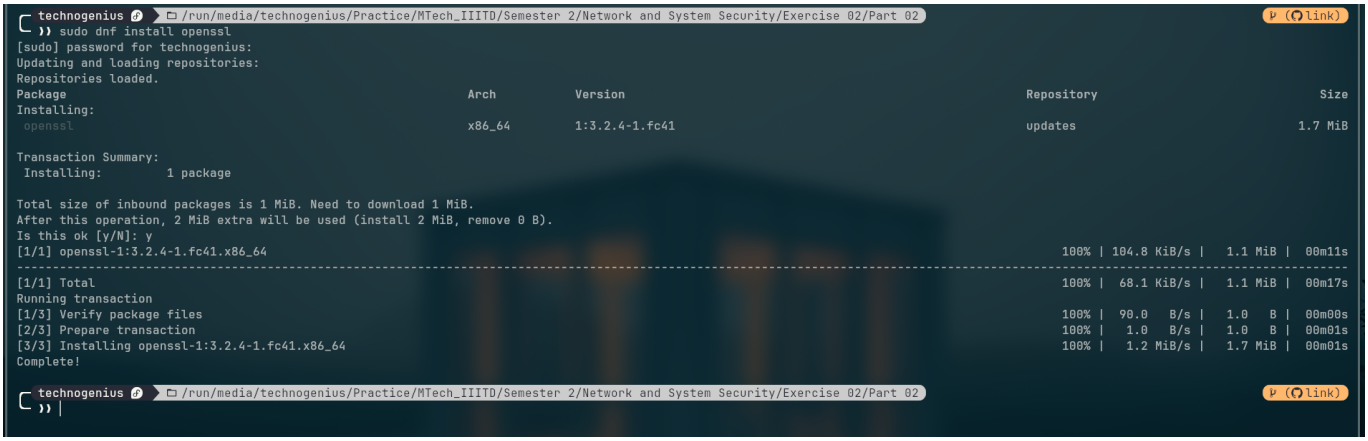
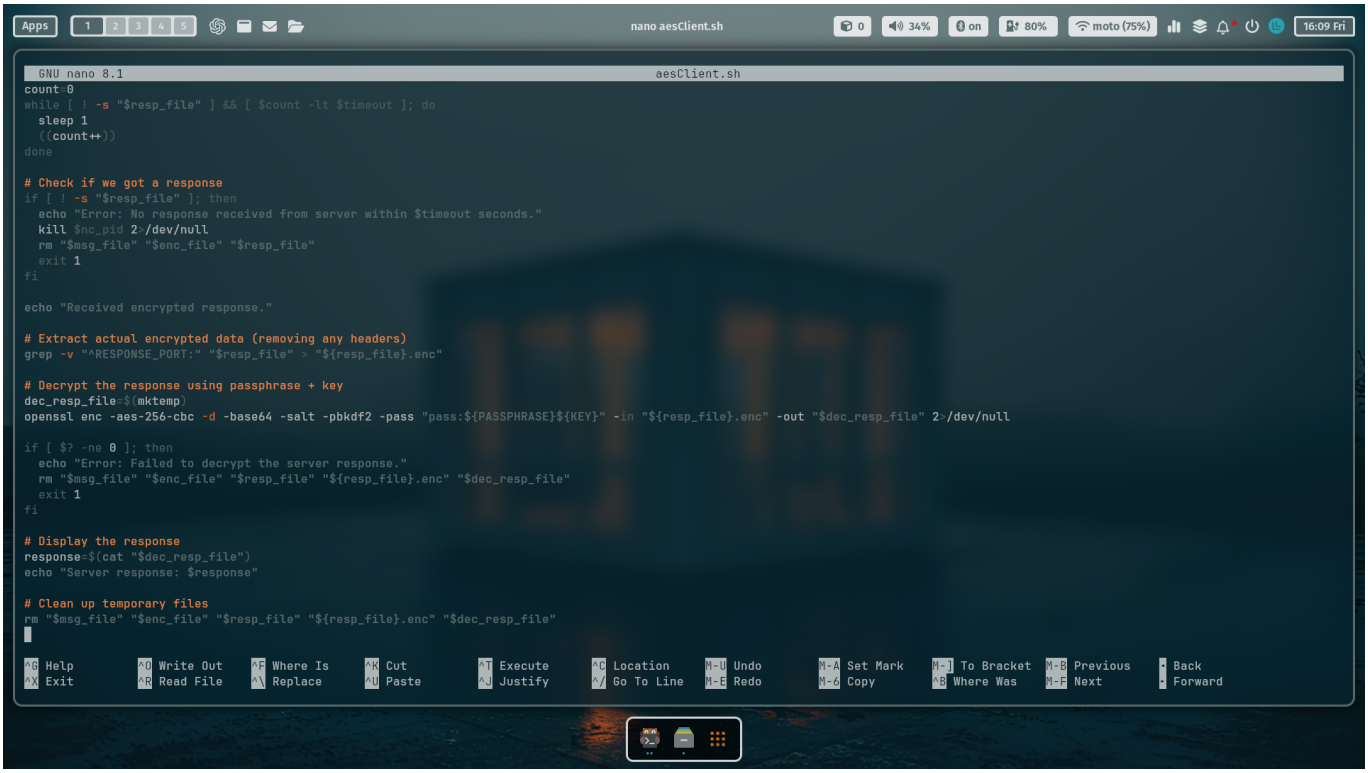
AES-Enabled Echo Server and Client Using OpenSSL and Netcat

This report provides an in-depth explanation of the commands used in the provided shell scripts to build an AES-enabled echo server and client. The goal is to encrypt communication between the client and server using **AES-256 encryption** and capture the encrypted traffic using `tcpdump`. Additionally, this report includes advanced concepts, detailed descriptions, and placeholders for output images to help you understand the process better.



1. Advanced Explanation of Commands

a. `aesClient.sh`



This script is the client-side program that sends an encrypted message to the server and waits for an encrypted response.

1. `source aesConfig.sh`
    - **Why**: This command loads the configuration file (`aesConfig.sh`) that contains variables like `SERVER_PORT`, `CLIENT_PORT`, `KEY_FILE`, etc.
    - **What it does**: It ensures the client knows which ports to use and where to find the encryption key.

- **Advanced**: The `source` command is used to include the configuration file in the current script, making the variables available for use.

2. `if [ ! -f "$KEY_FILE" ]; then ...`

   - **Why**: This checks if the key file exists. If not, the script stops because encryption cannot happen without a key.
   - **What it does**: It ensures the key file is present before proceeding.
   - **Advanced**: The `-f` flag checks if the file exists and is a regular file. This is a common practice in shell scripting to validate file existence.

3. `KEY=$(cat "$KEY_FILE")`

   - **Why**: This reads the AES key from the key file.
   - **What it does**: The key is stored in the `KEY` variable for later use in encryption.
   - **Advanced**: The `cat` command reads the contents of the file and stores it in the `KEY` variable. This key is used in conjunction with the passphrase for encryption.

4. `read name`

   - **Why**: This takes user input (e.g., a name like "Bob") to send to the server.
   - **What it does**: The input is stored in the `name` variable.
   - **Advanced**: The `read` command is used to capture user input interactively. This is useful for dynamic data entry.

5. `openssl enc -aes-256-cbc -base64 -salt -pbkdf2 -pass "pass:${PASSPHRASE}${KEY}" -in "$msg_file" -out "$enc_file"`

   - **Why**: This encrypts the message using AES-256 encryption.
   - **What it does**: It takes the user's input (stored in `msg_file`), encrypts it using the passphrase and key, and saves the encrypted data in `enc_file`.
   - **Advanced**:
     - `-aes-256-cbc`: Specifies the encryption algorithm (AES-256 in CBC mode).
     - `-base64`: Encodes the output in Base64 format for easy transmission.
     - `-salt`: Adds extra security by using a random salt.
     - `-pbkdf2`: Uses the PBKDF2 key derivation function for stronger key generation.
     - `-pass`: Combines the passphrase and key for encryption.

6. `nc -l $CLIENT_PORT > "$resp_file" &`

   - **Why**: This starts a netcat listener on the client's port to wait for the server's response.
   - **What it does**: It listens for incoming data on `CLIENT_PORT` and saves it to `resp_file`.
   - **Advanced**: The `&` at the end runs the command in the background, allowing the script to continue executing while waiting for the server's response.

7. `(echo "RESPONSE_PORT:$CLIENT_PORT"; cat "$enc_file") | nc localhost $SERVER_PORT`

   - **Why**: This sends the encrypted data to the server.
   - **What it does**: It sends the client's port number (for the server to respond) and the encrypted message to the server.

- **Advanced**: The `|` (pipe) operator is used to send the output of one command as input to another. Here, it sends the port number and encrypted data to the server.

8. `openssl enc -aes-256-cbc -d -base64 -salt -pbkdf2 -pass "pass:${PASSPHRASE}${KEY}" -in "${resp_file}.enc" -out "$dec_resp_file"`

   - **Why**: This decrypts the server's response.
   - **What it does**: It takes the encrypted response from the server, decrypts it, and saves the result in `dec_resp_file`.
   - **Advanced**: The `-d` flag is used for decryption. The rest of the options are the same as for encryption.

9. `rm "$msg_file" "$enc_file" "$resp_file" "${resp_file}.enc" "$dec_resp_file"`

   - **Why**: This cleans up temporary files created during the process.
   - **What it does**: It deletes all temporary files to free up space.
   - **Advanced**: The `rm` command is used to remove files. This is important for security, as it ensures that sensitive data (like encrypted messages) is not left on the system.

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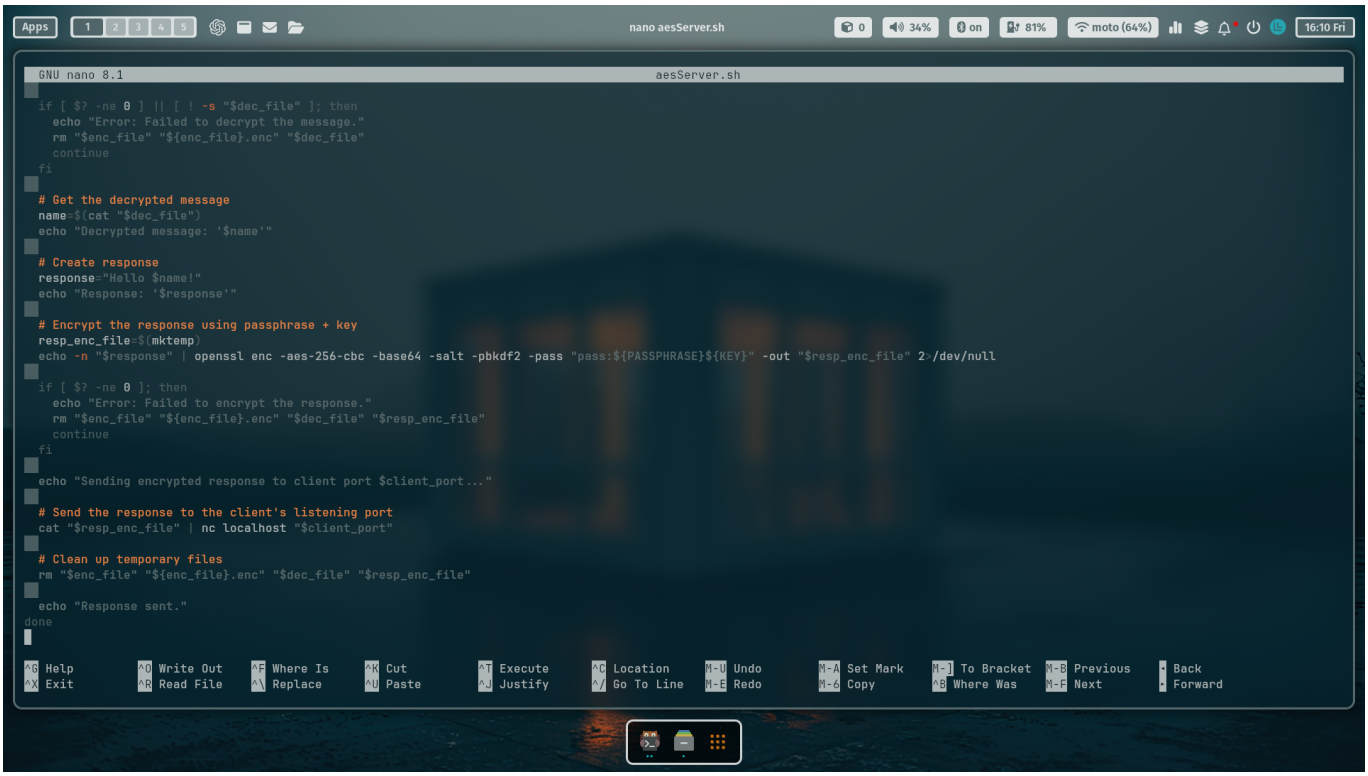
b. `aesServer.sh`



This script is the server-side program that listens for encrypted messages, decrypts them, and sends back an encrypted response.

1. `source aesConfig.sh`
    - **Why**: This loads the configuration file (`aesConfig.sh`) to get variables like `SERVER_PORT`, `KEY_FILE`, etc.
    - **What it does**: It ensures the server knows which port to listen on and where to find the encryption key.
    - **Advanced**: The `source` command is used to include the configuration file in the current script, making the variables available for use.

2. `KEY=$(cat "$KEY_FILE")`
    - **Why**: This reads the AES key from the key file.
    - **What it does**: The key is stored in the `KEY` variable for later use in decryption.
    - **Advanced**: The `cat` command reads the contents of the file and stores it in the `KEY` variable. This key is used in conjunction with the passphrase for decryption.

3. `nc -l $SERVER_PORT > "$enc_file"`
    - **Why**: This listens for incoming connections from the client.
    - **What it does**: It receives encrypted data from the client and saves it to `enc_file`.
    - **Advanced**: The `nc` (netcat) command is used to listen for incoming connections on the specified port.

4. `client_port=$(grep "^RESPONSE_PORT:" "$enc_file" | cut -d':' -f2)`
    - **Why**: This extracts the client's port number from the received data.
    - **What it does**: It tells the server where to send the response.

- **Advanced**: The `grep` command searches for the line containing `RESPONSE_PORT:`, and `cut` extracts the port number.

5. `openssl enc -aes-256-cbc -d -base64 -salt -pbkdf2 -pass "pass:${PASSPHRASE}${KEY}" -in "${enc_file}.enc" -out "$dec_file"`

   - **Why**: This decrypts the client's message.
   - **What it does**: It takes the encrypted data, decrypts it, and saves the result in `dec_file`.
   - **Advanced**: The `-d` flag is used for decryption. The rest of the options are the same as for encryption.

6. `response="Hello $name!"`

   - **Why**: This creates the server's response message.
   - **What it does**: It prepends "Hello" to the decrypted name (e.g., "Hello Bob!").
   - **Advanced**: This is a simple string concatenation, but it could be extended to include more complex logic.

7. `openssl enc -aes-256-cbc -base64 -salt -pbkdf2 -pass "pass:${PASSPHRASE}${KEY}" -out "$resp_enc_file"`

   - **Why**: This encrypts the server's response.
   - **What it does**: It encrypts the response message and saves it in `resp_enc_file`.
   - **Advanced**: The same encryption options are used as in the client script.

8. `cat "$resp_enc_file" | nc localhost "$client_port"`

   - **Why**: This sends the encrypted response back to the client.
   - **What it does**: It sends the encrypted data to the client's listening port.
   - **Advanced**: The `|` (pipe) operator is used to send the output of one command as input to another. Here, it sends the encrypted data to the client.

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c. `captureTraffic.sh`

This script captures network traffic between the client and server using `tcpdump`.

1. `tcpdump -i lo -w "$PCAP_FILE" "port $SERVER_PORT or port $CLIENT_PORT" &`
   - **Why**: This starts capturing network traffic on the loopback interface (`lo`) for the specified ports.
   - **What it does**: It saves the captured traffic to `PCAP_FILE` for later analysis.
   - **Advanced**: The `-i lo` flag specifies the loopback interface, and `-w` writes the output to a file. The `&` runs the command in the background.

2. `kill $(cat tcpdump.pid)`

- **Why**: This stops the `tcpdump` process.
- **What it does**: It ends the packet capture and saves the results.
- **Advanced**: The `kill` command terminates the process with the PID stored in `tcpdump.pid`.

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d. `genSecrets.sh`

This script generates the passphrase, initialization vector (IV), and AES key.

1. `echo "bhargavispass" > "$PASSPHRASE_FILE"`
   - **Why**: This creates a fixed passphrase for encryption.
   - **What it does**: It saves the passphrase to `PASSPHRASE_FILE`.
   - **Advanced**: A fixed passphrase is used for simplicity, but in a real-world scenario, a more secure method (e.g., random generation) should be used.
2. `openssl rand -hex 16 > "$IV_FILE"`
   - **Why**: This generates a random 16-byte IV for AES encryption.
   - **What it does**: It saves the IV to `IV_FILE`.
   - **Advanced**: The `openssl rand` command generates cryptographically secure random data.
3. `openssl rand -hex 32 > "$KEY_FILE"`
   - **Why**: This generates a random 32-byte key for AES-256 encryption.
   - **What it does**: It saves the key to `KEY_FILE`.
   - **Advanced**: The key is 32 bytes (256 bits), which is the required size for AES-256 encryption.

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2. Screenshots and Output Images

Screenshot 1: Running `genSecrets.sh`

- **Description**: This screenshot shows the output of running `genSecrets.sh`. It generates the passphrase, IV, and AES key, and saves them to their respective files.

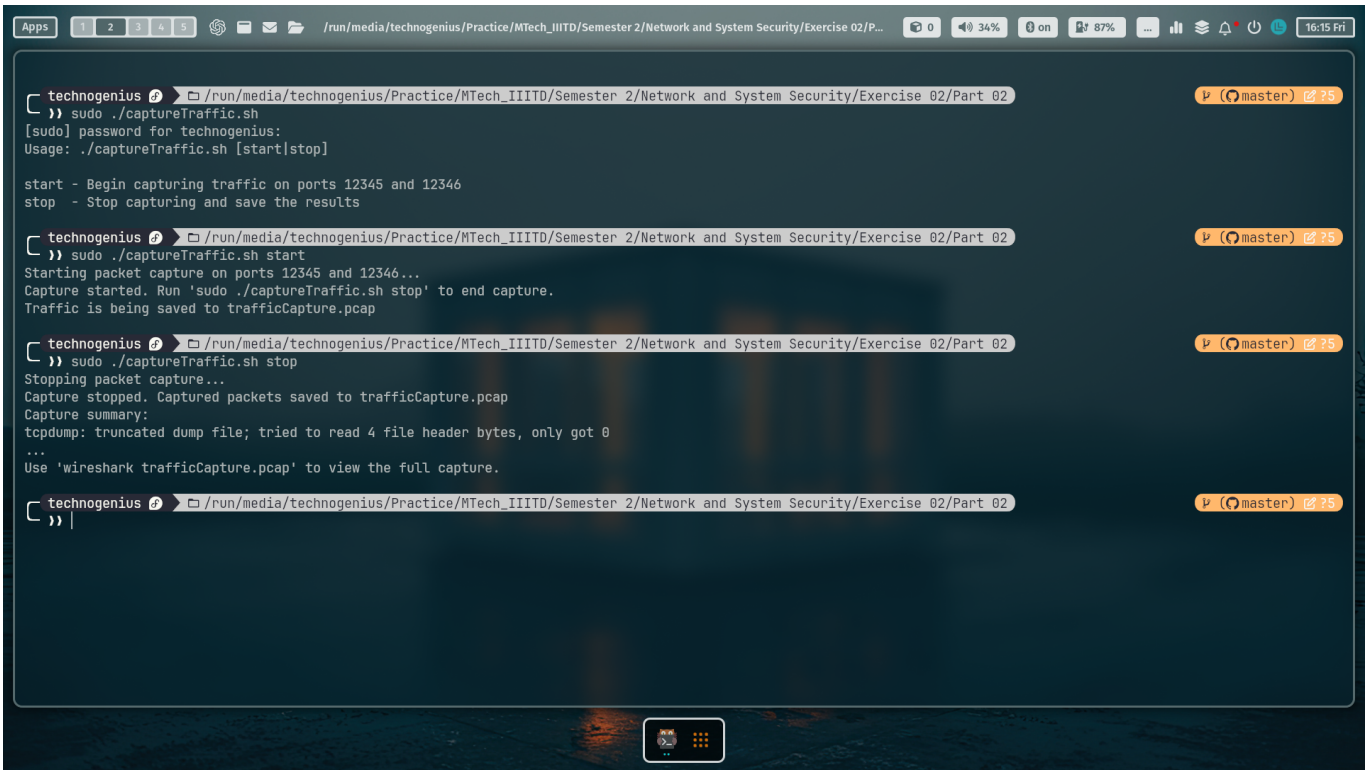
Screenshot 2: Running `aesServer.sh`

- **Description**: This screenshot shows the server starting and waiting for incoming connections on port `12345`.

Screenshot 3: Running `aesClient.sh`

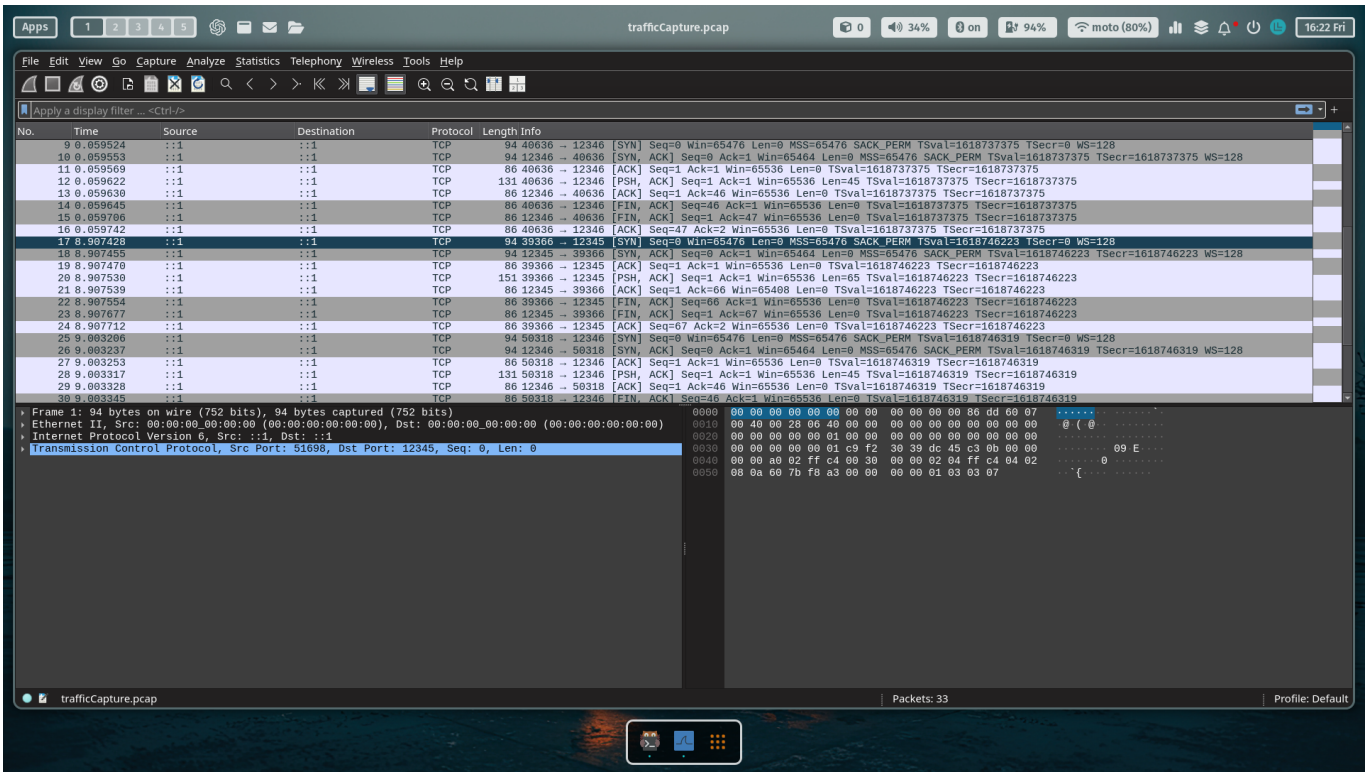
- **Description**: This screenshot shows the client sending an encrypted message to the server and receiving an encrypted response.

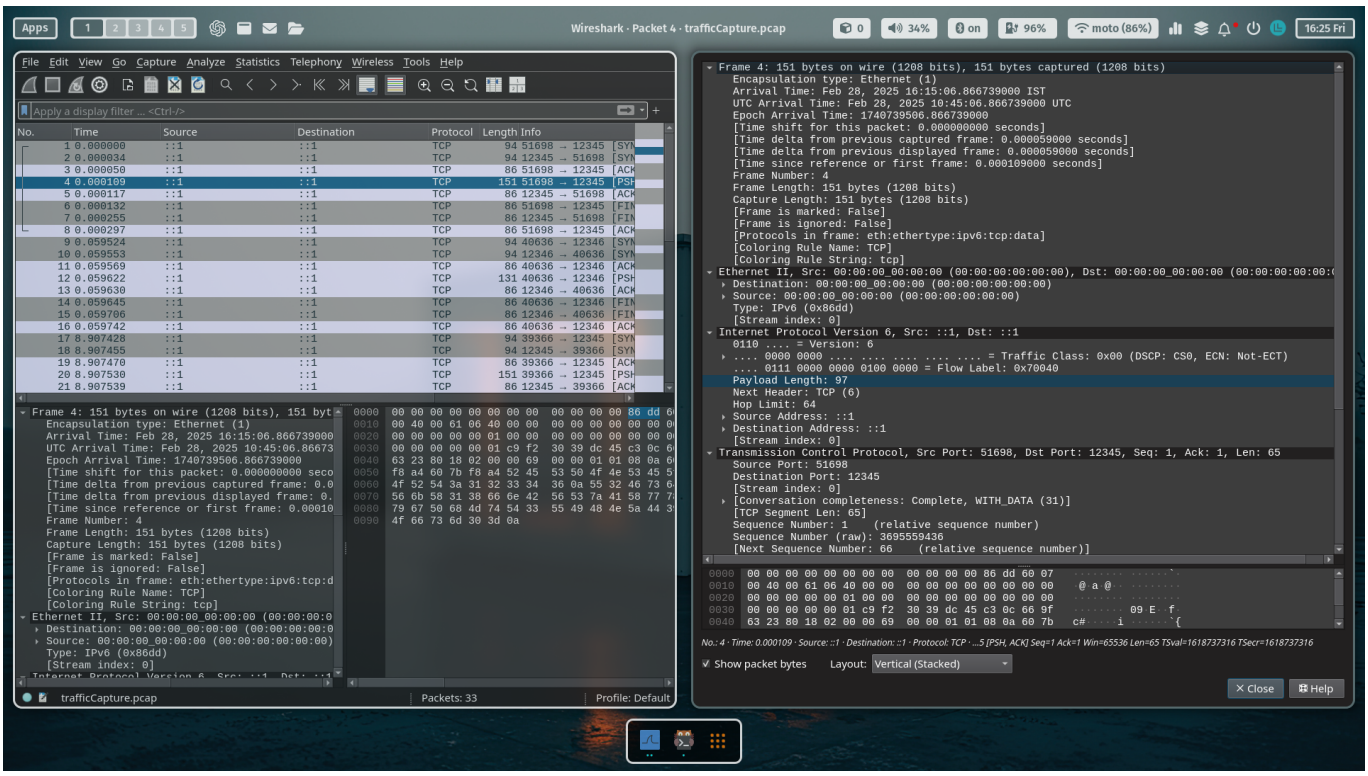
Screenshot 4: Capturing Traffic with `captureTraffic.sh`

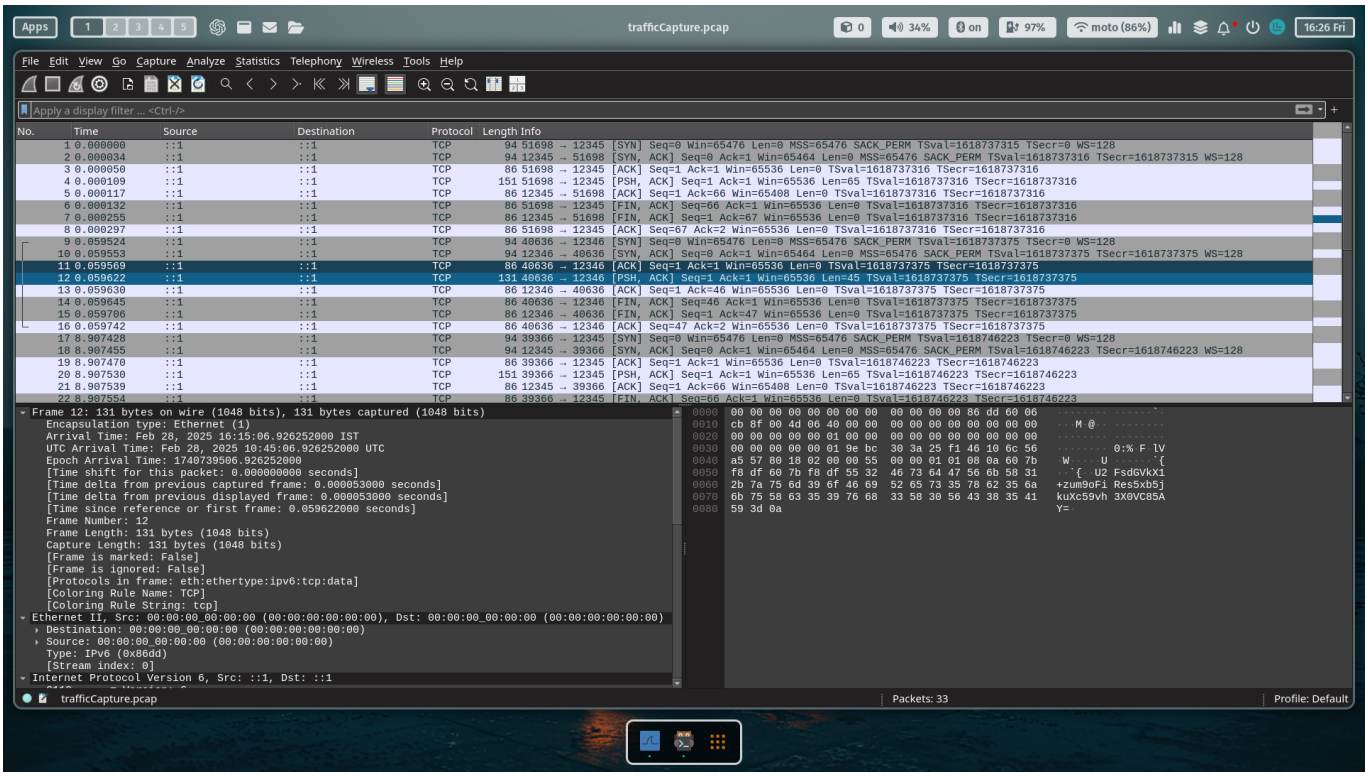


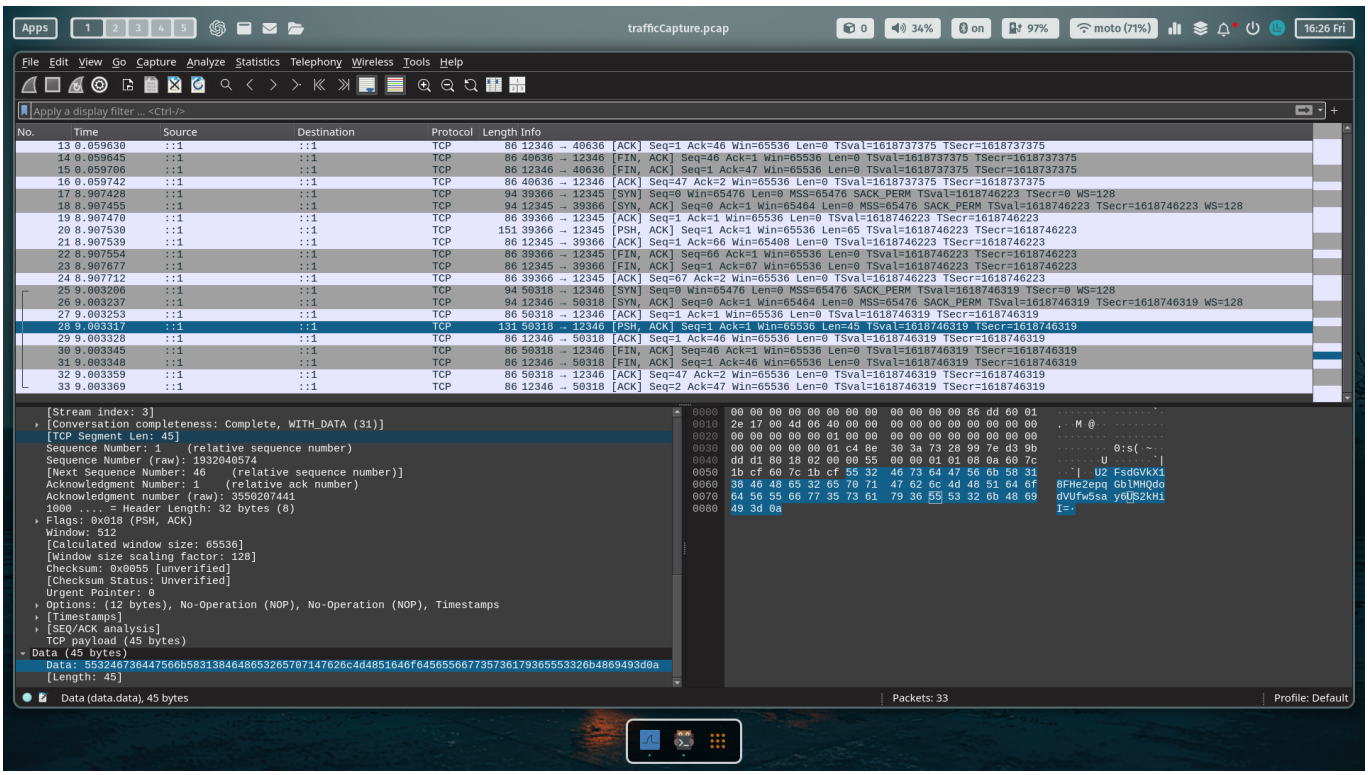
- **Description**: This screenshot shows the `tcpdump` process capturing traffic on ports `12345` and `12346`.

Screenshot 5: Wireshark Encrypted Traffic


trafficCapture.pcap
File Edit View Go Capture Analyze Statistics Telephony Wireless Tools Help
Apply a display filter ... <Ctrl-/>
No. Time Source Destination Protocol Length Info
Frame 1: 94 bytes on wire (752 bits), 94 bytes captured (752 bits)
Ethernet II, Src: 00:00:00_00:00:00 (00:00:00:00:00:00), Dst: 00:00:00_00:00:00 (00:00:00:00:00:00)
Internet Protocol Version 6, Src: ::1, Dst: ::1
Transmission Control Protocol, Src Port: 51698, Dst Port: 12345, Seq: 0, Len: 0
Packets: 33
Profile: Default


Wireshark · Packet 4 · trafficCapture.pcap
File Edit View Go Capture Analyze Statistics Telephony Wireless Tools Help
Apply a display filter ... <Ctrl-/>
No. Time Source Destination Protocol Length Info
Frame 4: 151 bytes on wire (1208 bits), 151 bytes captured (1208 bits)
Encapsulation type: Ethernet (1)
Arrival Time: Feb 28, 2025 16:15:06.866739000 IST
UTC Arrival Time: Feb 28, 2025 10:45:06.866739000 UTC
Epoch Arrival Time: 1740739506.866739000
[Time shift for this packet: 0.000000000 seconds]
[Time delta from previous captured frame: 0.000059000 seconds]
[Time delta from previous displayed frame: 0.000059000 seconds]
[Time since reference or first frame: 0.000109000 seconds]
Frame Number: 4
Frame Length: 151 bytes (1208 bits)
Capture Length: 151 bytes (1208 bits)
[Frame is marked: False]
[Frame is ignored: False]
[Protocols in frame: eth:ethertype:ipv6:tcp:data]
[Coloring Rule Name: TCP]
[Coloring Rule String: tcp]
Ethernet II, Src: 00:00:00_00:00:00 (00:00:00:00:00:00), Dst: 00:00:00_00:00:00 (00:00:00:00:00:00)
Destination: 00:00:00_00:00:00 (00:00:00:00:00:00)
Source: 00:00:00_00:00:00 (00:00:00:00:00:00)
Type: IPv6 (0x86dd)
[Stream index: 0]
Internet Protocol Version 6, Src: ::1, Dst: ::1
0110 .... = Version: 6
.... 0000 0000 .... = Traffic Class: 0x00 (DSCP: CS0, ECN: Not-ECT)
.... 0111 0000 0000 0100 0000 = Flow Label: 0x70040
Payload Length: 97
Next Header: TCP (6)
Hop Limit: 64
Source Address: ::1
Destination Address: ::1
[Stream index: 0]
Transmission Control Protocol, Src Port: 51698, Dst Port: 12345, Seq: 1, Ack: 1, Len: 65
Source Port: 51698
Destination Port: 12345
[Stream index: 0]
[Conversation completeness: Complete, WITH_DATA (31)]
[TCP Segment Len: 65]
Sequence Number: 1 (relative sequence number)
Sequence Number (raw): 3695559436
[Next Sequence Number: 66 (relative sequence number)]
No.: 4 · Time: 0.000109 · Source: ::1 · Destination: ::1 · Protocol: TCP · ...5 [PSH, ACK] Seq=1 Ack=1 Win=65536 Len=65 TSval=1618737316 TSecr=1618737316
Show packet bytes
Layout: Vertical (Stacked)
Close
Help
trafficCapture.pcap
Packets: 33
Profile: Default





- **Description**: This screenshot shows the encrypted traffic in Wireshark. The data appears as random bytes, confirming that the communication is encrypted.

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3. Encrypted Traffic in Wireshark

- **Screenshot**: Wireshark showing encrypted traffic between the client and server on ports 12345 and 12346.
- **Explanation**: The traffic is encrypted, so the data appears as random bytes. This confirms that the communication is secure.

Conclusion

This exercise demonstrates how to use OpenSSL for AES encryption, netcat for communication, and `tcpdump` for traffic capture. The client and server exchange encrypted messages, and the traffic is confirmed to be encrypted using Wireshark. This setup is a basic example of secure communication using symmetric encryption, but it can be extended with more advanced features like key rotation, secure key exchange, and more.