SocketProgramming\web\invalid

The full path shows where the server attempted to find the file on the filesystem, but it was not found.

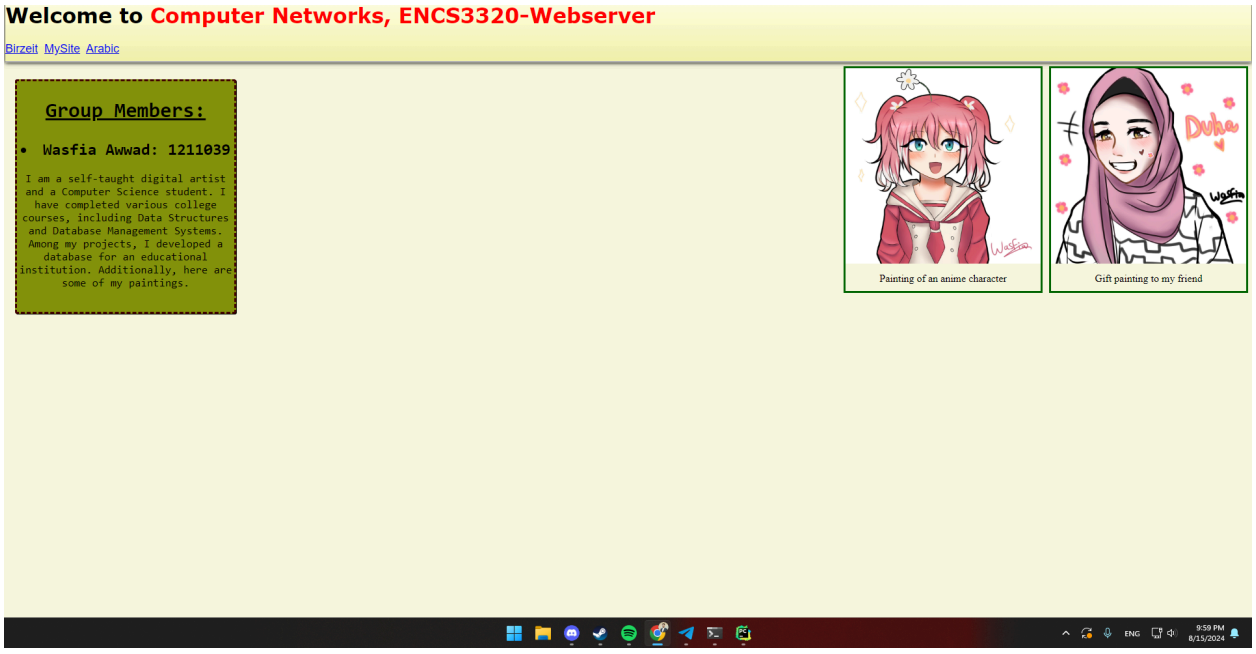
Additional Client Request (for /favicon.ico):

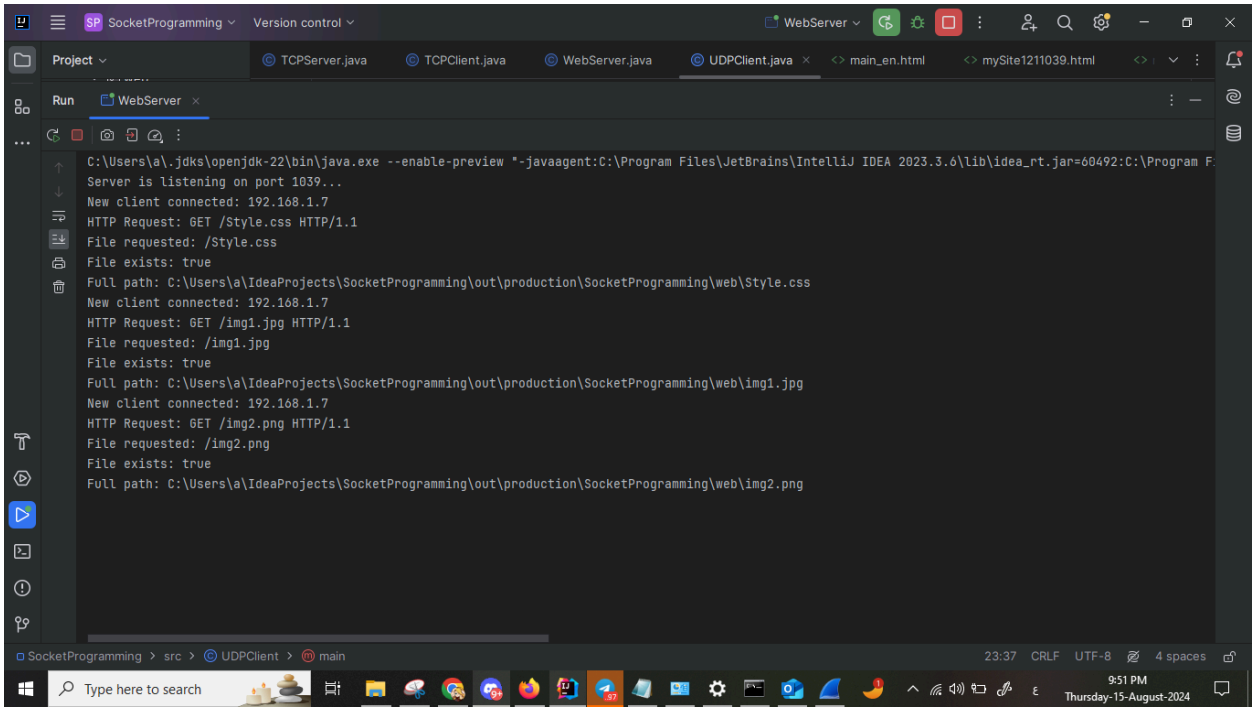
New Client Connected: 0:0:0:0:0:0:0:1

Another client connection was established, likely the browser automatically requesting the favicon after the initial request.

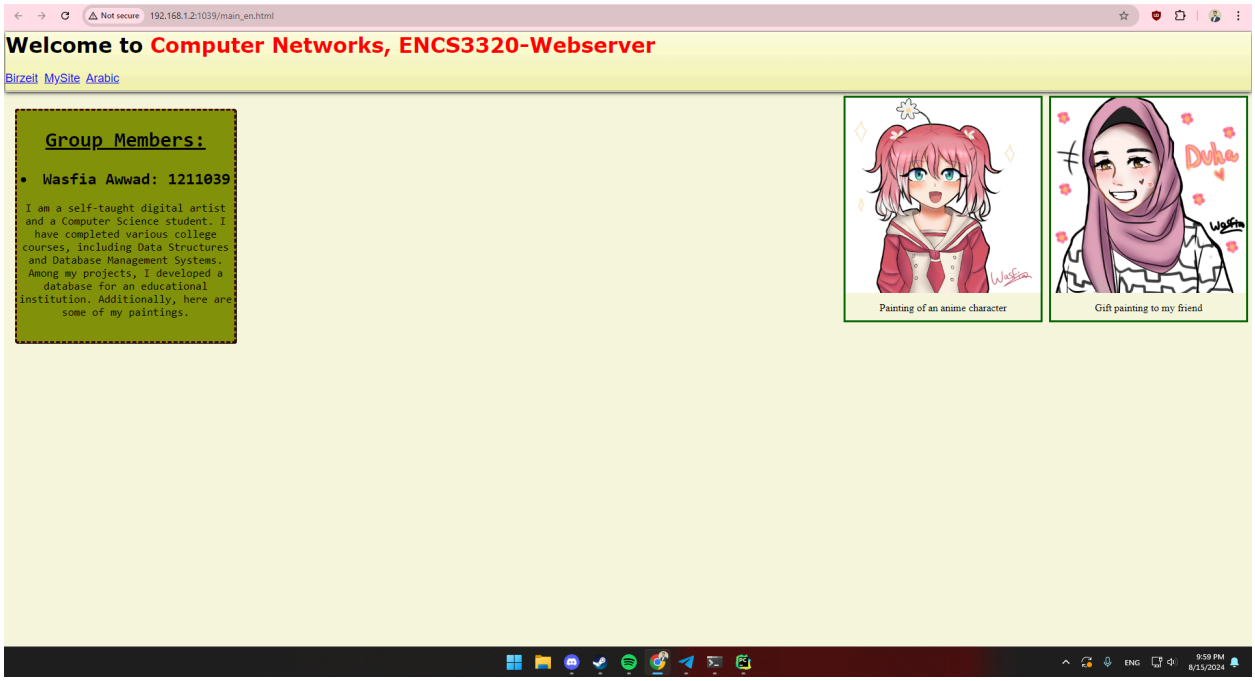
Accessing web server from another device:

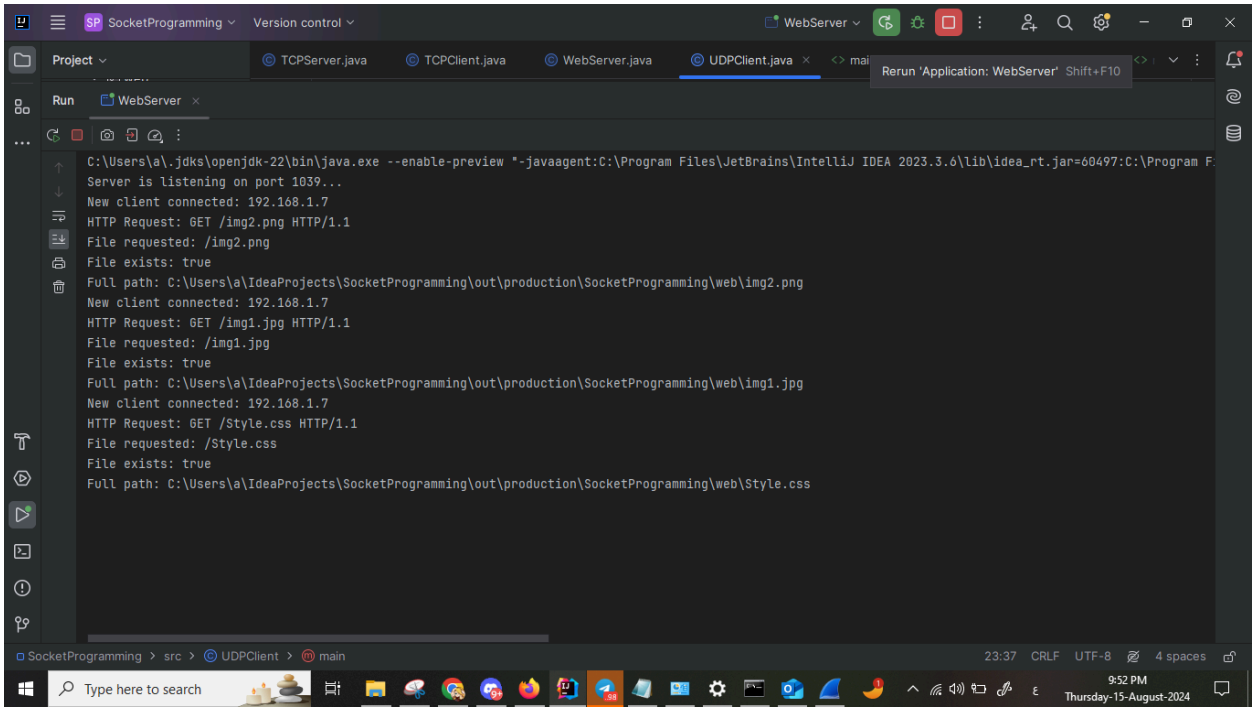
- http://localhost:1039/index.html



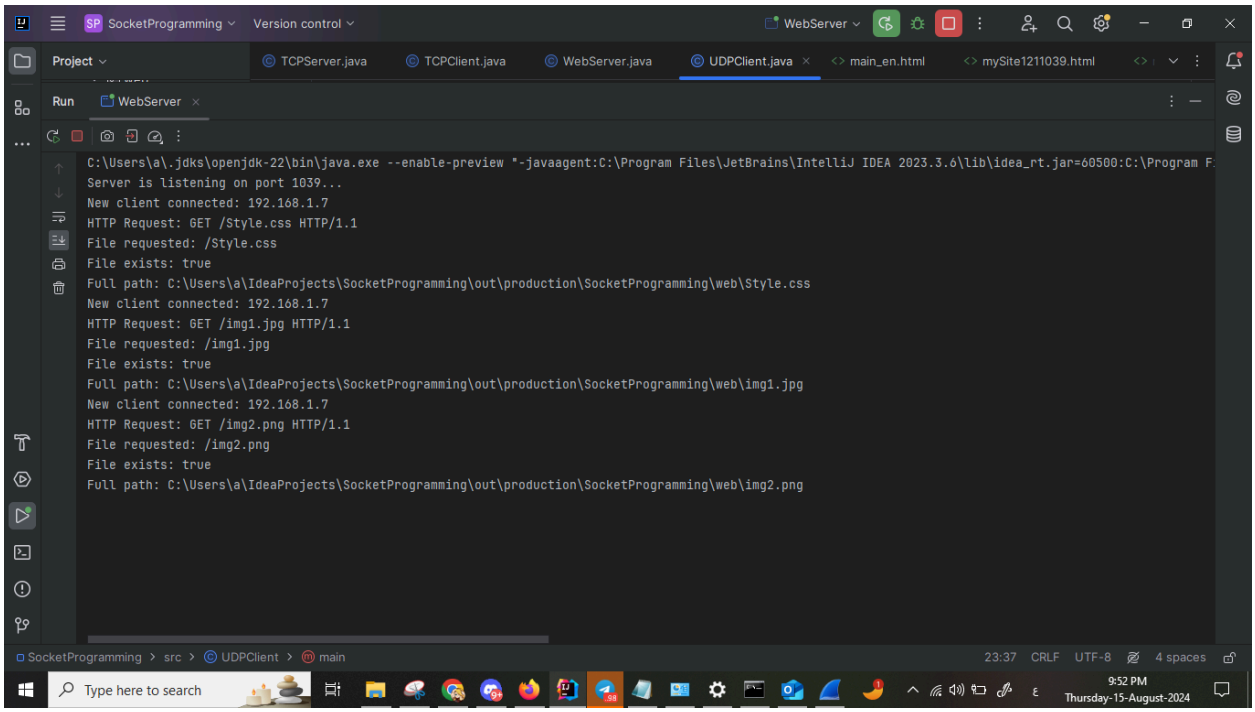


- http://localhost:1039/main_en.html

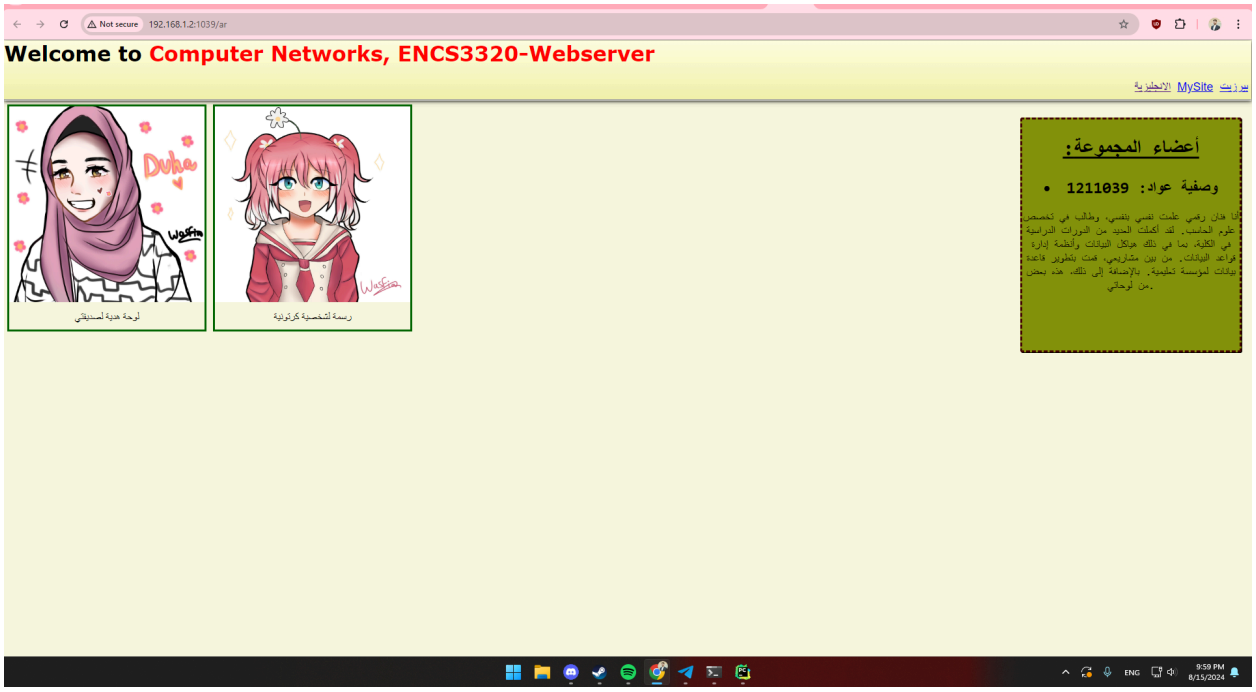


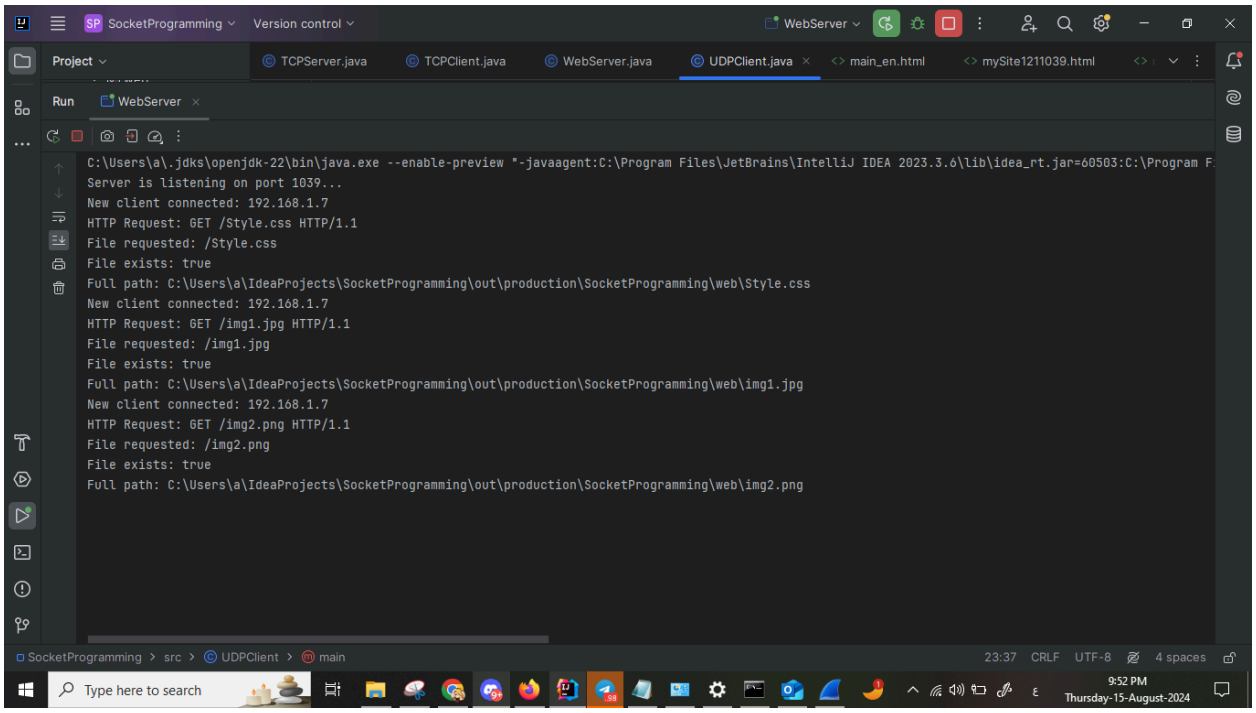


- http://localhost:1039/en

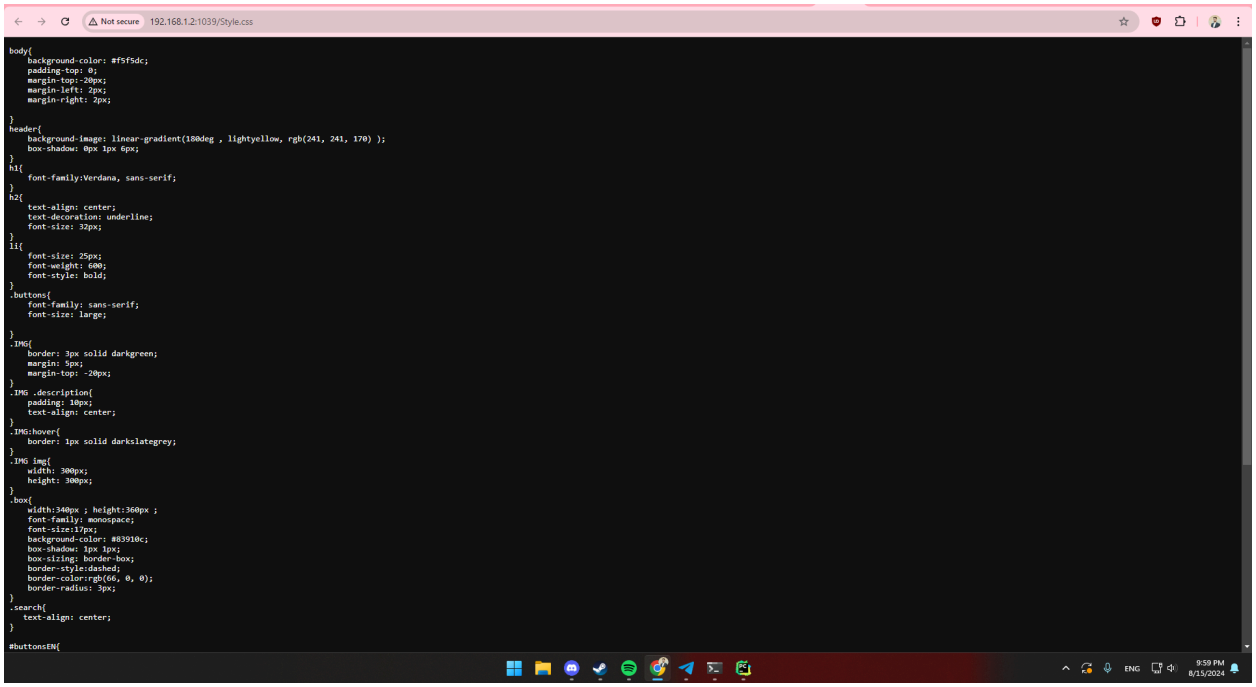


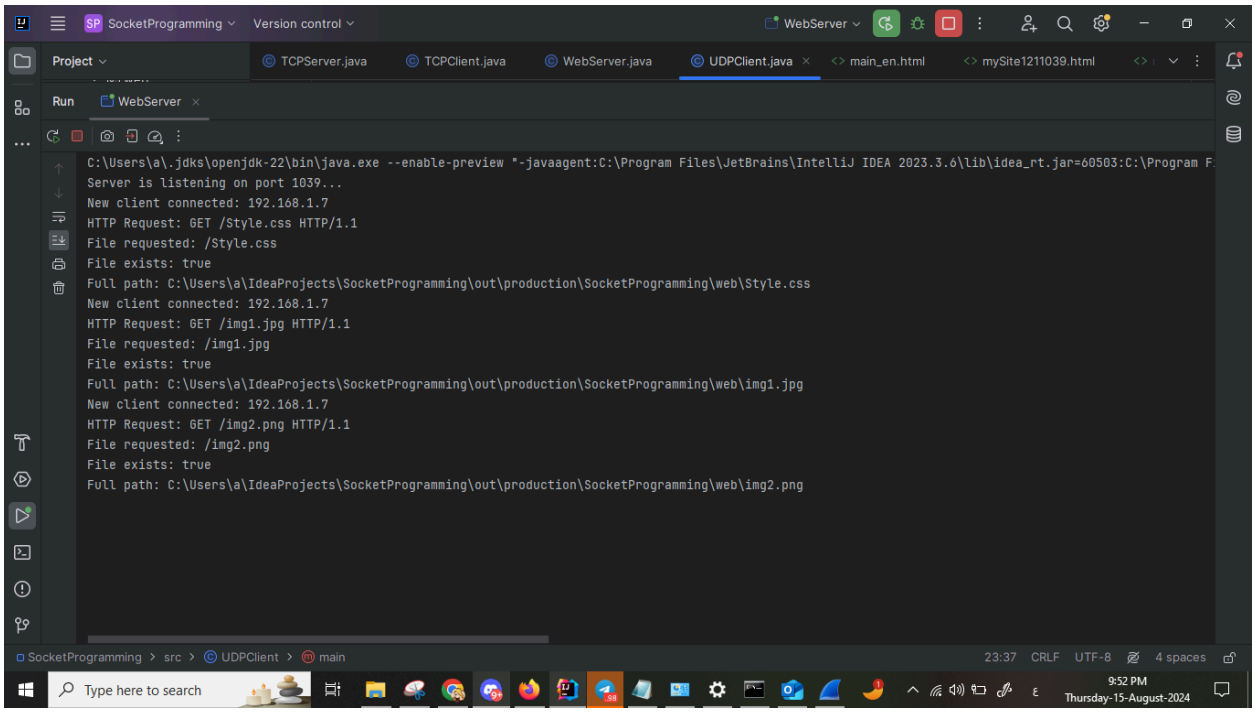
- http://localhost:1039/ar



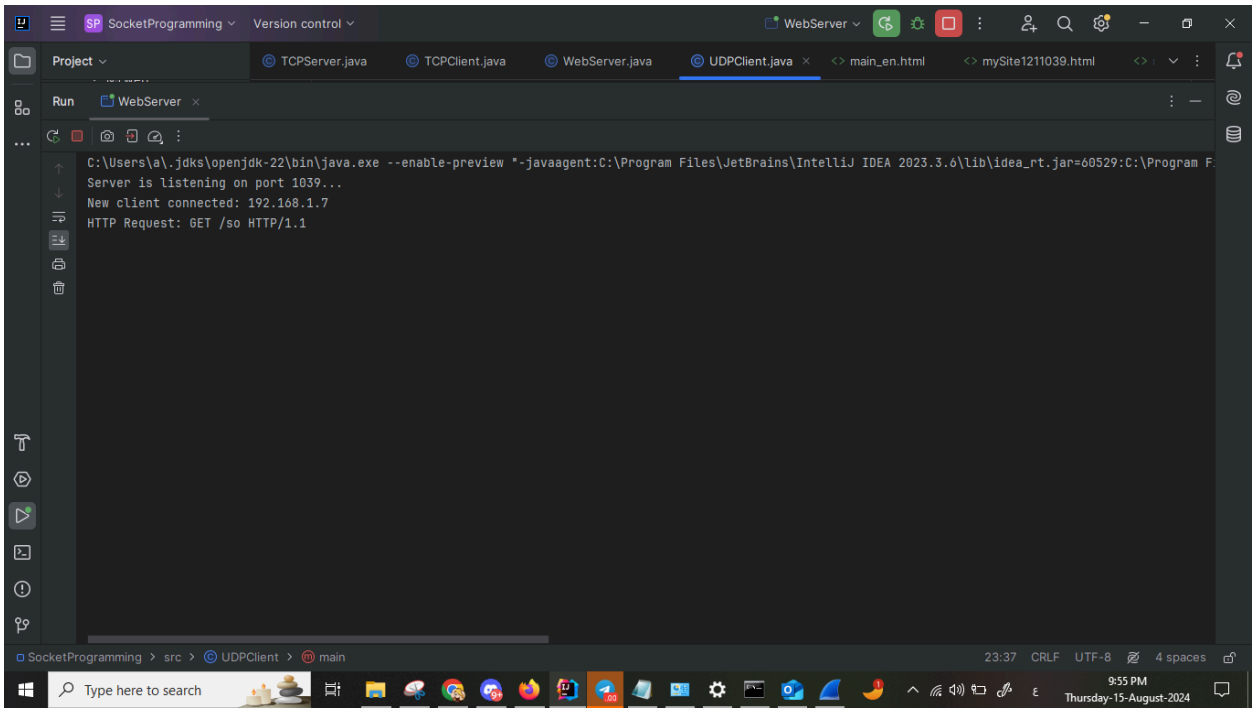


- http://localhost:1039/Style.css

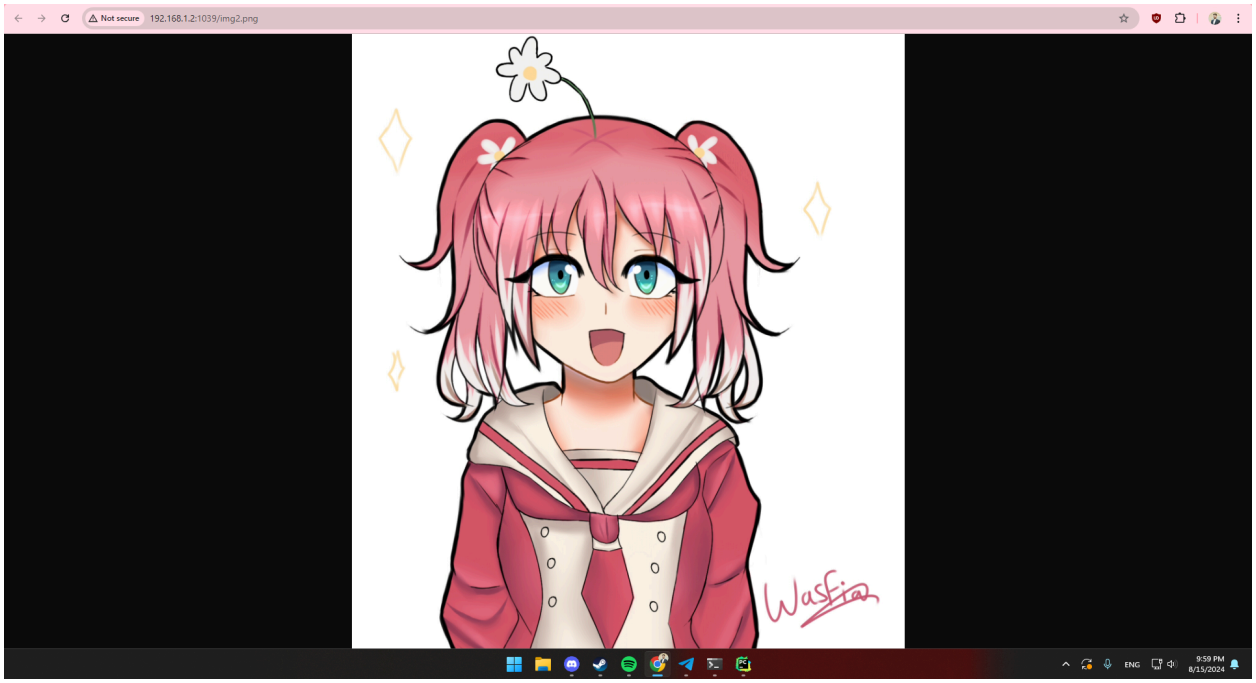


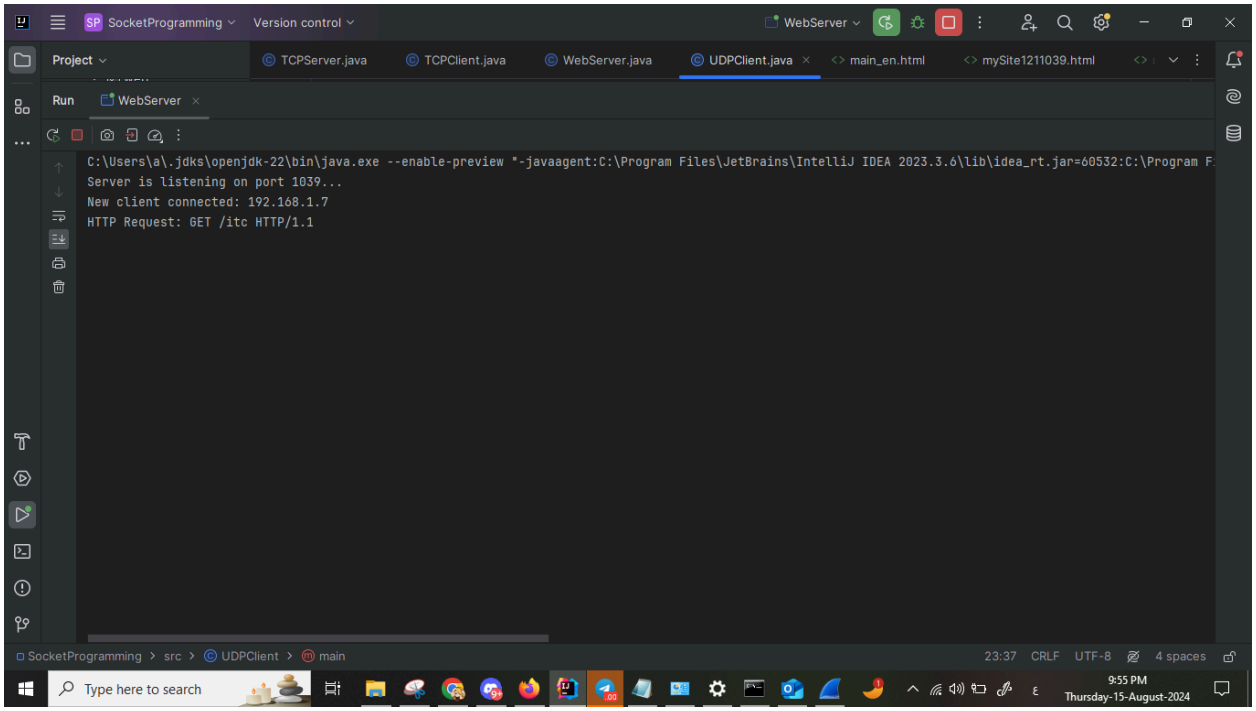


- http://localhost:1039/img1.jpg



- http://localhost:1039/img2.png


Not secure
192.168.1.2:1039/img2.png
Wasfia

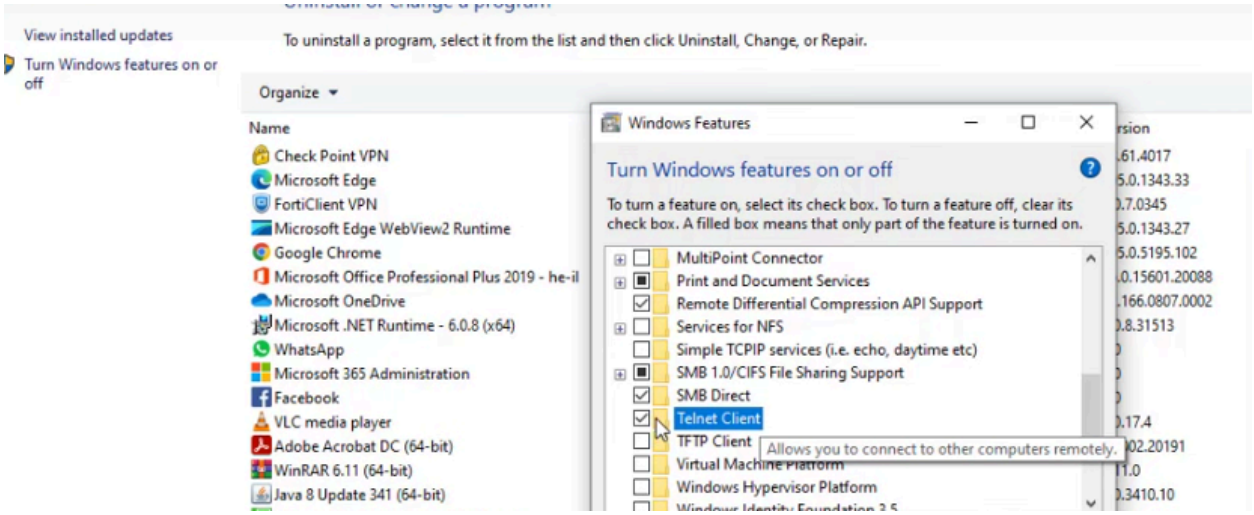

SocketProgramming
Version control
WebServer
Project
TCPServer.java
TCPClient.java
WebServer.java
UDPClient.java
main_en.html
mySite1211039.html
Run
WebServer
C:\Users\a\.jdks\openjdk-22\bin\java.exe --enable-preview "-javaagent:C:\Program Files\JetBrains\IntelliJ IDEA 2023.3.6\lib\idea_rt.jar=60532:C:\Program F
Server is listening on port 1039...
New client connected: 192.168.1.7
HTTP Request: GET /itc HTTP/1.1
SocketProgramming > src > UDPClient > main
23:37 CRLF UTF-8 4 spaces
Type here to search
9:55 PM
Thursday-15-August-2024

Alternatives Solutions, Issues and Limitations

Problem1: while solving task 1 i faced a problem while applying the telnet www.ox.ac.uk command, i had this output:

```
C:\Users\a> telnet www.ox.ac.uk.
'telnet' is not recognized as an internal or external command,
operable program or batch file.
```

The telnet command wasn't recognized, so i went to enable the Telnet client on my Windows system as shown in the screenshot below:



Then i tried running the command again and i had this output

```
C:\Users\a> telnet www.ox.ac.uk.
Connecting To www.ox.ac.uk....Could not open connection to the host, on port 23: Connect failed
```

So i figured that there's an issue with the port 23, most likely it's closed since the connection failed, so i searched for for "port checker" online and entered the port number, and it turned out that it was closed as shown in the screenshot below

Port Number

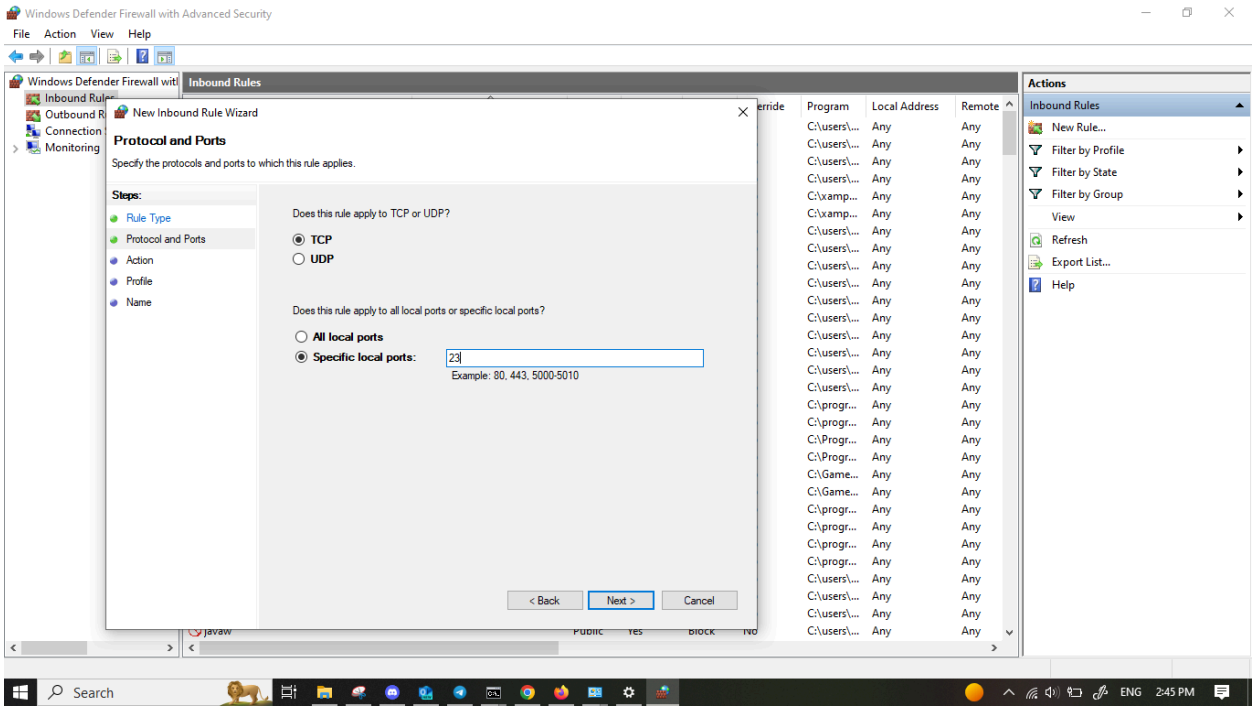
23

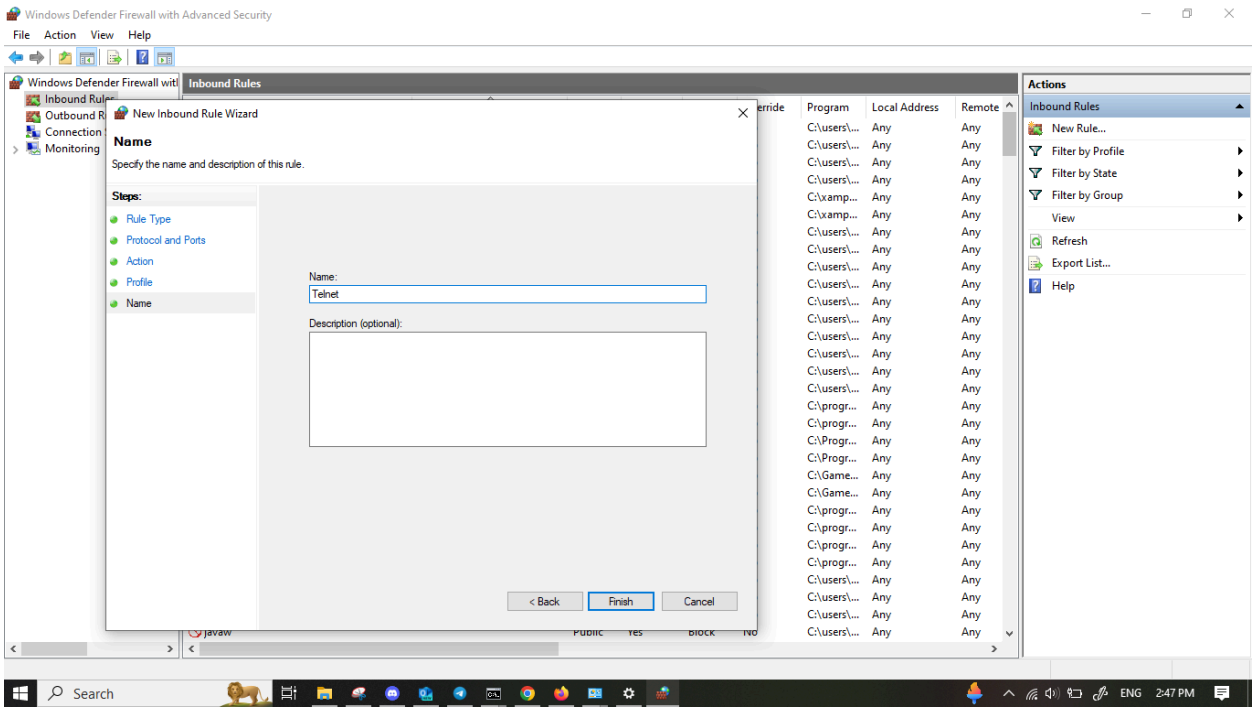
FTP - 21

Check

Port 23 is closed.

Checked the firewall





Problem still didn't get solved and i had the same error.

Problem2: While running my webServer code in task 3 i faced a "bind exception"

A bind expectation signals that an error occurred while attempting to bind a socket to a local address and port. Typically, the port is in use, or the requested local address could not be assigned.

According to [BindException (Java SE 11 & JDK 11) - Oracle Help Center]

```
    }
} catch (BindException e) {
    System.err.println("Server exception: Address already in use. Port " + PORT + " might be occupied.");
```

I catched the expectation with a catch block in my code, but had to solve the problem and avoid the exception to run my local web server.
I tried searching for the source that was keeping the port 1039 busy, but since i couldn’t find it, i had to terminate the process by force, so i opened the CMD and typed these commands:

As shown in the screenshot, The command “netstat -ano | findstr : 1039 “ lists active network connections on port 1039, showing two listening TCP connections with PID 17256. And the command “taskkill /PID 17256 /F “ successfully terminates the process with PID 17256, confirmed by the message "SUCCESS: The process with PID 17256 has been terminated." This action closes the network connections on port 1039 by force.

Conclusion

Through this project, I developed essential skills in networking and web development. I learned how to create TCP and UDP sockets and gained a solid understanding of HTML and web server basics. While I'm proud of what I accomplished on my own, I regret not working in a team. I realize now that collaborating with others could have cost less time and effort. This experience has taught me the importance of teamwork, and I'll make sure to embrace collaboration in future projects.

References:

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https://www.youtube.com/watch?v=-xKgxqG411c
Instructor video examples
BindException (Java SE 11 & JDK 11) - Oracle Help Center
https://www.youtube.com/watch?v=vmuIYa9DjfI
https://www.youtube.com/watch?v=qYh6k-S5xC4&t=175s