Assignment 1 (Part 1)
Linux and Setup

Version: May 13, 2022

This assignment is mostly about setup and learning things you will need in the future: working on the command line, using Wireshark to analyze traffic, working with Gradle and the example repo.
You will need a PDF or markup document that you will submit on Canvas AND in your GitHub repo (see below - ser321-summer2022-C-asurite), I will call this "document" during the assignment description. Your document needs to be formatted well, so we can navigate it easily and find your answers. If that is not fulfilled you might lose up to 5 points in this assignment (these points are not listed anywhere, these are additional deductions).

1. Command line and some setup (30 points)

Let's start of with practicing some command line commands and some setup.

Part I.
Linux, Setup

Prerequisites:

1. Familiarize yourself with the command line
2. Go through the information on Canvas

Learning outcomes for this first part:

1. Know how to use the command line to work efficiently
2. Get comfortable using command line pipelining and I/O redirection.

This assignment will sometimes tell you the specific commands to use, but it is up to you to read the *man* page (available from Linux) in order to be successful or use the internet for your research.
This part is meant to be done in a Linux environment and the tips provided are Linux specific. Things can be done in other environments but it will be up to you to figure out how to. **The team only supports Linux.**
In your document mention which system you are working on if you are not working on Linux, e.g. Windows Version so we know why the commands differ.

2. Command line tasks (15 points)

Deliverable

Mention which system you are using then use the numbering provided below and write the command you used to achieve what was expected, e.g.
Linux System: 1: mkdir cli_assignment
2: Your Command 2
3: Your command 3

Tasks

You start in any directory, preferably a test folder. You must work in a command line; you are not allowed to use your FileExplorer or Finder to accomplish these tasks.
Your individual answers are worth between 0.25 and 1 points, partial credit will be given as well.

1. Create a directory named "cli_assignment".
2. Change the current working directory to the new directory created in the previous step.
3. Create a new file named "stuff.txt". Use the *touch* command to do this. Read about the touch command using the manual (*man*) pages.
4. Add some text (multiple lines) to this text file using the *cat* command.
5. Count the number of words and the number of lines in the file "stuff.txt".
6. Append more text to the file "stuff.txt".
7. In the current working directory, create a new directory "draft".
8. Move the "stuff.txt" file to the directory "draft".
9. Change your working directory to "draft" and create a **hidden** file named "secret.txt".
10. Create a new directory ("final") as a copy of the "draft" directory (final should be on the same level as draft) using the copy command.
11. Rename the "draft" directory to "draft.remove". Use the **mv** command for this.
12. Move the "draft.remove" directory to inside the "final" directory. Use the **mv** command for this.
13. From inside the "cli_assignment" directory, list all the files and sub-directories and their permissions.
14. List the contents of the given file "NASA_access_log_Aug95.gz" without extracting it. (The file should be on the same level as your "cli_assignment" directory)
15. Extract the given file "NASA_access_log_Aug95.gz".
16. Rename the extracted file to "logs.txt".

17. Move the file "logs.txt" to the "cli_assignment" directory.
18. Read the top 100 lines of the file "logs.txt".
19. Create a new file "logs_top_100.txt" containing the top 100 lines using I/O redirection.
20. Read the bottom 100 lines of the file "logs.txt".
21. Create a new file "logs_bottom_100.txt" containing the bottom 100 lines using I/O redirection.
22. Create a new file "logs_snapshot.txt" by concatenating files "logs_top_100.txt" and "logs_bottom_100.txt".
23. Now append to the "logs_snapshot.txt" the line "asurite: This is a great assignment" and the current date (asurite is your asurite, e.g. amehlhas for me)
24. Read the file "logs.txt" using the less command.
25. Using the given file "marks.csv" (delimited by %), print the column "student_names" without the header (you can use the column num as index). Use the cut command and I/O redirection. (This file should be on the same level as your "cli_assignment" directory)
26. Using the given file "marks.csv", print the sorted list of marks in "subject_3". Use the sort command piped with the cut command.
27. Using the given file "marks.csv", print the average marks for "subject_2" (it is ok to us awk).
28. Save the average into a new file "done.txt" inside of the "cli_assignment" directory.
29. Move "done.txt" into your "final" directory.
30. Rename the "done.txt" file to "average.txt".

3. Some Setup and Examples (30 points)

3.1. Setup a GitHub repo to submit your assignments (5 points)

Create a **private** GitHub repository which you call "ser321-summer2022-C-asurite ", where asurite is **your asurite**. Make sure it is exactly this! Invite *ser316asu* to this repo as collaborator, which represents me and the grading team. I know it says 316 but that is correct, I am reusing my account.
If your repo is not called correctly that means we will not accept the invite and will not be able to get your submissions for grading, which might lead to 0 points!
In this repository create the following folders: Assignment1, Assignment2, Assignment3, Assignment4, Assignment5, Assignment6 (Git will not add/commit empty folder, figure out what to do to still add these folders).
This repository needs to be private, you are not allowed to delete this repository for the next year and you will need to keep me (ser316asu) as collaborator. You will submit all

your work on this repo, do not delete it and/or create a new one. We will always pull the repo after the due date.
I advise you to use Git while you work on your programming assignments later on. You do not have to. You do need to upload your solution to GitHub (into the correct directory) for submission at the end of an assignment though. You will always have to add the link to your repo on Canvas for each submission.
Failing to do so will lead to 0 points if we do not find your repo (we will not hunt for the link in old submissions) or -10% of the assignment points!
Deliverable: Add the GitHub repo link to the TOP of your assignment document which you submit on Canvas AND as a comment in your Canvas submission. This is graded as well!

3.2. Running examples (10 points)

Go to the Example GitHub repo.
I personally would advise you to create a fork of the repository and use this forked version to test things (there is a link on how to fork a repo in the repository Readme), so you can change things easily and keep track of your changes. You should not try to create PullRequests or make changes to the original repo. If you do find errors in any examples you can make a PR if you feel like it but for your testing and practicing only do that on your repo version.
Now, you should run at least 3 of the examples (no matter which ones BUT choose different folders and not just different Gradle commands in the same folder) through the command line (Gradle). I would advise you to spend some time on them as well so you understand the code better and also the Gradle parts, this will become increasingly important soon.
Deliverable: Name the three examples you ran and take a screenshot for each of your examples from your command line (if you needed more than one Window show all of them in your screenshot or have several screenshots) so we see you did run them. Add these to your document and make sure we can actually read the screenshots. Ensure your document is well formatted and does not "waste space". Explain each example and what you think it does briefly.
3 points per example (naming the example, screenshots, explanations), 1 point for having it well formatted and readable. If it is very badly formatted and we cannot find what we look for you might loose up to 5 points here.

3.3. Understanding Gradle (7.5 points)

Go to the Gradle/Java Gradle example, in the Gradle file you will see a comment "Try:" with some tasks following. Make appropriate changes to your Gradle file.
Deliverable: Copy the Java Gradle folder into your assignment repo "ser321-summer2022-C-asurite " into the Assignment1 directory.

3.4. Set up your second system (7.5 points)

We will only support AWS as your second system but, as stated on Canvas, you can use a Pi or a second computer (I would not necessarily advise this for later assignments though). Setup your second system (so either AWS, Pi or second computer) and mention in your document which system you setup as your second system.

Go to the Canvas AWS page; the last video on there explains how to run the JavaSimpleSock2 example on AWS.
I want you to create a similar video showing me that you ran the same example – **it is called JavaSimpleSock2 in the current repo**. The client should be run on your main system (the computer you usually work on) and your server on the second system you just setup. You do not need to explain things like I do in the video but I do want to see that it works even though we have not covered sockets yet. Based on the video, you should be able to run the example.
Deliverable: In your Deliverable document, mention what second system you setup and add a link to your screencast.

Part II.
Networking

4. Network traffic

This section is comprised of a collection of activities exploring networking protocols and tools for the data link, network (IP), and transport (TCP) layers of the network stack.
Advice: Do not just copy and paste the command from this document; this sometimes leads to issues when done from a PDF. I would also advise you to spend some time understanding what you are doing and not just blindly following the commands.
You will need to create a document in which you will add all screenshots, answers, etc. Please structure your document according to the tasks and activities in the assignment. If you want to you can of course remove information from your screen shots if you think they are things you want to keep private.

Learning outcomes

- Understand the nature of network traffic on your local computing device.

Objectives

- Understand the nature of network traffic at the data link, network, and transport layers.
- Gain basic competency using common command-line and GUI tools to analyze network traffic and routing.
- Explore the utility of the data link layer through the ARP protocol.
- Identify the structures in IP and TCP packets.
- Understanding packet routing (paths) across the open Internet.

Tools needed

- Ipconfig / ifconfig provide information regarding your network interfaces.

- The arp command has different flags on Windows and Linux, but allows you to see how data link and network layer addressing are bound on your local computer.
- The watch command will run a command repeatedly on a set interval (Unix).
- The netcat command gives you a command-line network tool to communicate over sockets using specific protocols and ports.
- The netstat command displays comprehensive network information, including socket states
- Wireshark is a packet sniffing application with mature facilities to filter and capture network traffic. There is an overview video on using Wireshark in the course shell.
- Traceroute and ping may be used to show routes taken by IP packets through different routers ("hops") using ICMP messages.

4.1. Explore the Data Link Layer with ARP (10 points)

Points are for the correct screencaptures and showing the right data in them. Each iteam is 1-2 points.

Step 1: Capture a Trace (6 points)

Proceed as follows to capture a trace of ARP traffic; alternatively, you may use a supplied trace. To gather ARP packets, we will cause your computer to send traffic to the local router when it does not know the router"s Ethernet address - your computer will then use ARP to discover the Ethernet address.

1 Find the Ethernet address of the main network interface of your computer with the ifconfig / ipconfig command. You will want to know this address for later analysis. Among the output will be a section for the main interface of the computer (likely an Ethernet interface) and its Ethernet address. Common names for the interface are "eth0", "en0", or "Ethernet adapter".

2 Find the IP address of the local router or default gateway that your computer uses to reach the rest of the Internet using the netstat / route command. You should be able to use the netstat command ("netstat -r" on Windows, Mac and Linux, may require ctrl-C to stop). Alternatively, you can use the route command ("route print" on Windows, "route" on Linux, "route -n get default" on Mac). In either case you are looking for the gateway IP address that corresponds to the destination of default or 0.0.0.0. An example is shown below.

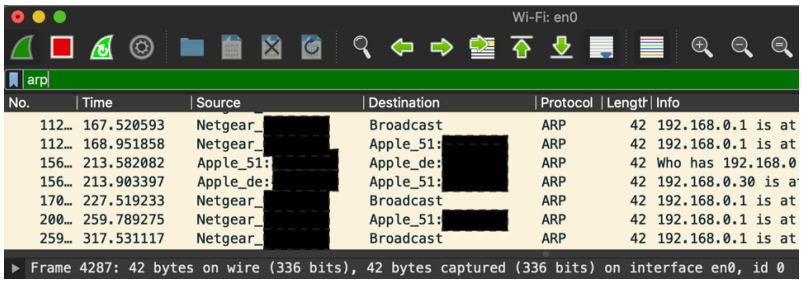
```
amankaushik->~$ netstat -r
Routing tables

Internet:
Destination        Gateway            Flags        Netif Expire
default            192.168.0.1        UGSc           en0
```

```
amankaushik->~$ route -n get default
   route to: default
destination: default
       mask: default
    gateway: 192.168.0.1
  interface: en0
      flags: <UP,GATEWAY,DONE,STATIC,PRCLONING>
 recvpipe  sendpipe  ssthresh  rtt,msec    rttvar  hopcount      mtu     expire
       0         0         0         0         0         0     1500          0
```

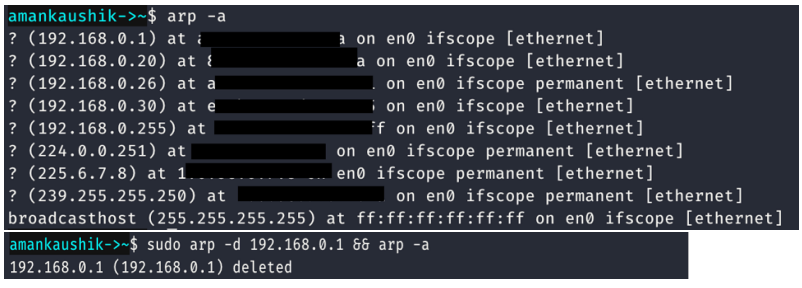
Deliverable: Provide a screen capture of your calls to identify your network interface and gateway. Similar to the above screenshots.

3 Launch Wireshark and start a capture with a filter of "arp". Your capture window should be similar to the one pictured below other than our highlighting. Select the interface from which to capture as the main wired or wireless interface used by your computer to connect to the Internet. If unsure, guess and revisit this step later if your capture is not successful. Uncheck "capture packets in promiscuous mode". This mode is useful to overhear packets sent to/from other computers on broadcast networks. We only want to record packets sent to/from your computer. Leave other options at their default values. The capture filter, if present, is used to prevent the capture of other traffic your computer may send or receive.



Deliverable: Provide a screen capture of your Wireshark instance with the appropriate filters also being visible.

4 When the capture is started, use the "arp" command to clear the default gateway from the ARP cache. Using the command "arp -a" will show you the contents of the ARP cache as a check that you can run "arp". You should see an entry for the IP address of the default gateway. To clear this entry, use the arp command ("arp -d" on Windows). This usage of arp will need administrator privileges to run, so you should login as root on your machine. Note that the command should run without error but the ARP entry may not appear to be cleared if you check with "arp -a". This is because your computer will send ARP packets to repopulate this entry as soon as you need to send a packet to a remote IP address, and that can happen very quickly due to background activity on the computer. Note some flags may be different on Windows. Run "arp -help" to get info on the flags.



Deliverable: Provide screen captures of your arp -a and arp -d commands. After running the arp -d be sure to run arp -a again to demonstrate the node successfully deleted.

5 Clear your entire ARP cache using arp -d (you need to lookup the proper flag). Also clear your Wireshark entries.

Then fetch a remote page with your Web browser (just go to a webpage). This will cause ARP to find the Ethernet address of the default gateway so that the packets can be sent. These ARP packets will be captured by Wireshark. You might clear

the ARP cache and fetch a document a couple of times. Hopefully there will also be other ARP packets sent by other computers on the local network that will be captured. These packets are likely to be present if there are other computers on your local network. In fact, if you have a busy computer and extensive local network then you may capture many ARP packets. The ARP traffic of other computers will be captured when the ARP packets are sent to the broadcast address, since in this case they are destined for all computers including the one on which you are running Wireshark. Because ARP activity happens slowly, you may need to wait up to 30 seconds to observe some of this background ARP traffic.

6 Once you have captured some ARP traffic, stop the capture. You will need the trace, plus the Ethernet address of your computer and the IP address of the default gateway for the next steps.

Deliverable: Screen capture the updated trace in Wireshark, add this to your document.

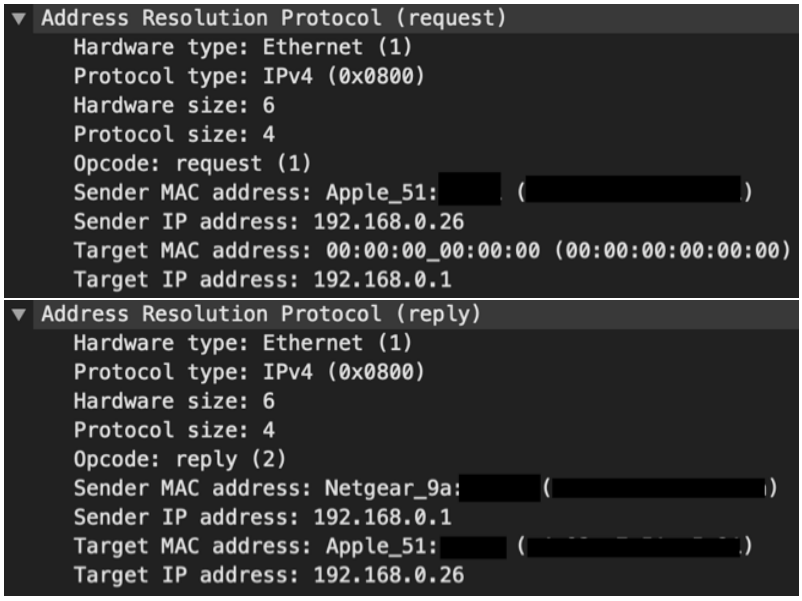
Step 2: Inspect the Trace (2 points)

Now we can look at an ARP exchange! Since there may be many ARP packets in your trace, we"ll first narrow our view to only the ARP packets that are sent directly from or to your computer.

1. Find and select an ARP request for the default gateway and examine its fields. There are two kinds of ARP packets, a request and a reply, and we will look at each one in turn. The Info line for the request will start with "Who has ...". You want to look for one of these packets that asks for the MAC address of the default gateway, e.g., "Who has xx.xx.xx.xx ..." where xx.xx.xx.xx is your default gateway. You can click on the + expander or icon for the Address Resolution Protocol block to view the fields:
   - Hardware and Protocol type are set to constants that tell us the hardware is Ethernet and the protocol is IP. This matches the ARP translation from IP to Ethernet address.
   - Hardware and Protocol size are set to 6 and 4, respectively. These are the sizes of Ethernet and IP addresses in bytes.
   - The opcode field tells us that this is a request.
   - Next come the four key fields, the sender MAC (Ethernet) and IP and the target MAC (Ethernet) and IP. These fields are filled in as much as possible. For a request, the sender knows their MAC and IP address and fills them in. The sender also knows the target IP address it is the IP address for which an Ethernet address is wanted. But the sender does not know the target MAC address, so it does not fill it in.
2. Next, select an ARP reply and examine its fields.
   - The Hardware and Protocol type and sizes are set as before.
   - The opcode field has a different value that tells us that this is a reply.

     Next come the four key fields, the sender MAC (Ethernet) and IP and the target MAC (Ethernet) and IP just as before. These fields are reversed from the

corresponding request, since the old target is the new sender (and vice versa). The fields should be filled in since both computers supplied their addresses.



Deliverable: Screen capture the ARP request and reply from this step and add to your document.

Step 3: Details of ARP over Ethernet (2 points)

ARP packets are carried in Ethernet frames, and the values of the Ethernet header fields are chosen to support ARP. For instance, you may wonder how an ARP request packet is delivered to the target computer so that it can reply and tell the requester its MAC address. The answer is that the ARP request is (normally) broadcast at the Ethernet layer so that it is received by all computers on the local network including the target. Look specifically at the destination Ethernet address of a request: it is set to ff:ff:ff:ff:ff:ff, the broadcast address. So the target receives the request and recognizes that it is the intended recipient of the message; other computers that receive the request know that it is not meant for them. Only the target responds with a reply. However, anyone who receives an ARP packet can learn a mapping from it: the sender MAC and sender IP pair.
To look at further details of ARP, examine an ARP request and ARP reply to answer these questions in your document:

1. What opcode is used to indicate a request? What about a reply?
2. How large is the ARP header for a request? What about for a reply? You will need to research this (hint: some sources define what belongs to the header differently, name which source you base your answer on)
3. What value is carried on a request for the unknown target MAC address?
4. What Ethernet Type value indicates that ARP is the higher layer protocol?

Deliverable: Add your answers to the questions above to your document.

4.2. Understanding TCP network sockets (12.5 points)

Steps:

1. The network should be observed for a period of at least 10 minutes during which a decent amount of network activity takes place. Network activity in this context would mean basic web browsing - emails, social media, streaming. Ideally a mix of the mentioned activities. Another option would be, to set this up in a terminal window and then do activities 4 and 5 and then go back to this section.

2. This network activity observation should be done via netstat. You'll need to continuously monitor the output of the netstat command. This must be automated/scripted.
   a) The watch, grep, and netstat commands could be one way to do this.
   b) Grab readings every 30 seconds and filter for socket connections that are in state ESTABLISHED or LISTEN. You will need to find out the command to use here. Tip: print the current time every 30 seconds before the data that you are grabbing so you can distinguish the different time steps.

3. Once you have the required data points, import them into Excel or a suitable graphing tool and make a line chart of each socket state count over the 10-minute period. So show how many Sockets are listening and established at every 30sec mark (two lines).

Deliverable: Include the command/script you used and the graph of socket states over the 10 minutes in your document.

4.3. Sniffing TCP/UDP traffic (11 points)

Step 1 (TCP) (5.25 points)

1. Setup Wireshark to intercept and log network traffic.
   a) Start a trace on the Loopback: lo0 interface with a filter on the tcp port, tcp.port=3333. The port here could be anything between 1K and 48K, but let"s use 3333.

2. To generate traffic we are going to use netcat. netcat is a utility program for reading from and writing to network connections using TCP or UDP.
   a) To read, run on the command line: nc -k -l 3333. Keep the command window open after running this. Please make sure that port number here (3333) matches the port number set as a filter in step 1a and the port number in 2b.
   b) Open a second command window: To write, run on the command line: nc 127.0.0.1 3333. After running the command, in this window, type in

      SER321

      Rocks!
   c) Make sure that you type the above as it is, with a newline in between

3. To stop both the commands from 2, press Ctrl + C on the terminal windows running the commands.

4. Stop the Wireshark recording and take a screenshot of your data with the appropriate filter.

5. Answer the following questions (0.75 points for each)
   a) Explain both the commands you used in detail. What did they actually do?
   b) How many frames were send back and forth to capture these 2 lines (Frames: 4 – I counted all frames that were sent)?
   c) How many packets were send back and forth to capture only those 2 lines?
   d) How many packets were needed to capture the whole "process" (starting the communication, ending the communication)?
   e) How many bytes is the data (only the data) that was send?
   f) How many total bytes went over the wire (back and forth) for the whole process?
   g) How much overhead was there. Basically how many bytes was the whole process compared to the actually data that we did send.

Step 2 (UDP) (5.75 points)

Basically, do the same thing as above just with UDP, I will only give the basics here.

1. Setup Wireshark to intercept and log network traffic.
   a) Start a trace on the Loopback: lo0 interface with a filter on the tcp port, udp.port=3333. The port here could be anything between 1K and 48K.

2. To generate traffic:
   a) Run: nc -k -l -u 3333.
   b) Run: nc -u 127.0.0.1 3333. After running the command, in the same window, type

      SER321

      Rocks!
   c) Make sure that you type the above as it is, with a newline in between

3. Stop the client and server.

4. Stop the Wireshark recording and take a screenshot of your data with the appropriate filter. 0.75 points for each:
   a) Explain both the commands you used in detail. What did they actually do?
   b) How many frames were needed to capture those 2 lines?
   c) How many packets were needed to capture those 2 lines?
   d) How many packets were needed to capture the whole "process" (starting the communication, ending the communication)?
   e) How many total bytes went over the wire?
   f) How many bytes is the data (only the data) that was send?

g) Basically how many bytes was the whole process compared to the actually data that we did send.?

h) What is the difference in relative overhead between UDP and TCP and why? Specifically, what kind of information was exchanged in TCP that was not exchanged in UDP? Show the relative parts of the packet traces.

Deliverable: Put the following in your document

- TCP: Screenshot of Wireshark capture with appropriate filter
- TCP: Answers to all the questions in Step 1
- UDP: Screenshot of Wireshark capture with appropriate filter
- UDP: Answers to all the questions in Step 2

4.4. Internet Protocol (IP) Routing (5 points)

Step

1. Download and install Open Visual Traceroute OR you can use traceroute (*nix), tracert (windows) commands – I only used traceroute since I did not feel like installing anything.
2. Open "OpenVisualTraceroute" (or use traceroute) and on your home network, do a traceroute to www.asu.edu. Export the results from OVT to a CSV.
   a) If using traceroute/tracert, run traceroute www.asu.edu
   b) The results of the above commands would have to be manually exported to a CSV file (copied).
3. Switch to a different network. Possibilities are local coffee shops, libraries (if they do not block traceroute traffic), ASU, or mobile hotspot. Repeat #2
4. Now compare the 2 routes and answer the following questions
   a) Which is the fastest?
   b) Which has the fewest hops?

If for some reason you cannot test a different network please reach out to me directly for an alternative.

Deliverable:

- Route 1 (ASU Network) - screenshot into your document
- Route 2 (Non-ASU Network) - screenshot into your document
- Answers to the questions in 2

4.5. Running client servers in different ways (15 points)

In this section I want you to run the JavaSimpleSock2 example from the repo. You will also need to have Wireshark open to capture the traffic between client and server.

4.5.1. Running things locally (6 points)

Run your client and server locally on your computer (so both of them on localhost). Setup Wireshark so that it show the traffic for your client/server connection. Send a couple of Strings and numbers to the server and wait for the response.
Take a short screencast (max. 2min) and add the link to this video to your document. In this video talk us through the Wireshark traffic and show us where the Strings and Ints are send to the server and where to find the response on Wirehshark.
In your document add screenshots of your command line windows showing all the command you called and the output in the console.

4.5.2. Server on AWS (5 points)

Now, run your server on AWS and your client locally on your computer. Make sure you use the correct IP and port and that the port on AWS is opened for traffic.
Setup Wireshark to capture the traffic again and send over some data as before.
Add screenshots of your command line windows to your document.
Also describe what changed compared to when just running things locally, what did you need to change on Wireshark, what did you need to change in your Gradle calls (where there changes?)?.

4.5.3. Client on AWS (2.5 points)

Consider the case you want to run your server locally (so on your home computer) and your client on AWS (you do **not** have to do this but you can try). Does this work without issues? Can you do it in the same way as in 4.5.2? Why or why not? What is different?

4.5.4. Client on AWS 2 (3 points)

In this context also explain how the differences in local IP addresses, how your router plays into all of this. Why can you easily reach your server on AWS with a client running in your local network but not as easily go the other direction? And what can you do to reach your server in your local network if you want to reach it from outside your network (you do not have to do that)? What is the "issue" if you want to run your server locally and reach it from the "outside world"?
Deliverable:
Answer all questions from above, non of them are rhetorical in this section. Remember the link to your screen cast, your screenshots and explanations.

5. Submission

On Canvas submit the link to your GitHub repo "ser321-summer2022-C-asurite ". In the main/master branch of this repo you should now have 6 directories (one for each assignment).
In the Assignment1 direcotry on GitHub you should have:

- Assign1.pdf (or markup) document with all your Command line commands and all your answers/explanations from the other sections into your Assignment1 folder on GitHub. Remeber this needs to be well formatted (this will be graded).

- Gradle/Java directory from the 3.3 section.