Aalto University
School of Electrical
Engineering

ELEC-E7130 Internet Traffic Measurements and Analysis

Assignment 3. User traffic

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Task 1: Introduction to the traffic data

1. What is the passive measurement in terms of network traffic? What kind of information does it provide, and what is its role or significance?

- Passive measurement of network traffic is the process of observing and collecting network traffic data without actively interfering with or modifying the traffic itself. This type of measurement is non-intrusive and relies on monitoring and analyzing the way network traffic naturally flows through the network. Passive measurements do not inject test traffic or generate additional network load.
- Passive measurement systems collect various types of data from network traffic. This data can include packet headers, payload content, flow statistics, timestamps, and more.
- Passive measurement is important because it provides a comprehensive and non-intrusive view of network behavior. It can help optimize network performance, enhance security, and ensure better quality of service for end users.

2. Please provide an explanation of the concepts of packet capture and flow data. What kind of information they can provide? Additionally, discuss the advantages, disadvantages, and importance of both packet capture and flow data in network analysis.

➢ Packet capture
    - Packet capture is the process of intercepting and recording packets traveling over a network. It involves capturing individual network packets transmitted over the network infrastructure.
    - Each packet typically contains a portion of the data being sent, as well as metadata such as source and destination IP addresses, ports, protocol information, and timestamps.
    - Advantages:
        1) Detail: provides the most detailed information allowing in-depth analysis of network traffic.
        2) Security: detects network intrusions, malware and suspicious activity by examining packet contents.
        3) Troubleshooting: helps identify and diagnose network problems, performance bottlenecks, and communication issues.
    - Disadvantages:

   1) Amount of data: capturing all packets may generate large amounts of data quickly, requiring large amounts of storage capacity.
   2) Privacy concerns: packet capture can raise privacy concerns, especially when capturing sensitive or personal data.
   3) Processing overhead: capturing, storing, and analyzing packet data may consume significant computational resources.
- Importance:

  Packet capture is critical for monitoring and analyzing network traffic. It helps diagnose network problems, optimize network performance and identify security threats.

➢ Flow data

- Flow data represents a summarized view of network traffic.
- Flow data records information about traffic flows that share common attributes such as source and destination IP addresses, ports, and protocols. Flow data is typically generated by network devices such as routers and switches and sent to a collector for analysis.
- Advantages:
   1) Efficiency: requires fewer storage and processing resources than packet capture due to data aggregation.
   2) Scalability: suitable for analyzing large-scale networks with high traffic volumes.
- Disadvantages:
   1) Limited level of detail: lack of detailed information makes it unsuitable for deep packet inspection.
   2) Unable to capture payload: flow data does not capture the actual contents of the packet, including application data.
- Importance:

  Flat data is important for monitoring network usage, identifying traffic patterns and detecting potential security threats, especially in large and complex network environments.

3. What is hashing? How does the hash algorithm work and what is the relation with the memory management in the large data analysis?

- Hashing is a mathematical function that maps input data of arbitrary length to output data of fixed length. The main purpose of the hashing algorithm is to create a fixed-size piece of data called a hash (or hash value) that should ideally be unique for different input data.

- Hash algorithms receive input data, which can be text, files, passwords, or numbers of arbitrary length. The algorithm takes the input data and converts it into a fixed-length binary string through mathematical operations, such as modulo, bitwise operations, and encryption. After processing, the algorithm generates a unique hash value, usually a fixed-length binary or hexadecimal string.
- In big data analytics, data is usually distributed across multiple nodes or servers. Through hashing algorithms, data can be sliced and distributed to different nodes according to a particular criterion to achieve distributed storage and processing of data.

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Task 2: Analyse flow data

- Data acquisition

```
# Get network adapter information
Get-NetAdapter
# Capture network traffic using dumpcap
Start-Process -FilePath "dumpcap" -ArgumentList "-i", "WLAN", "-w",
"D:\data\ass3.pcap" -NoNewWindow -Wait
```

- First execute the command to get information about the network adapters on the computer. It is usually used to list the details of the network adapters installed on the computer, including name, status, speed, etc.
- Then executes the command to capture network packets, which is used in conjunction with the Wireshark network analysis tool. It specifies the network adapter ("WLAN") to be captured and saves the captured packets to the file "D:\data\ass3.pcap".

- Data processing

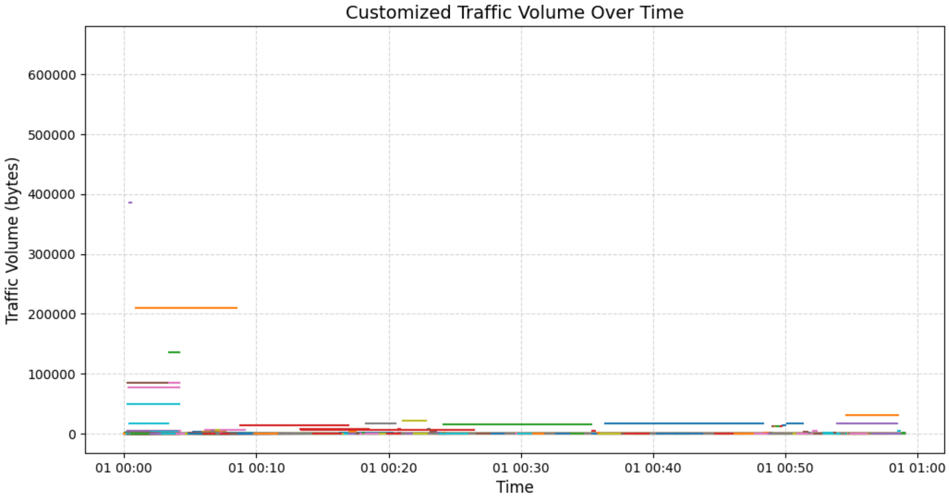
```
# Update package list
sudo apt-get update
# Install tshark
sudo apt-get install tshark
# Analyze the PCAP file and save flow data to flow_data.txt
tshark -r T2_data.pcap -q -z conv,tcp > flow_data.txt
# Analyze the PCAP file with verbose output and save flow data to
flow_data1.txt
tshark -r T2_data.pcap -q -z conv,tcp -V > flow_data1.txt
```

- First update system's package list to ensure that the latest version of the package can be installed. And install Tshark, which is the command line version of the Wireshark network analysis tool. Tshark is used to analyze network packets and can extract information about network traffic from PCAP files.
- Then use Tshark to extract the TCP network flow information from the PCAP file named "T2_data.pcap" and output the result to a text file named "flow_data.txt". More detailed information, including packet contents for each TCP session, is output to a text file named "flow_data1.txt".

1. Provide basic statistics of flow data, including
   - total number of flows,
   - minimum, median, mean and maximum flow sizes in bytes and packets

Item	Value
Total number of flows	1522
Minimum flow size (bytes)	54
Median flow size (bytes)	756.5
Mean flow size (bytes)	159005.5959264126
Maximum flow size (bytes)	96468992
Minimum flow size (packets)	1
Median flow size (packets)	10.0s
Mean flow size (packets):	345.65834428383704
Maximum flow size (packets)	95011

2. Plot the traffic volume (bytes) of the flow data file.



3. Please provide the top 5 most commonly used protocols, as well as the five most common source ports and five most common destination ports based on flows. Detail in a table for each one
   - the number of flows
   - the number of packets
   - the amount of data (bytes)
   - the application or usage

Top 5 Protocols				
Protocol	Flows	Packets	Bytes	Application
eth:ethertype:ip:udp:dtls	782217	782217	632113440	HTTP
eth:ethertype:ip:tcp:tls	285111	285111	65997699	HTTP
eth:ethertype:ip:tcp	228697	228697	154422789	HTTP
eth:ethertype:ip:udp:quic	191186	191186	203161985	HTTP
eth:ethertype:ip:udp:stun	20518	20518	2567736	HTTP

Top 5 Source Ports	
Port	Count
443	453247
11599	247252
64150	125608
55021	103432
62415	52097

Top 5 Destination Ports	
Port	Count
443	252321
64150	247277
11599	125568
51969	107335
62415	103445

4. Which are the top-ten host pairs based on
   - number of flows
   - number of bytes

   Are there the same pairs?

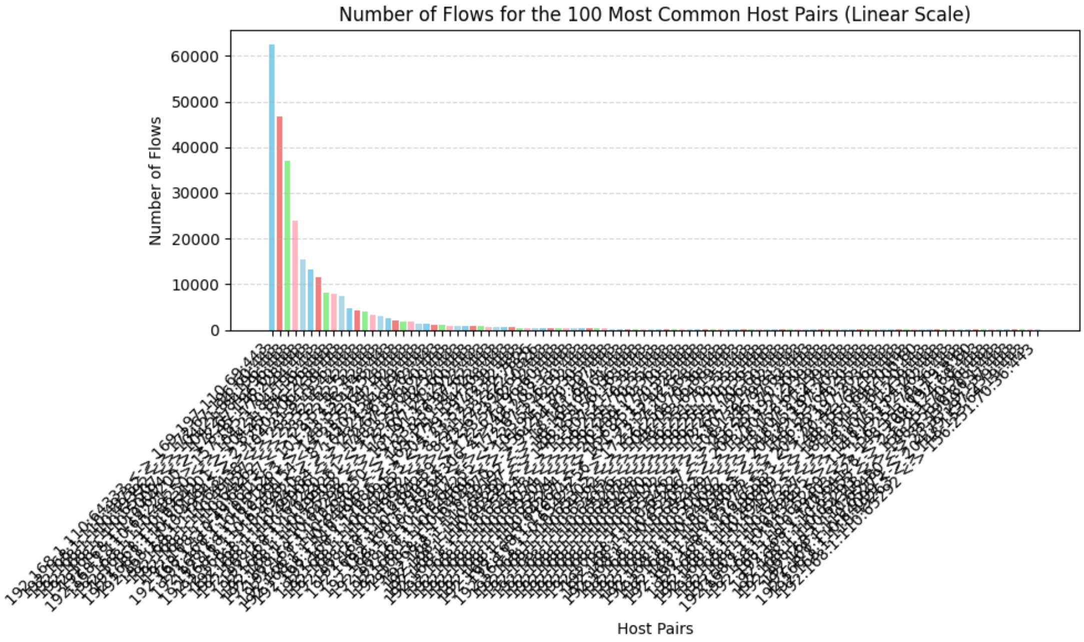
- No, there are different pairs.

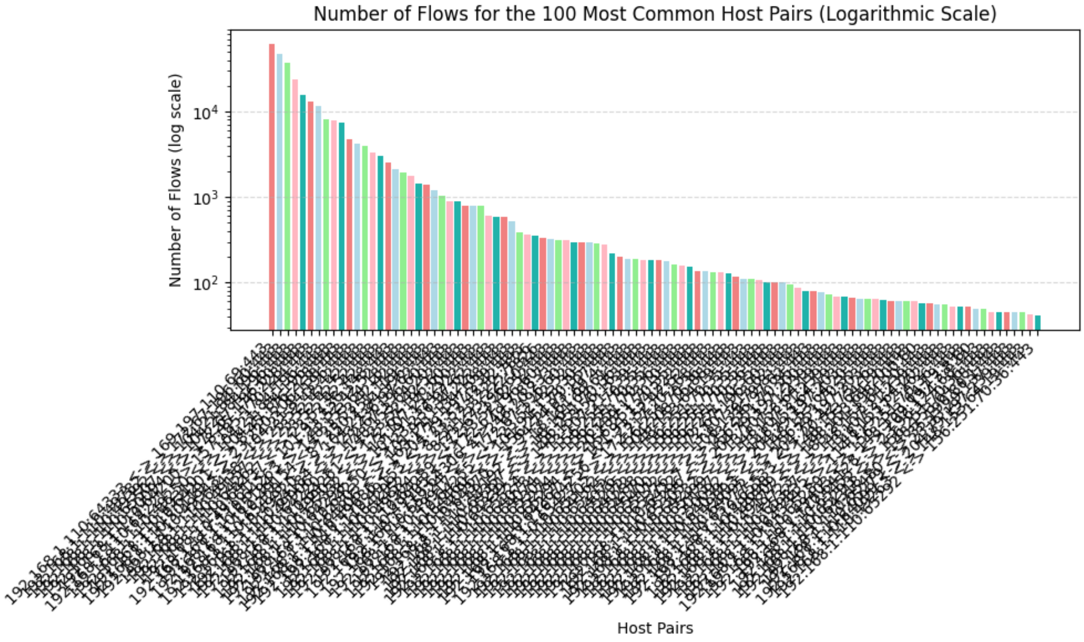
Top-ten host pairs based on number of flows		
Pairs	Number of flows	Number of bytes
192.168.1.110:64333 <-> 169.197.110.69:443	62457	94371840
192.168.1.110:49782 <-> 172.67.196.60:443	46611	6878208
192.168.1.110:49392 <-> 104.21.84.196:443	37049	6151168
192.168.1.110:65507 <-> 104.21.84.196:443	23885	3646464
192.168.1.110:50094 <-> 172.67.196.60:443	15445	2847744
192.168.1.110:64200 <-> 8.45.176.228:443	13224	18874368

192.168.1.110:64221 <-> 157.185.170.144:443	11478	17825792
192.168.1.110:49250 <-> 104.21.84.196:443	8225	1394688
192.168.1.110:49310 <-> 104.21.84.196:443	7891	1370112
192.168.1.110:64201 <-> 8.45.176.228:443	7340	10485760

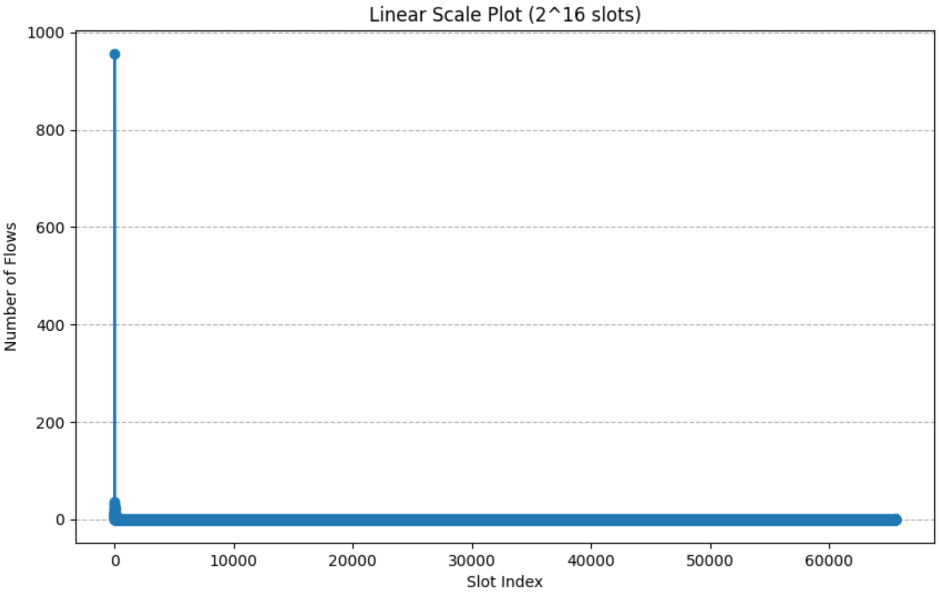
Top-ten host pairs based on number of flows		
Pairs	Number of flows	Number of bytes
192.168.1.110:64333 <-> 169.197.110.69:443	62457	94371840
192.168.1.110:64200 <-> 8.45.176.228:443	13224	18874368
192.168.1.110:64221 <-> 157.185.170.144:443	11478	17825792
192.168.1.110:64201 <-> 8.45.176.228:443	7340	10485760
192.168.1.110:50119 <-> 23.220.206.138:443	4690	7142400
192.168.1.110:49782 <-> 172.67.196.60:443	46611	6878208
192.168.1.110:64438 <-> 23.52.42.42:443	4009	6181888
192.168.1.110:49392 <-> 104.21.84.196:443	37049	6151168
192.168.1.110:49157 <-> 23.52.42.42:443	3337	5089280
192.168.1.110:64262 <-> 23.52.42.52:443	3064	4714496

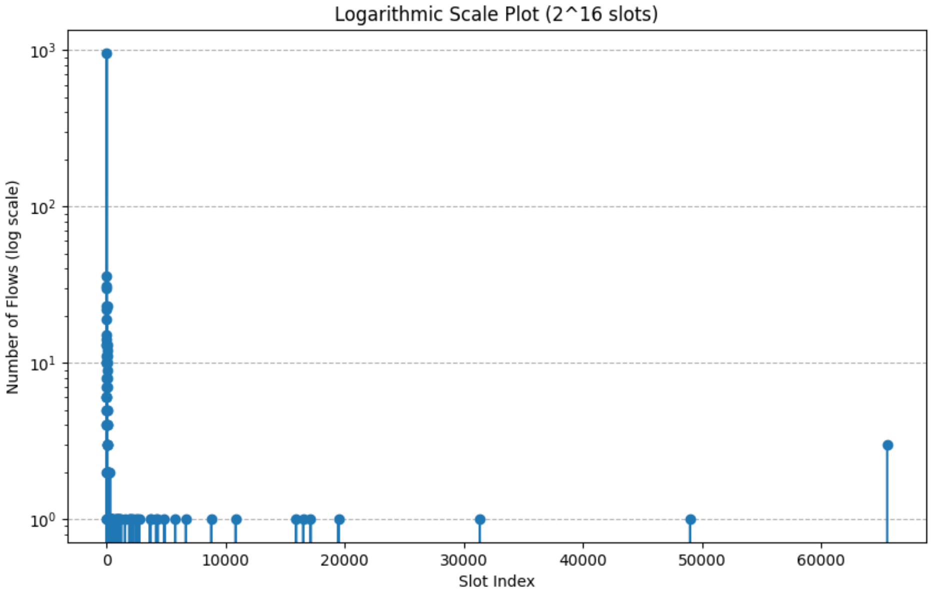
5. Plot the number of flows for the 100 most common pairs of hosts
   - Using linear scale
   - Using logarithmic scale





6. Repeat the previous plot (both linear and logarithmic scale) using this time fixed size (2^{16} slots) array approach (Network capture tutorial - Large data analysis, pp. 8 and solution #2, pp. 10). What can you say about the results?





- In linear scale, the number of flows is concentrated in the front slots.
- In logarithmic scale, the number of flows is concentrated in the front and back slots.

7. Is there a more efficient approach in terms of running time and memory consumption to accomplish this task?

- Use Tshark's filtering options to reduce the amount of data that needs to be processed. Use the -Y option to specify display filtering expressions to focus on specific types of traffic, protocols, or IP addresses. This can significantly reduce the number of packets Tshark needs to analyze.
- Create batch scripts or use a scripting language such as Python to automate the process. This makes it possible to process multiple files consecutively without manual intervention.
- Make sure that the system has enough RAM to handle the size of the PCAP files. Insufficient RAM may slow down the analysis or even cause the analysis tool to crash.
- Access to a multi-core processor system and explore parallel processing options to analyze PCAP files concurrently, which can significantly reduce overall processing time.

Task 3: Analyse packet capture (user traffic)

- Main function

```
# Function to convert bytes to kilobytes
def bytes_to_kilobytes(bytes_value, unit):
    byte_units = {'bytes': 1, 'kb': 1024, 'mb': 1024**2}
    return bytes_value * byte_units.get(unit.lower(), 1)
```

- This function accepts two arguments: bytes_value for the byte value to be converted and unit for the byte unit ('bytes', 'kilobytes', 'mb'). It will convert the byte value to kilobytes (KB) according to the byte unit and return the result.

```
def geocode(address, attempt=1, max_attempts=5):
    try:
        geolocator = Nominatim(user_agent="geoip_app")
        return geolocator.geocode(address)
    except GeocoderTimedOut:
        if attempt <= max_attempts:
            return do_geocode(address, attempt=attempt+1)
```

- This function is used to geocode by address, i.e. to convert an address to geographic coordinates (longitude and latitude). This function uses recursion to handle exceptions and retries if the geocoding request times out.

```
source_ips = df['source_interface'].apply(lambda x:
x.split(':')[0]).unique()
dest_ips = df['destination_interface'].apply(lambda x:
x.split(':')[0]).unique()
```

- This code is used to extract the unique IPv4 address from the data, which can be used for further analysis or to count the number of different IPv4 addresses.

1. How many IPv4 hosts (and IPv6, if any) are communicating?

    - The number of IPv4 hosts is 162.

2. Top 5 host countries (e.g. GeoIP)

Top 5 Host Countries	
Country	Count
العراق	19
United States	7
Türkiye	7
Česko	4
Canada	3

3. Top 15 hosts by byte counts.

Top 15 Hosts by Byte Counts	
IP	Bytes
192.168.1.110:64333	96468992
192.168.1.110:64200	19922944
192.168.1.110:64221	17825792
192.168.1.110:49782	12582912
192.168.1.110:64201	11534336
192.168.1.110:49392	10485760

192.168.1.110:50119	7266304
192.168.1.110:65507	6728704
192.168.1.110:64438	6290432
192.168.1.110:49157	5196800
192.168.1.110:64262	4799488
192.168.1.110:50094	4628480
192.168.1.110:64437	3939328
192.168.1.110:64263	2999296
192.168.1.110:49250	2282496

4. Top 15 hosts by packet counts. Were there any differences between the top 15 hosts in terms of byte counts and packet counts?

    - Yes.

Top 15 Hosts by Packet Counts	
IP	Bytes
192.168.1.110:49782	95011
192.168.1.110:64333	91367
192.168.1.110:49392	76099
192.168.1.110:65007	48991
192.168.1.110:50094	31331
192.168.1.110:64200	19474

192.168.1.110:64221	17122
192.168.1.110:49250	16517
192.168.1.110:49310	15905
192.168.1.110:64201	10844
192.168.1.110:49943	8797
192.168.1.110:50119	6660
192.168.1.110:64438	5761
192.168.1.110:49157	4862
192.168.1.110:64262	4283

5. Top 10 TCP and top 5 UDP port numbers (by packet count).

- UDP is not used.

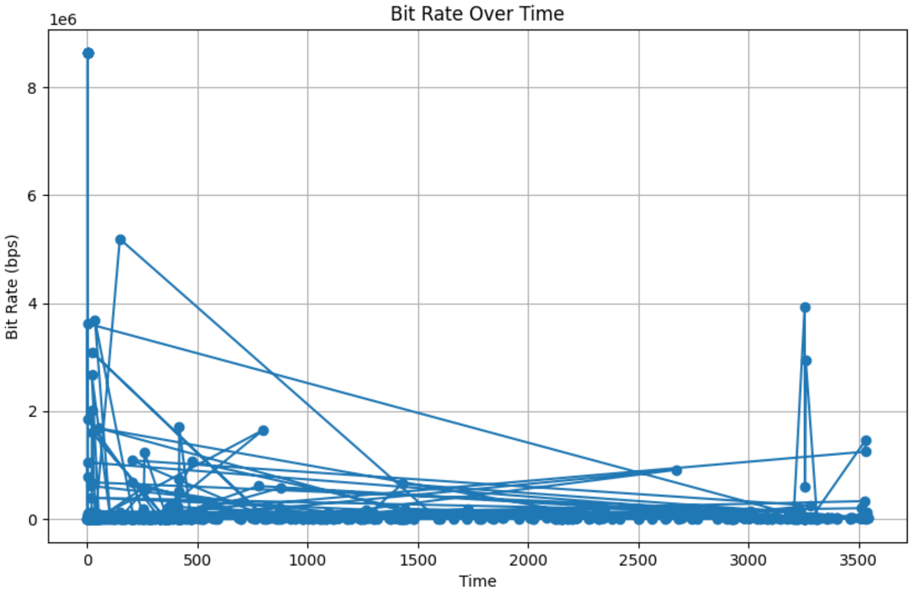
Top 10 TCP Port Numbers (by Packet Count)	
Port	Count
443	513920
53	9716
7826	1686
80	482
1900	120
63984	26
63985	26

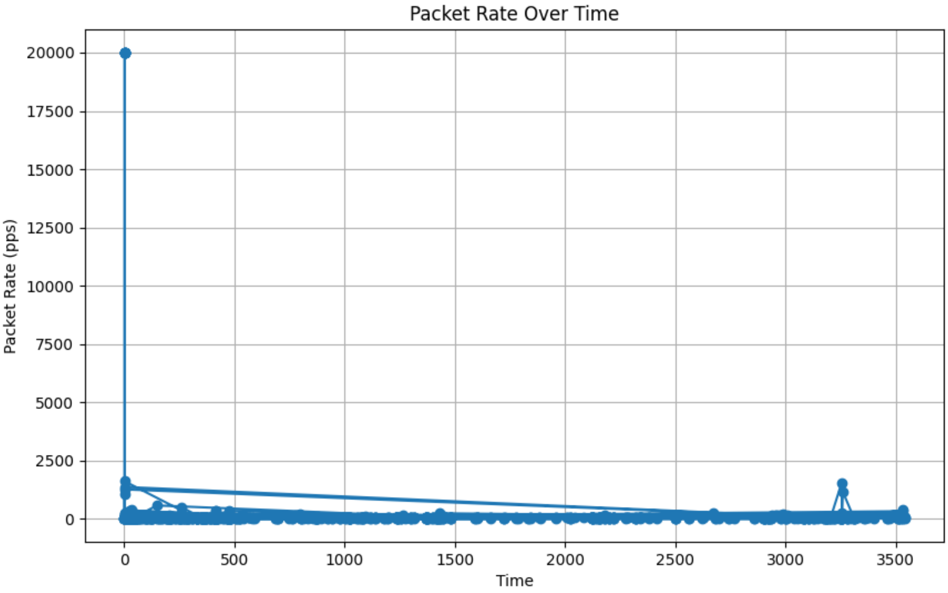
63989	26
64110	11
64123	11

6. Top 10 fastest TCP connections

Top 10 Fastest TCP Connections		
First IP interface	Second IP interface	Speed
192.168.1.110:64047	49.4.45.146:443	1.080000e+06
192.168.1.110:64031	49.4.17.138:443	1.080000e+06
192.168.1.110:64003	49.4.17.138:443	1.080000e+06
192.168.1.110:64004	49.4.17.138:443	1.080000e+06
192.168.1.110:64032	49.4.17.138:443	1.080000e+06
192.168.1.110:64010	47.246.20.231:443	1.080000e+06
192.168.1.110:64014	49.4.17.138:443	1.080000e+06
192.168.1.110:64002	49.4.17.138:443	1.080000e+06
192.168.1.110:64406	163.171.134.108:443	6.484586e+05
fe80::cad9:c2c0:7c6c:9cd9:50105	fe80::3e6a:48ff:fec3:e6ed:1900	4.911538e+05

7. Bit and packet rate over time (e.g. tcpstat, capinfos)





8. How many hosts were tried to contact to, but communication failed for a reason or another? Can you identify different subclasses of failed communications?

    - The number of hosts that tried to communicate but failed is 0, which means there is no failed communication.

➢ Summarize

- In this task, I initially captured the data packets transmitted by the computer over a specific time frame, resulting in the acquisition of a pcap (packet capture) file. Subsequently, I proceeded to transform this pcap file into flow data and subsequently conducted a comprehensive analysis of the captured information.
- After analyzing the flow data, I extracted basic statistical information regarding the flow data, host pairs, flow count, and data volume. This information helps us gain a deeper understanding of the characteristics and trends in network activity.
- The packet capture was subjected to analysis, from which we extracted valuable information including host count, IP addresses, and TCP-related data.