Comparing HTTP, CoAP, and MQTT Protocols

Course Title: Internet of Things

Course Code: CSE 406

Section: 01

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Title: Comparing HTTP, CoAP, and MQTT Protocols

1. Introduction

The Internet of Things (IoT) operates under strict resource constraints, such as limited bandwidth, power, and computational capacity. To address these challenges, efficient communication protocols are crucial. In this lab, we compare three communication protocols commonly used in IoT: HTTP, CoAP, and MQTT. These protocols were implemented using NodeMCU ESP8266 microcontrollers and Python scripts. The main objective is to evaluate the performance of these protocols in terms of packet size, efficiency, transport mechanisms, and their suitability for IoT applications. Network traffic was captured and analyzed using Wireshark to measure packet sizes, header sizes, and payload details.

2. Procedure Summary

2.1. Hardware Setup:

- **NodeMCU ESP8266 Microcontrollers:** These low-cost WiFi boards were used to implement the protocols. Each board was programmed to run one of the communication protocols: HTTP, CoAP, or MQTT.
- **Wi-Fi Network:** All devices and servers were connected to a common Wi-Fi network, ensuring proper communication between the ESP8266 and the servers.
- **External Devices (optional):** Sensors or LEDs could be connected to the ESP8266, though for this experiment, the code was set up with hardcoded values (e.g., temperature, humidity) for simplicity.

2.2. Software Setup:

- **Arduino IDE:** The Arduino IDE was used for writing and uploading code to the NodeMCU ESP8266. Required libraries like ESP8266WiFi, PubSubClient, and coap-simple were included.
- **Visual Studio Code (VS Code):** Used for Python development, particularly for the Flask server (main.py) and CoAP client (CoapClient.py).
- **Python 3:** Libraries such as aiocoap (for CoAP) and flask (for HTTP) were installed via pip.

- **Wireshark:** This tool was used for packet capture and analysis. It allowed filtering and examination of the network traffic generated by the protocols.

2.3. Task Breakdown:

- **Task 1: Setup and Packet Capture**
    - The software was configured to run on NodeMCU ESP8266 for all three protocols: HTTP, CoAP, and MQTT.
    - The Flask server (main.py) was run on a Python machine, which accepted HTTP requests. For CoAP, the CoAP server was run on NodeMCU, while for MQTT, a local or cloud MQTT broker (e.g., HiveMQ) was used.
    - Wireshark was employed to capture the network traffic, allowing analysis of request/response packets for each protocol.
- **Task 2: Analyze Packet Details**
    - Captured packets were analyzed for each protocol (GET, PUT, PUBLISH) to measure the total packet size, header size, and payload size.
- **Task 3: Comparison**
    - A comparative analysis was done based on packet sizes, header sizes, payload sizes, and other protocol-specific details (e.g., transport layer, overhead).

3. Tools Used:

- **Wireshark:** Essential for capturing and analyzing the network traffic generated by HTTP, CoAP, and MQTT protocols.
- **Arduino IDE:** Used for programming the NodeMCU ESP8266 boards with the required protocol implementations.
- **Visual Studio Code:** A versatile code editor used for writing Python scripts, including the Flask server (main.py) and CoAP client (CoapClient.py).
- **Python:** Used for creating the REST server and CoAP client to interact with the ESP8266 boards. Python libraries like flask and aiocoap were used for handling HTTP and CoAP protocols, respectively.

4. Setup:

- **NodeMCU ESP8266:** Configured to run HTTP, CoAP, and MQTT protocols based on the provided code examples.

- **Network Configuration:** ESP8266 was connected to the Wi-Fi network, and server IP addresses were updated in the corresponding code files (e.g., CoapClient.py, CSE406_HTTPbasicClient.ino).
- **Wireshark Capture:** The tool was used to capture network traffic for each protocol. Filters such as http, udp.port = 5683 (for CoAP), and tcp.port = 8883 (for MQTT) were applied to isolate the relevant packets.

5. Results and Analysis

5.1. Analysis

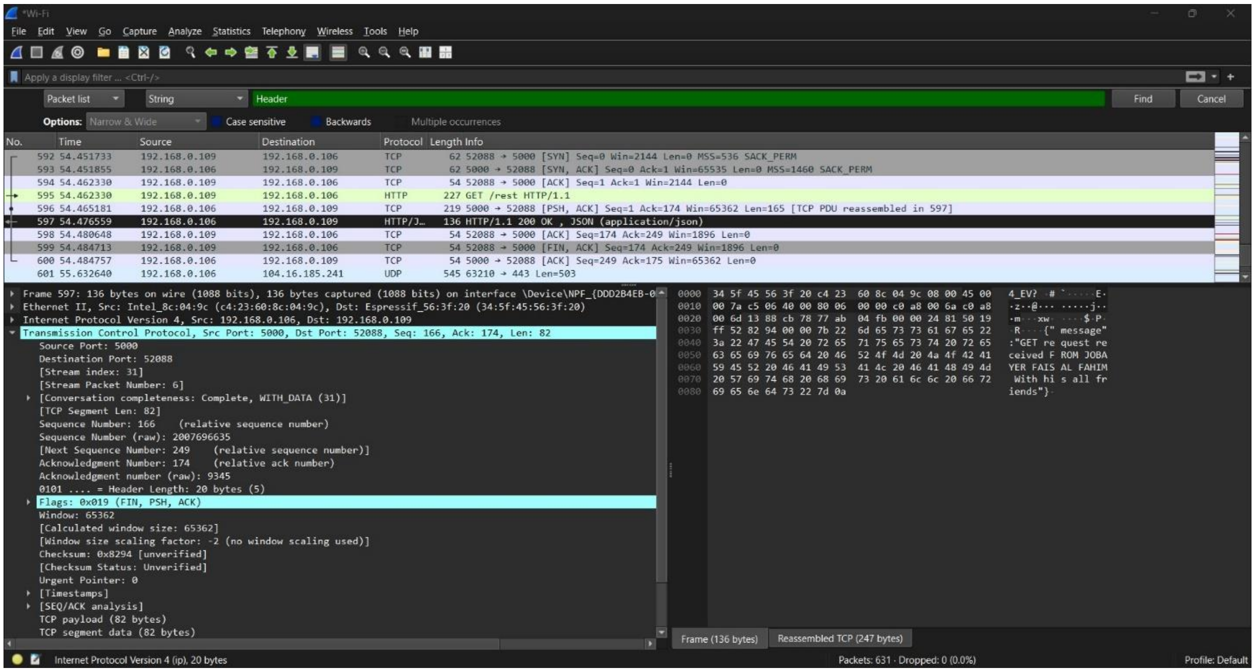
- **HTTP Protocol (GET Request):**
  - HTTP packets had a larger size due to verbose headers, such as the Host, Content-Length, and Accept fields.
  - The total packet size was considerably larger compared to CoAP and MQTT, reflecting the protocol's resource-heavy nature.

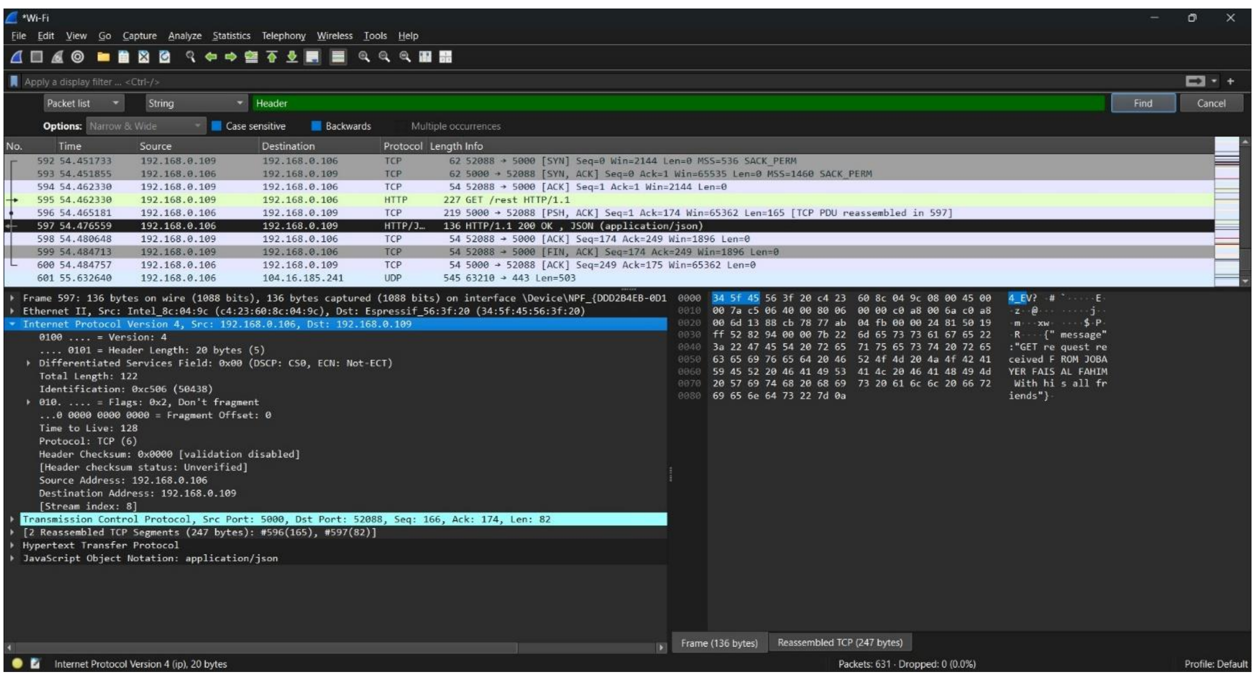
Output:

```
WiFi connected
IP address:
192.168.0.109
[HTTP] begin...
[HTTP] GET...
[HTTP] GET... code: 200
[HTTP] GET... code: 200
{"message":"GET request received FROM JOBAYER FAISAL FAHIM With his all friends"}


WiFi connected
IP address:
192.168.0.109
[HTTP] begin...
[HTTP] GET...
[HTTP] GET... code: 200
[HTTP] GET... code: 200
{"message":"GET request received FROM JOBAYER FAISAL FAHIM With his all friends"}
```

170	16.504409	192.168.0.109	192.168.0.106	TCP	62	55083 → 5000 [SYN] Seq=0 Win=2144 Len=0 MSS=536 SACK_PERM
171	16.504507	192.168.0.106	192.168.0.109	TCP	62	5000 → 55083 [SYN, ACK] Seq=0 Ack=1 Win=65535 Len=0 MSS=1460 SACK_PERM
172	16.508080	192.168.0.109	192.168.0.106	TCP	54	55083 → 5000 [ACK] Seq=1 Ack=1 Win=2144 Len=0
173	16.510470	192.168.0.109	192.168.0.106	HTTP	227	GET /rest HTTP/1.1
174	16.511439	192.168.0.106	192.168.0.109	TCP	219	5000 → 55083 [PSH, ACK] Seq=1 Ack=174 Win=65362 Len=165 [TCP PDU reassembled in 175]
175	16.529244	192.168.0.106	192.168.0.109	HTTP/J…	115	HTTP/1.1 200 OK , JSON (application/json)
176	16.541513	192.168.0.109	192.168.0.106	TCP	54	55083 → 5000 [ACK] Seq=174 Ack=228 Win=1917 Len=0
177	16.541513	192.168.0.109	192.168.0.106	TCP	54	55083 → 5000 [FIN, ACK] Seq=174 Ack=228 Win=1917 Len=0
178	16.542008	192.168.0.106	192.168.0.109	TCP	54	5000 → 55083 [ACK] Seq=228 Ack=175 Win=65362 Len=0
179	19.689822	192.168.0.106	104.16.185.241	UDP	540	63210 → 443 Len=498
180	19.692564	104.16.185.241	192.168.0.106	UDP	67	443 → 63210 Len=25
181	19.701399	104.16.185.241	192.168.0.106	UDP	223	443 → 63210 Len=181


*Wi-Fi
File Edit View Go Capture Analyze Statistics Telephony Wireless Tools Help
Apply a display filter ... <Ctrl-/>
Packet list
String
Header
Find
Cancel
Options: Narrow & Wide
Case sensitive
Backwards
Multiple occurrences
No. Time Source Destination Protocol Length Info
592 54.451733 192.168.0.109 192.168.0.106 TCP 62 52088 → 5000 [SYN] Seq=0 Win=2144 Len=0 MSS=536 SACK_PERM
593 54.451855 192.168.0.106 192.168.0.109 TCP 62 5000 → 52088 [SYN, ACK] Seq=0 Ack=1 Win=65535 Len=0 MSS=1460 SACK_PERM
594 54.462330 192.168.0.109 192.168.0.106 TCP 54 52088 → 5000 [ACK] Seq=1 Ack=1 Win=2144 Len=0
595 54.462330 192.168.0.109 192.168.0.106 HTTP 227 GET /rest HTTP/1.1
596 54.465181 192.168.0.106 192.168.0.109 TCP 219 5000 → 52088 [PSH, ACK] Seq=1 Ack=174 Win=65362 Len=165 [TCP PDU reassembled in 597]
597 54.476559 192.168.0.106 192.168.0.109 HTTP/J… 136 HTTP/1.1 200 OK , JSON (application/json)
598 54.480648 192.168.0.109 192.168.0.106 TCP 54 52088 → 5000 [ACK] Seq=174 Ack=249 Win=1896 Len=0
599 54.484713 192.168.0.109 192.168.0.106 TCP 54 52088 → 5000 [FIN, ACK] Seq=174 Ack=249 Win=1896 Len=0
600 54.484757 192.168.0.106 192.168.0.109 TCP 54 5000 → 52088 [ACK] Seq=249 Ack=175 Win=65362 Len=0
601 55.632640 192.168.0.106 104.16.185.241 UDP 545 63210 → 443 Len=503
Frame 597: 136 bytes on wire (1088 bits), 136 bytes captured (1088 bits) on interface \Device\NPF_{DDD2B4EB-0
Ethernet II, Src: Intel_8c:04:9c (c4:23:60:8c:04:9c), Dst: Espressif_56:3f:20 (34:5f:45:56:3f:20)
Internet Protocol Version 4, Src: 192.168.0.106, Dst: 192.168.0.109
Transmission Control Protocol, Src Port: 5000, Dst Port: 52088, Seq: 166, Ack: 174, Len: 82
Source Port: 5000
Destination Port: 52088
[Stream index: 31]
[Stream Packet Number: 6]
[Conversation completeness: Complete, WITH_DATA (31)]
[TCP Segment Len: 82]
Sequence Number: 166 (relative sequence number)
Sequence Number (raw): 2007696635
[Next Sequence Number: 249 (relative sequence number)]
Acknowledgment Number: 174 (relative ack number)
Acknowledgment number (raw): 9345
0101 .... = Header Length: 20 bytes (5)
Flags: 0x019 (FIN, PSH, ACK)
Window: 65362
[Calculated window size: 65362]
[Window size scaling factor: -2 (no window scaling used)]
Checksum: 0x8294 [unverified]
[Checksum Status: Unverified]
Urgent Pointer: 0
[Timestamps]
[SEQ/ACK analysis]
TCP payload (82 bytes)
TCP segment data (82 bytes)
0000 34 5f 45 56 3f 20 c4 23 60 8c 04 9c 08 00 45 00
0010 00 7a c5 06 40 00 80 06 00 00 c0 a8 00 6a c0 a8
0020 00 6d 13 88 cb 78 77 ab 04 fb 00 00 24 81 50 19
0030 ff 52 82 94 00 00 7b 22 6d 65 73 73 61 67 65 22
0040 3a 22 47 45 54 20 72 65 71 75 65 73 74 20 72 65
0050 63 65 69 76 65 64 20 46 52 4f 4d 20 4a 4f 42 41
0060 59 45 52 20 46 41 49 53 41 4c 20 46 41 48 49 4d
0070 20 57 69 74 68 20 68 69 73 20 61 6c 6c 20 66 72
0080 69 65 6e 64 73 22 7d 0a
{" message"
:"GET re quest re
ceived F ROM JOBA
YER FAIS AL FAHIM
With hi s all fr
iends"}
Frame (136 bytes)
Reassembled TCP (247 bytes)
Internet Protocol Version 4 (ip), 20 bytes
Packets: 631 · Dropped: 0 (0.0%)
Profile: Default


*Wi-Fi
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Packet list
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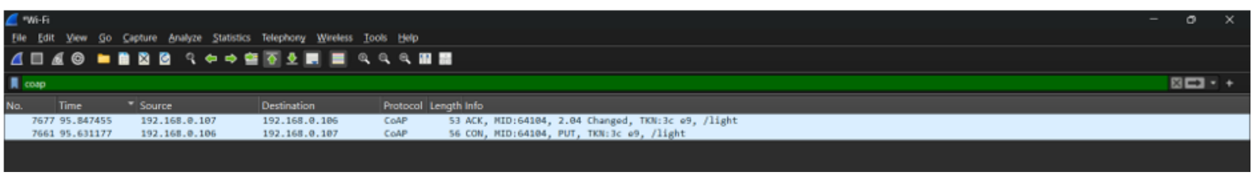
No. Time Source Destination Protocol Length Info
592 54.451733 192.168.0.109 192.168.0.106 TCP 62 52088 → 5000 [SYN] Seq=0 Win=2144 Len=0 MSS=536 SACK_PERM
593 54.451855 192.168.0.106 192.168.0.109 TCP 62 5000 → 52088 [SYN, ACK] Seq=0 Ack=1 Win=65535 Len=0 MSS=1460 SACK_PERM
594 54.462330 192.168.0.109 192.168.0.106 TCP 54 52088 → 5000 [ACK] Seq=1 Ack=1 Win=2144 Len=0
595 54.462330 192.168.0.109 192.168.0.106 HTTP 227 GET /rest HTTP/1.1
596 54.465181 192.168.0.106 192.168.0.109 TCP 219 5000 → 52088 [PSH, ACK] Seq=1 Ack=174 Win=65362 Len=165 [TCP PDU reassembled in 597]
597 54.476559 192.168.0.106 192.168.0.109 HTTP/J… 136 HTTP/1.1 200 OK , JSON (application/json)
598 54.480648 192.168.0.109 192.168.0.106 TCP 54 52088 → 5000 [ACK] Seq=174 Ack=249 Win=1896 Len=0
599 54.484713 192.168.0.109 192.168.0.106 TCP 54 52088 → 5000 [FIN, ACK] Seq=174 Ack=249 Win=1896 Len=0
600 54.484757 192.168.0.106 192.168.0.109 TCP 54 5000 → 52088 [ACK] Seq=249 Ack=175 Win=65362 Len=0
601 55.632640 192.168.0.106 104.16.185.241 UDP 545 63210 → 443 Len=503
Frame 597: 136 bytes on wire (1088 bits), 136 bytes captured (1088 bits) on interface \Device\NPF_{DDD2B4EB-0D1
Ethernet II, Src: Intel_8c:04:9c (c4:23:60:8c:04:9c), Dst: Espressif_56:3f:20 (34:5f:45:56:3f:20)
Internet Protocol Version 4, Src: 192.168.0.106, Dst: 192.168.0.109
0100 .... = Version: 4
.... 0101 = Header Length: 20 bytes (5)
Differentiated Services Field: 0x00 (DSCP: CS0, ECN: Not-ECT)
Total Length: 122
Identification: 0xc506 (50438)
010. .... = Flags: 0x2, Don't fragment
...0 0000 0000 0000 = Fragment Offset: 0
Time to Live: 128
Protocol: TCP (6)
Header Checksum: 0x0000 [validation disabled]
[Header checksum status: Unverified]
Source Address: 192.168.0.106
Destination Address: 192.168.0.109
[Stream index: 8]
Transmission Control Protocol, Src Port: 5000, Dst Port: 52088, Seq: 166, Ack: 174, Len: 82
[2 Reassembled TCP Segments (247 bytes): #596(165), #597(82)]
Hypertext Transfer Protocol
JavaScript Object Notation: application/json
0000 34 5f 45 56 3f 20 c4 23 60 8c 04 9c 08 00 45 00
0010 00 7a c5 06 40 00 80 06 00 00 c0 a8 00 6a c0 a8
0020 00 6d 13 88 cb 78 77 ab 04 fb 00 00 24 81 50 19
0030 ff 52 82 94 00 00 7b 22 6d 65 73 73 61 67 65 22
0040 3a 22 47 45 54 20 72 65 71 75 65 73 74 20 72 65
0050 63 65 69 76 65 64 20 46 52 4f 4d 20 4a 4f 42 41
0060 59 45 52 20 46 41 49 53 41 4c 20 46 41 48 49 4d
0070 20 57 69 74 68 20 68 69 73 20 61 6c 6c 20 66 72
0080 69 65 6e 64 73 22 7d 0a
4_EV?
{" message"
:"GET re quest re
ceived F ROM JOBA
YER FAIS AL FAHIM
With hi s all fr
iends"}
Frame (136 bytes)
Reassembled TCP (247 bytes)
Internet Protocol Version 4 (ip), 20 bytes
Packets: 631 · Dropped: 0 (0.0%)
Profile: Default

- ❖ **CoAP Protocol (PUT Request):**
  - ➢ CoAP packets were much more compact, using binary headers and a lightweight structure. The fixed header size (4 bytes) and minimal options reduced the total packet size.

Output:

```
[Light] Request received.
Payload received: 1
Instruction:
[Light] Request received.
Payload received: 1
Instruction:
[Light] Request received.
Payload received: 1
Instruction:
[Light] Request received.
Payload received: 1
Instruction:
[Light] Request received.
Payload received: 1
Instruction: Turn ON
```



```
Frame 7677: 53 bytes on wire (424 bits), 53 bytes captured (424 bits) on interface \Device\NPF_{DDD2B4EB-0D1C
    Section number: 1
    Interface id: 0 (\Device\NPF_{DDD2B4EB-0D1C-42DD-A7BE-6E4B4FDE874F})
    Encapsulation type: Ethernet (1)
    Arrival Time: Aug 17, 2025 23:02:38.276243000 Bangladesh Standard Time
    UTC Arrival Time: Aug 17, 2025 17:02:38.276243000 UTC
    Epoch Arrival Time: 1755450158.276243000
    [Time shift for this packet: 0.000000000 seconds]
    [Time delta from previous captured frame: 0.003975000 seconds]
    [Time delta from previous displayed frame: 0.216278000 seconds]
    [Time since reference or first frame: 95.847455000 seconds]
    Frame Number: 7677
    Frame Length: 53 bytes (424 bits)
    Capture Length: 53 bytes (424 bits)
    [Frame is marked: False]
    [Frame is ignored: False]
    [Protocols in frame: eth:ethertype:ip:udp:coap:data]
    [Coloring Rule Name: UDP]
    [Coloring Rule String: udp]
Ethernet II, Src: Espressif_56:3f:20 (34:5f:45:56:3f:20), Dst: Intel_8c:04:9c (c4:23:60:8c:04:9c)
    Destination: Intel_8c:04:9c (c4:23:60:8c:04:9c)
    Source: Espressif_56:3f:20 (34:5f:45:56:3f:20)
    Type: IPv4 (0x0800)
    [Stream index: 14]
Internet Protocol Version 4, Src: 192.168.0.107, Dst: 192.168.0.106
    0100 .... = Version: 4
    .... 0101 = Header Length: 20 bytes (5)
    Differentiated Services Field: 0x00 (DSCP: CS0, ECN: Not-ECT)
    Total Length: 39
    Identification: 0x0003 (3)
    000. .... = Flags: 0x0
    ...0 0000 0000 0000 = Fragment Offset: 0
    Time to Live: 255
    Protocol: UDP (17)
    Header Checksum: 0x399d [validation disabled]
    [Header checksum status: Unverified]
    Source Address: 192.168.0.107
    Destination Address: 192.168.0.106
    [Stream index: 23]
```

```
User Datagram Protocol, Src Port: 5683, Dst Port: 53371
    Source Port: 5683
    Destination Port: 53371
    Length: 19
    Checksum: 0xdf5c [unverified]
    [Checksum Status: Unverified]
    [Stream index: 50]
    [Stream Packet Number: 2]
    [Timestamps]
    UDP payload (11 bytes)
Constrained Application Protocol, Acknowledgement, 2.04 Changed, MID:64104
    01.. .... = Version: 1
    ..10 .... = Type: Acknowledgement (2)
    .... 0010 = Token Length: 2
    Code: 2.04 Changed (68)
    Message ID: 64104
    Token: 3ce9
    Opt Name: #1: Content-Format: application/octet-stream
    End of options marker: 255
    Payload: Payload Content-Format: application/octet-stream, Length: 1
    [Uri-Path: /light]
    [Request In: 7661]
    [Response Time: 0.216278000 seconds]
Data (1 byte)
    Data: 31
    [Length: 1]
```

❖ **MQTT Protocol (PUBLISH):**

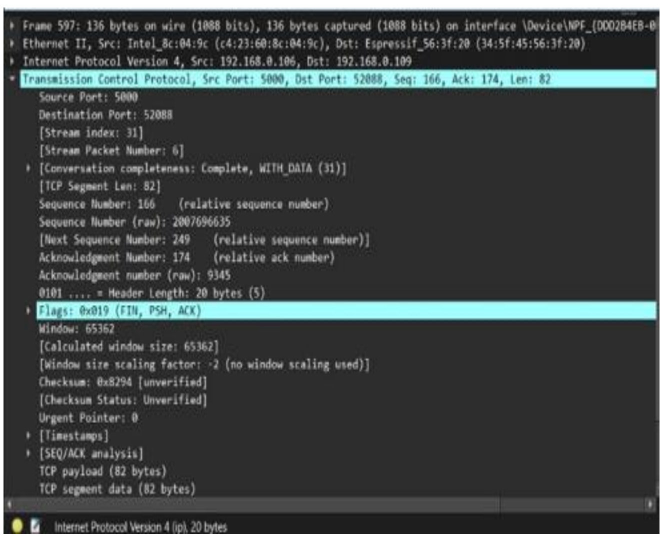
   ➢ MQTT's packet sizes were smaller than HTTP but larger than CoAP. MQTT's fixed header size (1–2 bytes) and its minimalistic approach made it highly efficient for constrained environments.

5.2. Comparative Analysis

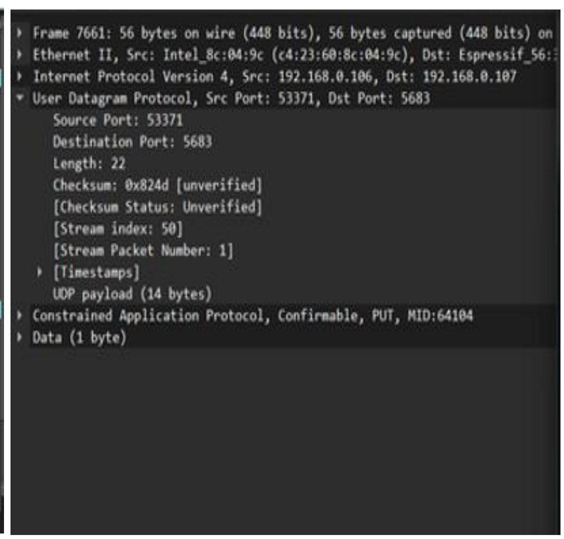
Protocol	Request Type	Total Packet Size (bytes)	Header Size (bytes)	Payload Size (bytes)	Key Details
HTTP	GET	136	20	82	Verbose headers, TCP-based
CoAP	PUT	56	8	14	Lightweight, UDP-based
MQTT	PUBLISH	--	--	--	Small header, Pub/Sub model

Reference:

HTTP



CoAP



6. Pros and Cons of Each Protocol:

6.1. HTTP:

- **Pros:**
  - Well-established and widely used in web communication.
  - Simple request/response model.
  - Mature libraries and tools.
- **Cons:**
  - Large header size increases overhead.
  - TCP-based, making it slower compared to UDP.
  - Not ideal for constrained devices or networks.

6.2. CoAP:

- **Pros:**
  - Lightweight, using binary headers, and efficient for low-power, low-bandwidth devices.
  - UDP-based, providing faster transmission with less overhead.
  - Well-suited for simple IoT applications (e.g., device control).
- **Cons:**
  - UDP lacks built-in reliability, which may cause data loss in some cases.
  - Fewer tools and libraries compared to HTTP.

6.3. MQTT:

- **Pros:**
  - Efficient, minimal header size.

- Suitable for large-scale IoT networks with many devices.
- Pub/Sub model allows easy scalability and management of many-to-many communication.

- **Cons:**
    - Requires a central broker, introducing a potential single point of failure.
    - Overhead due to TCP, though smaller compared to HTTP.

7. Conclusion

The lab successfully compared three communication protocols - HTTP, CoAP, and MQTT - focusing on their efficiency and suitability for IoT applications. While HTTP is reliable and widely used, it is not the most efficient for resource-constrained devices. CoAP and MQTT offer more efficient alternatives, with CoAP excelling in constrained environments due to its lightweight design and UDP transport, while MQTT shines in scalable, large-scale networks due to its pub/sub model and low overhead. The choice of protocol depends on specific use cases, with MQTT being ideal for sensor networks and CoAP suited for simple device control.