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Network Performance Analysis Using Time-Series Events and Protocols

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Abstract

The main goal of this research is to employ simulation and data visualization to analyze the behavior and performance of network protocols. The project assesses important parameters like throughput, latency, and protocol usage using event-based network data. The objective is to highlight the performance differences between Ethernet, UDP, and TCP protocols and comprehend how they function under particular circumstances.

Introduction

The rapid growth of modern networks necessitates efficient and reliable protocols to manage increasing data traffic. This project focuses on analyzing the performance and behavior of key network protocols, specifically **Ethernet**, **UDP**, and **TCP**. Through simulation and data visualization, we aim to evaluate critical metrics such as throughput, latency, and protocol usage, providing insights into how these protocols operate under varying conditions

Project Outlines

1. Dataset Creation

A simulated dataset of network events was generated to extract key metrics like throughput,latency, and packet counts for Ethernet, UDP, and TCP protocols.

2. Implementation

Scapy was used for packet analysis and Matplotlib was used for data visualization in thePython implementation of the project.In order to compute different metrics, the code parses network events and logs comprehensive data for analysis.

3. Metrics Analyzed

- Throughput: The speed at which data moves over time.
- Latency: How long does it take for packets to move across a network?
- Protocol Usage: How many packets are sent using each protocol.

Functions Used

• **display_packet_details(protocol, src, dest, size)**
This function prints the details of a captured packet, including protocol type, source and destination addresses, and packet size.

• **save_to_log(protocol, src, dest, size, timestamp)**
Logs packet details into a file (**network_events.log**) with a timestamp and calls **display_packet_details** to print the information to the console.

• **record_packet_info(protocol, src_addr, dest_addr, size, timestamp)**
Updates shared data structures with captured packet information, tracking throughput, connection counts, and unique MAC/IP addresses. It also records latency for TCP/UDP.

• **handle_packet(packet)**
Processes each captured packet by checking its type (**Ethernet**, **IP**, **TCP**, or **UDP**) and calling the appropriate logging and recording functions.

• **compute_throughput(interval=10)**
Calculates and prints throughput (in **bps**) for each protocol over a specified time interval, updating the throughput timeline for visualization.

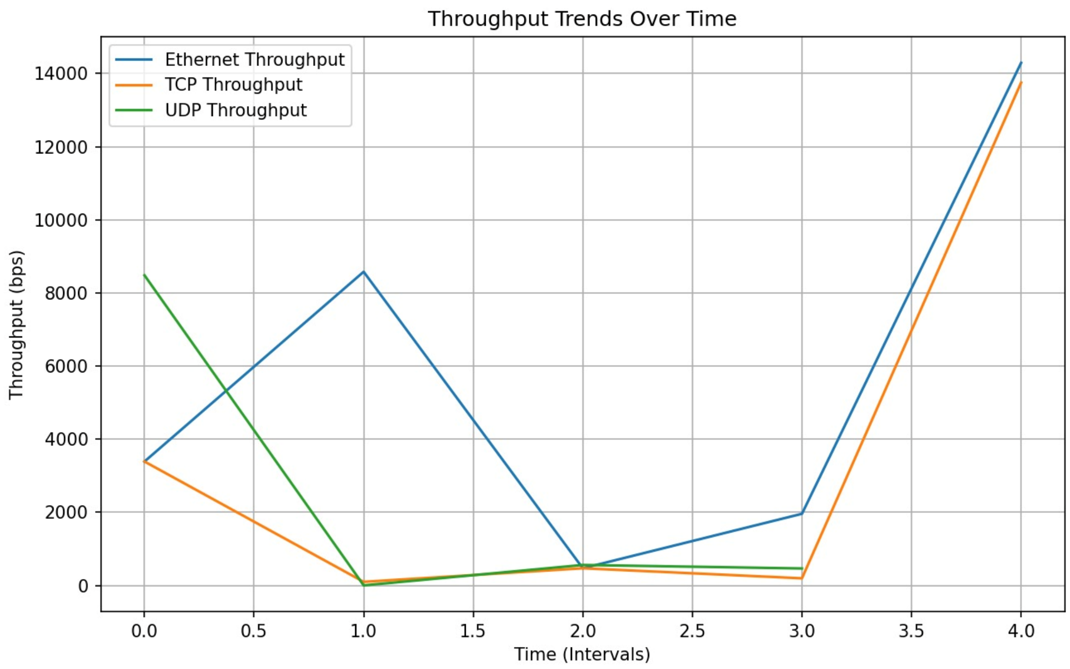
• **compute_latency()**
Calculates average latency for **TCP/UDP** connections by comparing timestamps of request and response packets, printing the average in milliseconds.

• **show_statistics()**
Displays a summary of network monitoring statistics, including connections for each protocol, average packet sizes, and counts of unique **IP** and **MAC** addresses.

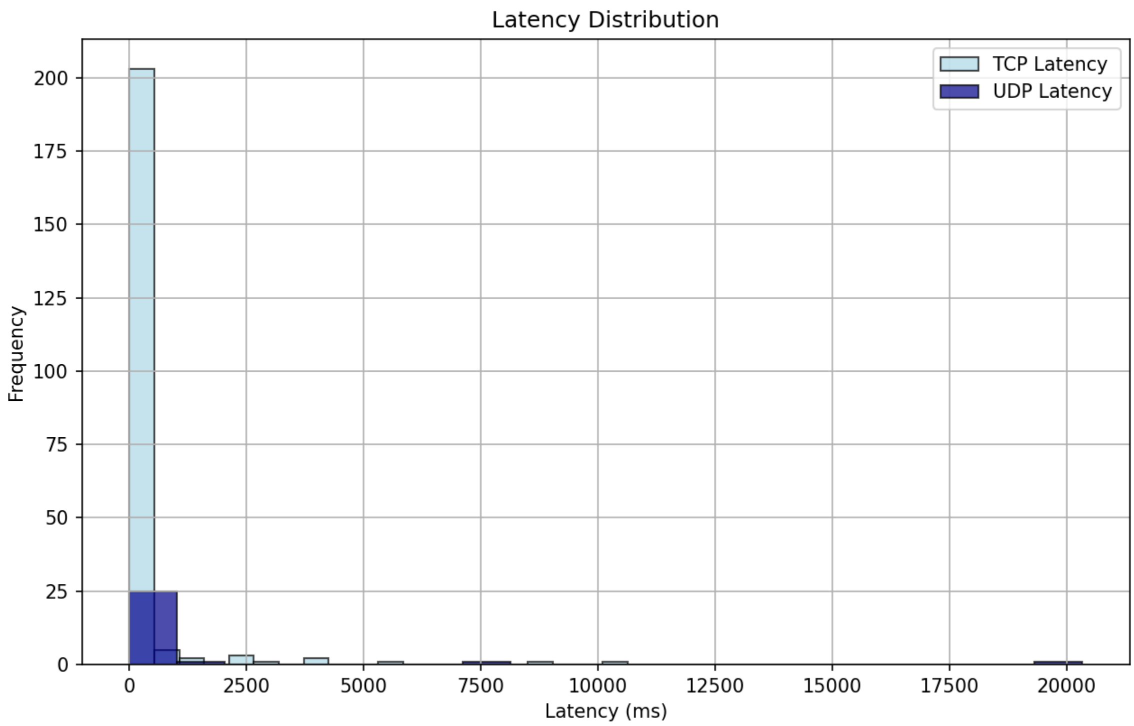
• **generate_visuals()**
Generates visual reports using **Matplotlib**, plotting throughput trends, latency distribution, and protocol usage statistics, saving the plots as images.

• **start_packet_capture()**
Initiates packet sniffing using **Scapy**, capturing **IP**, **TCP**, and **UDP** packets and passing them to the **handle_packet**function for processing.

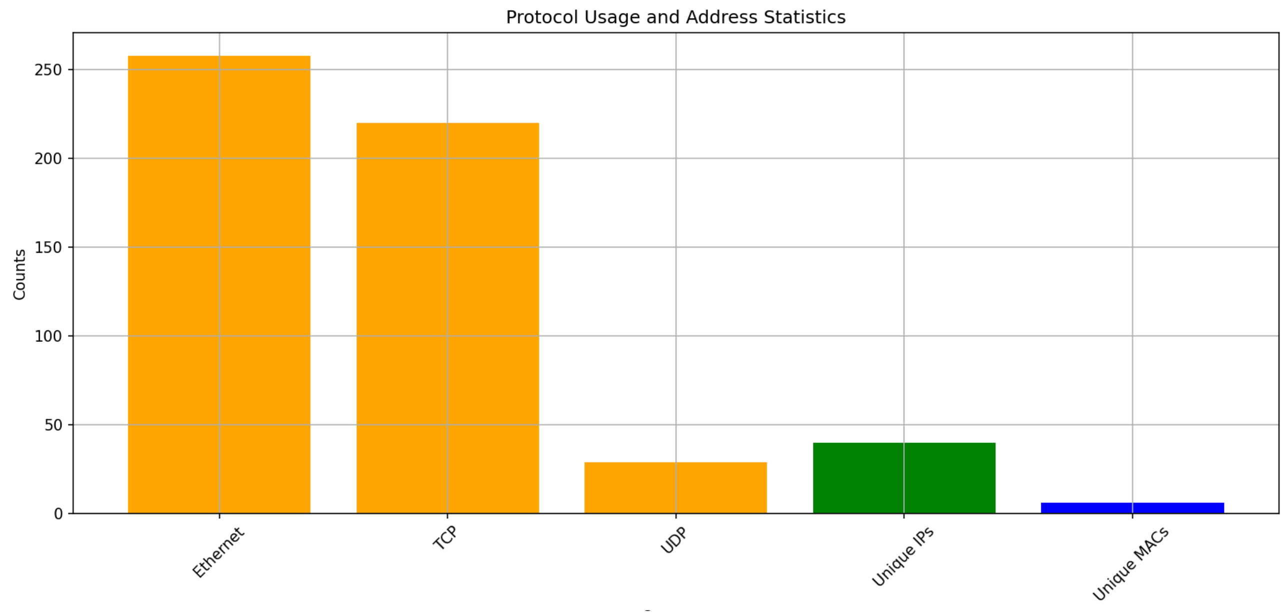
Results



This graph shows the fluctuating throughput rates over time across the different protocols.



This chart indicates that most connections have low response times, with some cases experiencing higher



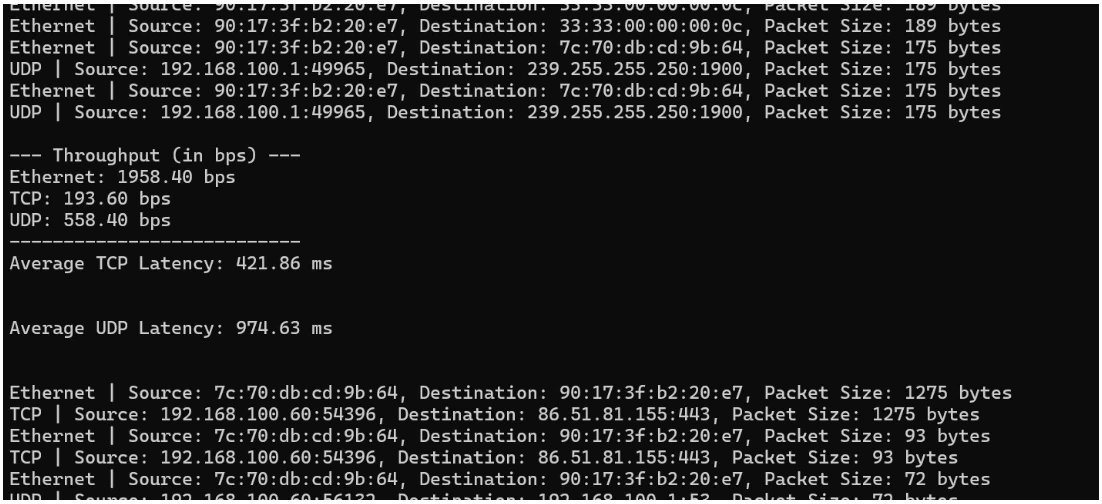
This graph highlights the dominance of the Ethernet protocol in network usage, with lower activity for TCP and UDP.

The output

When we run the code

```
PS C:\Users\lenovo> python "C:\Users\lenovo\Downloads\Project (1).py"
Ethernet | Source: 12:02:71:dc:20:93, Destination: 7c:70:db:cd:9b:64, Packet Size: 60 bytes
TCP | Source: 86.51.81.56:443, Destination: 192.168.1.122:59472, Packet Size: 60 bytes
Ethernet | Source: 7c:70:db:cd:9b:64, Destination: 12:02:71:dc:20:93, Packet Size: 54 bytes
TCP | Source: 192.168.1.122:59472, Destination: 86.51.81.56:443, Packet Size: 54 bytes
Ethernet | Source: 7c:70:db:cd:9b:64, Destination: 12:02:71:dc:20:93, Packet Size: 88 bytes
UDP | Source: 192.168.1.122:54709, Destination: 86.51.35.24:53, Packet Size: 88 bytes
Ethernet | Source: 12:02:71:dc:20:93, Destination: 7c:70:db:cd:9b:64, Packet Size: 172 bytes
UDP | Source: 86.51.35.24:53, Destination: 192.168.1.122:54709, Packet Size: 172 bytes
Ethernet | Source: 7c:70:db:cd:9b:64, Destination: 12:02:71:dc:20:93, Packet Size: 66 bytes
TCP | Source: 192.168.1.122:59482, Destination: 4.245.161.190:443, Packet Size: 66 bytes
Ethernet | Source: 12:02:71:dc:20:93, Destination: 7c:70:db:cd:9b:64, Packet Size: 66 bytes
TCP | Source: 4.245.161.190:443, Destination: 192.168.1.122:59482, Packet Size: 66 bytes
Ethernet | Source: 7c:70:db:cd:9b:64, Destination: 12:02:71:dc:20:93, Packet Size: 54 bytes
TCP | Source: 192.168.1.122:59482, Destination: 4.245.161.190:443, Packet Size: 54 bytes
Ethernet | Source: 7c:70:db:cd:9b:64, Destination: 12:02:71:dc:20:93, Packet Size: 362 bytes
TCP | Source: 192.168.1.122:59482, Destination: 4.245.161.190:443, Packet Size: 362 bytes
Ethernet | Source: 12:02:71:dc:20:93, Destination: 7c:70:db:cd:9b:64, Packet Size: 1454 bytes
TCP | Source: 4.245.161.190:443, Destination: 192.168.1.122:59482, Packet Size: 1454 bytes
Ethernet | Source: 12:02:71:dc:20:93, Destination: 7c:70:db:cd:9b:64, Packet Size: 1454 bytes
TCP | Source: 4.245.161.190:443, Destination: 192.168.1.122:59482, Packet Size: 1454 bytes
Ethernet | Source: 7c:70:db:cd:9b:64, Destination: 12:02:71:dc:20:93, Packet Size: 54 bytes
TCP | Source: 192.168.1.122:59482, Destination: 4.245.161.190:443, Packet Size: 54 bytes
Ethernet | Source: 12:02:71:dc:20:93, Destination: 7c:70:db:cd:9b:64, Packet Size: 1125 bytes
TCP | Source: 4.245.161.190:443, Destination: 192.168.1.122:59482, Packet Size: 1125 bytes
Ethernet | Source: 7c:70:db:cd:9b:64, Destination: 12:02:71:dc:20:93, Packet Size: 212 bytes
TCP | Source: 192.168.1.122:59482, Destination: 4.245.161.190:443, Packet Size: 212 bytes
Ethernet | Source: 12:02:71:dc:20:93, Destination: 7c:70:db:cd:9b:64, Packet Size: 105 bytes
TCP | Source: 4.245.161.190:443, Destination: 192.168.1.122:59482, Packet Size: 105 bytes
Ethernet | Source: 7c:70:db:cd:9b:64, Destination: 12:02:71:dc:20:93, Packet Size: 141 bytes
TCP | Source: 192.168.1.122:59482, Destination: 4.245.161.190:443, Packet Size: 141 bytes
Ethernet | Source: 7c:70:db:cd:9b:64, Destination: 12:02:71:dc:20:93, Packet Size: 415 bytes
TCP | Source: 192.168.1.122:59482, Destination: 4.245.161.190:443, Packet Size: 415 bytes
Ethernet | Source: 7c:70:db:cd:9b:64, Destination: 12:02:71:dc:20:93, Packet Size: 1454 bytes
TCP | Source: 192.168.1.122:59482, Destination: 4.245.161.190:443, Packet Size: 1454 bytes
Ethernet | Source: 7c:70:db:cd:9b:64, Destination: 12:02:71:dc:20:93, Packet Size: 1275 bytes
TCP | Source: 192.168.1.122:59482, Destination: 4.245.161.190:443, Packet Size: 1275 bytes
Ethernet | Source: 12:02:71:dc:20:93, Destination: 7c:70:db:cd:9b:64, Packet Size: 196 bytes
TCP | Source: 4.245.161.190:443, Destination: 192.168.1.122:59482, Packet Size: 196 bytes
Ethernet | Source: 12:02:71:dc:20:93, Destination: 7c:70:db:cd:9b:64, Packet Size: 60 bytes
TCP | Source: 4.245.161.190:443, Destination: 192.168.1.122:59482, Packet Size: 60 bytes
Ethernet | Source: 7c:70:db:cd:9b:64, Destination: 12:02:71:dc:20:93, Packet Size: 92 bytes
TCP | Source: 192.168.1.122:59482, Destination: 4.245.161.190:443, Packet Size: 92 bytes
Ethernet | Source: 12:02:71:dc:20:93, Destination: 7c:70:db:cd:9b:64, Packet Size: 687 bytes
TCP | Source: 4.245.161.190:443, Destination: 192.168.1.122:59482, Packet Size: 687 bytes
Ethernet | Source: 7c:70:db:cd:9b:64, Destination: 12:02:71:dc:20:93, Packet Size: 54 bytes
TCP | Source: 192.168.1.122:59482, Destination: 4.245.161.190:443, Packet Size: 54 bytes
Ethernet | Source: 7c:70:db:cd:9b:64, Destination: 12:02:71:dc:20:93, Packet Size: 81 bytes
UDP | Source: 192.168.1.122:54709, Destination: 86.51.35.24:53, Packet Size: 81 bytes
Ethernet | Source: 12:02:71:dc:20:93, Destination: 7c:70:db:cd:9b:64, Packet Size: 241 bytes
UDP | Source: 86.51.35.24:53, Destination: 192.168.1.122:54709, Packet Size: 241 bytes
Ethernet | Source: 7c:70:db:cd:9b:64, Destination: 12:02:71:dc:20:93, Packet Size: 66 bytes
TCP | Source: 192.168.1.122:59483, Destination: 13.107.42.16:443, Packet Size: 66 bytes
Ethernet | Source: 12:02:71:dc:20:93, Destination: 7c:70:db:cd:9b:64, Packet Size: 66 bytes
```

Throughput and latency appears every 10 sec



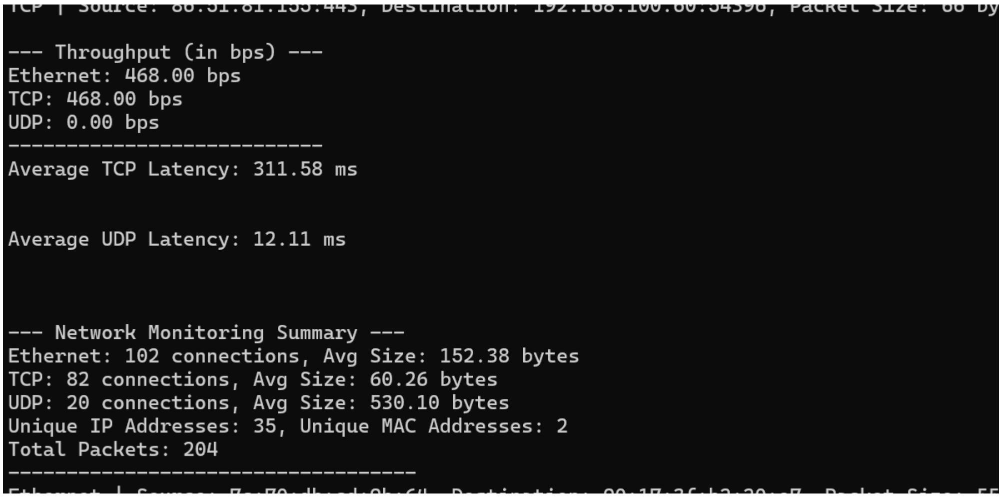
```
Ethernet | Source: 90:17:3f:b2:20:e7, Destination: 33:33:00:00:00:0c, Packet Size: 189 bytes
Ethernet | Source: 90:17:3f:b2:20:e7, Destination: 7c:70:db:cd:9b:64, Packet Size: 175 bytes
UDP | Source: 192.168.100.1:49965, Destination: 239.255.255.250:1900, Packet Size: 175 bytes
Ethernet | Source: 90:17:3f:b2:20:e7, Destination: 7c:70:db:cd:9b:64, Packet Size: 175 bytes
UDP | Source: 192.168.100.1:49965, Destination: 239.255.255.250:1900, Packet Size: 175 bytes

--- Throughput (in bps) ---
Ethernet: 1958.40 bps
TCP: 193.60 bps
UDP: 558.40 bps
--------------------------
Average TCP Latency: 421.86 ms


Average UDP Latency: 974.63 ms


Ethernet | Source: 7c:70:db:cd:9b:64, Destination: 90:17:3f:b2:20:e7, Packet Size: 1275 bytes
TCP | Source: 192.168.100.60:54396, Destination: 86.51.81.155:443, Packet Size: 1275 bytes
Ethernet | Source: 7c:70:db:cd:9b:64, Destination: 90:17:3f:b2:20:e7, Packet Size: 93 bytes
TCP | Source: 192.168.100.60:54396, Destination: 86.51.81.155:443, Packet Size: 93 bytes
Ethernet | Source: 7c:70:db:cd:9b:64, Destination: 90:17:3f:b2:20:e7, Packet Size: 72 bytes
```

Summary statistics appears every 30 sec



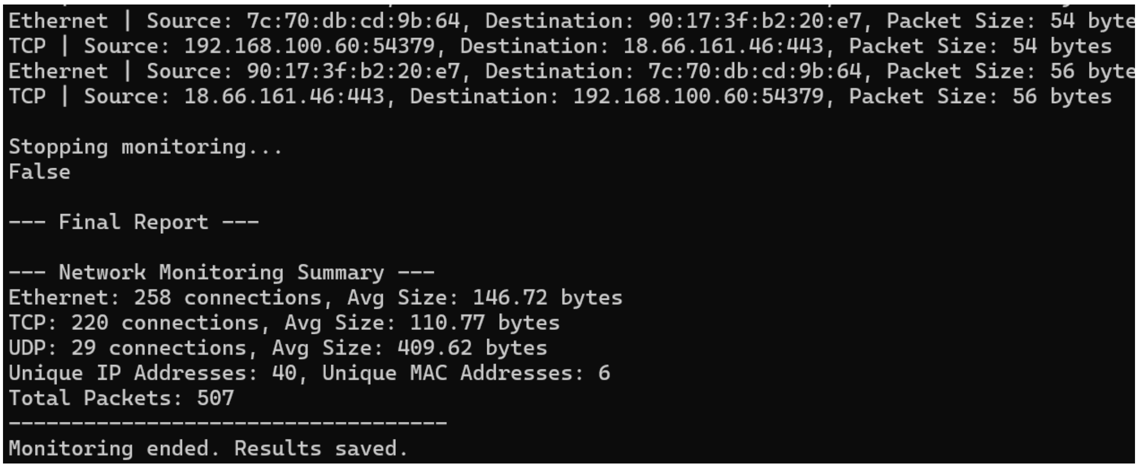
```
--- Throughput (in bps) ---
Ethernet: 468.00 bps
TCP: 468.00 bps
UDP: 0.00 bps
--------------------------
Average TCP Latency: 311.58 ms


Average UDP Latency: 12.11 ms



--- Network Monitoring Summary ---
Ethernet: 102 connections, Avg Size: 152.38 bytes
TCP: 82 connections, Avg Size: 60.26 bytes
UDP: 20 connections, Avg Size: 530.10 bytes
Unique IP Addresses: 35, Unique MAC Addresses: 2
Total Packets: 204
-----------------------------------
```

Final statistics appears when we press ctrl+c



```
Ethernet | Source: 7c:70:db:cd:9b:64, Destination: 90:17:3f:b2:20:e7, Packet Size: 54 byte
TCP | Source: 192.168.100.60:54379, Destination: 18.66.161.46:443, Packet Size: 54 bytes
Ethernet | Source: 90:17:3f:b2:20:e7, Destination: 7c:70:db:cd:9b:64, Packet Size: 56 byte
TCP | Source: 18.66.161.46:443, Destination: 192.168.100.60:54379, Packet Size: 56 bytes

Stopping monitoring...
False

--- Final Report ---

--- Network Monitoring Summary ---
Ethernet: 258 connections, Avg Size: 146.72 bytes
TCP: 220 connections, Avg Size: 110.77 bytes
UDP: 29 connections, Avg Size: 409.62 bytes
Unique IP Addresses: 40, Unique MAC Addresses: 6
Total Packets: 507
-----------------------------------
Monitoring ended. Results saved.
```

Discussion Section on the Network Environment

1. Throughput Analysis

- **Ethernet:** Consistently strong, peaking at **14,000 bps**, showcasing adaptability under high traffic.
- **TCP:** Lower throughput but peaks at **10,000 bps** later, likely due to adaptive retransmissions.
- **UDP:** Balanced performance, peaking at **8,000 bps**, ideal for time-sensitive tasks with low overhead.

2. Latency Analysis

- **TCP:** Most latencies below **2,500 ms**, indicating reliable performance.
- **UDP:** Wider spread, with significant values around **5,000 ms**, showing a trade-off between speed and reliability.
- **Outliers:** Latencies up to **20,000 ms** suggest occasional network delays needing further investigation.

3.Protocol Usage Analysis

- Ethernet has the highest usage, with around 250 counts.
- TCP has the second highest usage, with around 200 counts.
- UDP has a much lower usage, with only around 50 counts.
- Unique IPv4s and Unique MACs have the lowest usage, with around 10 and 5 counts respectively.

Overall Analysis

- **Ethernet:** Backbone of the network with strong throughput and highest usage.
- **TCP:** Reliable with low latency, ideal for error-sensitive tasks despite moderate throughput.
- **UDP:** Lightweight and fast, suitable for time-critical applications, though with a wider latency spread.
- **Network Diversity:** Moderate IP and MAC diversity reflect controlled but active network activity.
- **Insights:** Ethernet ensures stability, TCP ensures reliability, and UDP offers speed, highlighting their complementary roles.

Conclusion

The performance of the Ethernet, UDP, and TCP protocols was effectively examined and illustrated in this project. The results demonstrate:

- E**thernet's dominance** in throughput, showcasing its stability and reliability under traffic.
- **UDP's balance** between speed and dependability, making it ideal for time-sensitive tasks.
- **TCP's suitability** for error-sensitive applications due to its reliable transmission mechanisms.

Future work could involve analyzing additional protocols or testing under varying network conditions for a more comprehensive study.