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Performance Analysis of QoS for the MQTT-SN Protocol with Industry Oriented MQTT-SN Gateway and Integration with Cloud MQTT-Server, IOT-Application

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Abstract

Internet is a global communication network to provide various services like file transfer, email and other services using various heterogeneous application messaging protocol HTTP, MQTT, COAP, DDS,AMQP. Each of this application messaging protocols are designed and implemented as per different application requirements considering the computational resources and available communication bandwidth. These protocols are not suitable for constrained sensor devices due to limitation of computational power and bandwidth. MQTT protocol is designed and implemented for Machine to Machine communication, but still not suitable for low power sensor devices. More Efficient MQTT-SN protocol is (Message Queue Telemetry Transport-Sensor Network) proposed for sensor devices considering the wireless sensor network characteristics, power constraint and bandwidth limitations. In this paper we discussed MQTT-SN protocol important features,MQTT-SN QOS impact analysis for the IOT applications, End to End delay(Sensor Node to IOT Application) calculations, message overhead analysis for MQTT-SN,MQTT,COAP protocols andMQTT-SN Gateway Integration with Industry oriented Cloud MQTT-Server.

Keywords*— IOT, MQTT-SN, TCP, UDP, MQTT, HTTP, COAP, WIRESHARK*

I. INTRODUCTION

Current wireless sensor networks are designed and developed for various applications like home automation, smart cities,environmental monitoring ,structural health monitoring etc using either preparatory application messaging protocols or incompatible protocols with current wide spread internet communication protocols. Currently various application messaging protocols are designed and developed for internet communication like MQTT, COAP, XMPP, DDS and HTTP. These protocols are not suitable for constrained sensor devices due to low power and bandwidth limitation. More Efficient Application protocol needed for sensor devices considering lossy wireless network, low power and bandwidth limitation. Message Queue Telemetry Transport -Sensor Network (MQTT-SN) protocol is right choice protocol for Sensor Devices due to Low message overhead compared other available messaging protocols. MQTT-Message Queue Telemetry Transport protocol designed and developed for machine to machine communication .MQTT is light weight protocol, but underlying transportation mechanism used as TCP/IP. TCP transport protocol too complex for low power sensor devices. MQTT-SN uses UPD/IP Transport communication protocol .UDP is light weight compared with TCP/IP.As Per [1] MQTT-SN full detailed design specification is mentioned .some of the MQTT-SN important features are discussed in Section III.As per [2], Theoretical comparison of IOT messaging protocols are discussed in terms message overhead, throughput and bandwidth. As per [3] MQTT-SN End to End delayperformance simulated using NS-2 Simulator. The organization of the paper as follows: In Section II, IOT Architecture [Sensor Node, IOT Gateway, MQTT Server, and IOT Application] is explained. Section III discusses import MQTT-SN protocol features, MQTT-SN messages description, MQTT-SN QoS model and MQTT-SN Topic management, message flows for different QoS. In Section IV discussesIOT application development process. In Section V discusses Experimental setup hardware and Message overhead, End to end Delay analysis, message loss analysis. In Section VI, Important trace logs are

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discussed for all nodes (Sensor Device, IOT Gateway, MQTT Server, and IOT Application). In Section VII results and conclusions are explained.

II. IOT SYSTEM ARCHITECTURE

Overall IOT System architecture shown in Fig -01

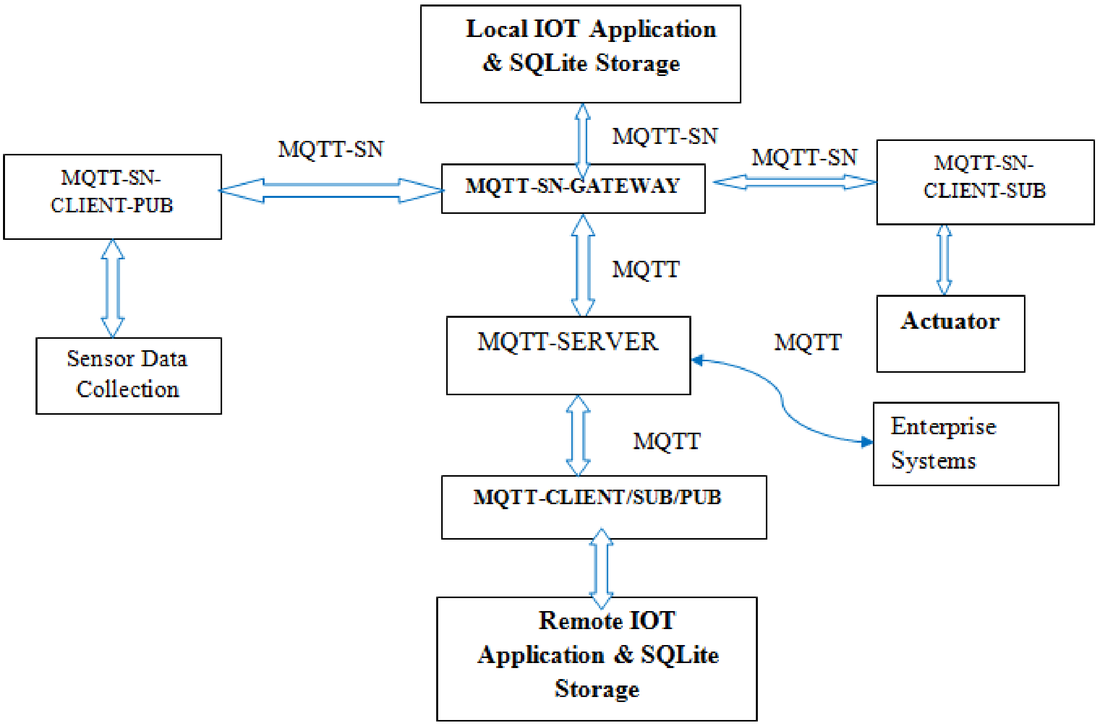

Fig 01: IOT System architecture

A. Sensor Node Platform

Sensor devices capture the sensor data with predefined time interval. Sensor Node platform pack the sensor data with the JSON data format and Publish Packed sensor data to the IOT MQTT-SN Gateway with pre-configured time interval. Sensor Node platform as shown in Fig-02

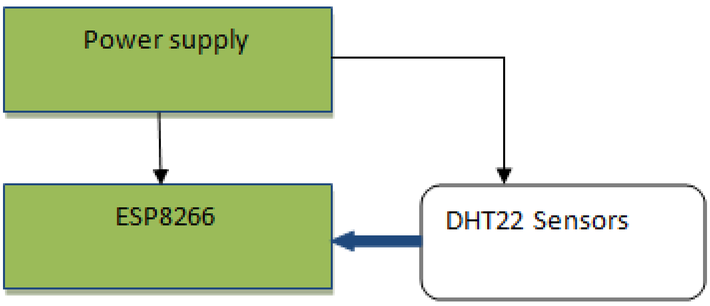

Fig 02: Sensor Node IOT platform

B. MQTT-SN Gateway

MQTT-SN Gateway is crucial computing Node in the IOT Architecture. Main function of MQTT-SN Gateway is receives the MQTT-SN messages from sensor devices and Translate to the MQTT Messages as per MQTT Protocol specifications. MQTT-SN (Message Queue Telemetry

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Transport-Sensor Network) and MQTT protocols are different protocols, but it is closely related. MQTT-Gateway designed and developed with four multi-threaded tasks-MQTT-SN Receiver Task, MQTT-SN Sender Task, MQTT Sender Task, MQTT Receiver Task and Event Queue Manager.

MQTT-SN Receiver Task: It receives MQTT-SN messages from sensor devices, decode the messages and store the message parameters in the Event Queue Manager for sending to the MQTT-Server and also maintain MQTT-SN Receiver Process State machine.

MQTT Sender Task: It takes the MQTT-SN parameters from the Event Queue Manager and Encode to the MQTT Messages, send to the MQTT-Server as per MQTT Protocol Specification and maintain the **MQTT Sender Process State machine.**

MQTT Receiver Task: It receives MQTT messages, decode the MQTT Messages and store the relevant message parameters in the event queue manager.

MQTT-SN Sender Task: It takes the MQTT parameters from the event queue manager and encode to the MQTT-SN Messages, send to the sensor IOT Platform as per MQTT-SN Protocol Specification and maintain the **MQTT-SN Sender process state machine.**

Gatewayprotocol software process diagram as shown in Fig -03

*C. **MQTT Server***

MQTT- Message Queue Telemetry Transport protocol is light weight protocol designed and developed for machine to machine communication devices.MQTT Server receives the publish messages from the MQTT-SN Gateway and publishes the messages to the Subscribed devices. Publish and subscribe Mechanism is an asynchronous process. In this project MQTT-MOSQUITTO server used for Gateway integration.

*D. **IOT Application***

IOT Application is any type of application for taking appropriate action, control the actuator devices and monitoring sensor/actuator devices. Sensor devices data stored in the SQL lite data base for the future processing.

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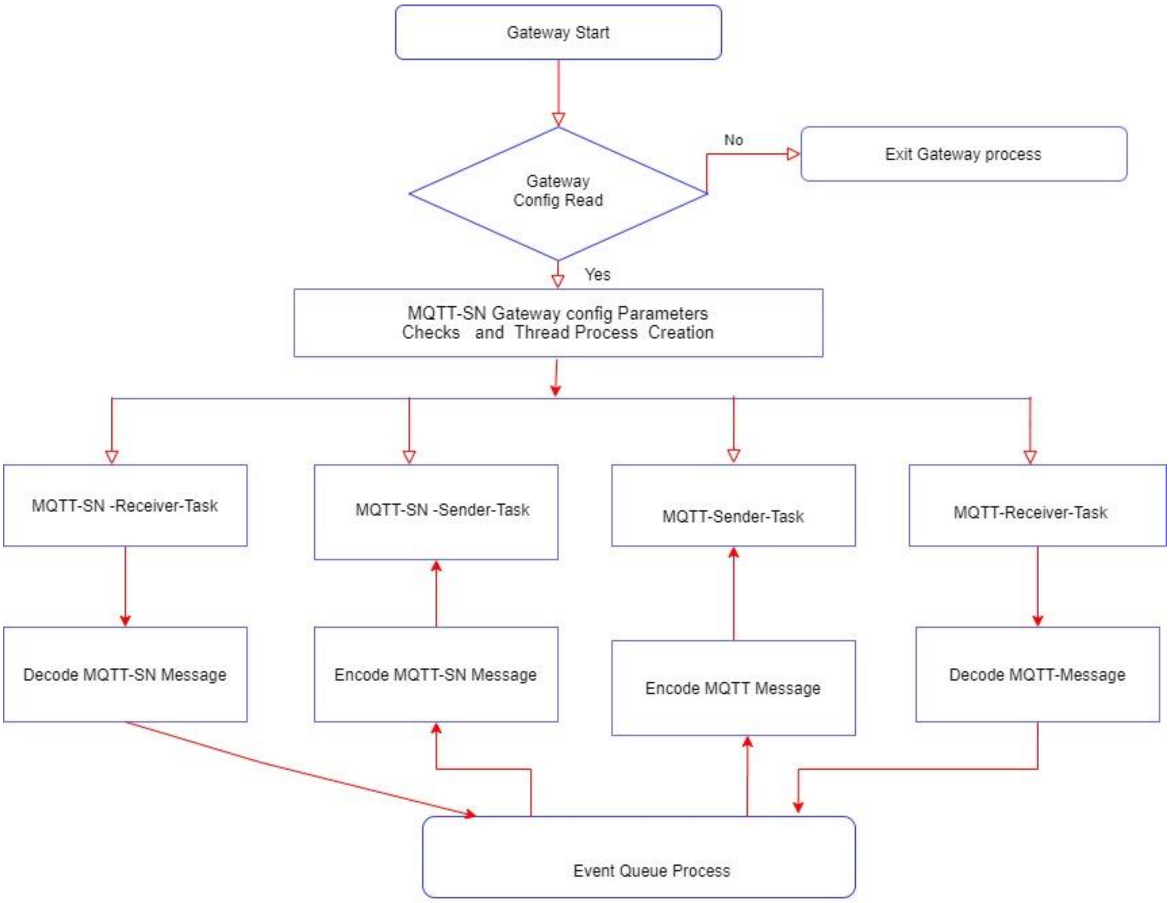

Fig 03: Gateway Software Architecture

III. *MQTT-SN NEW FEATURE COMPARED WITH MQTT PROTOCOL*

A. *Gateway Advertise feature*

GW Advertise service periodically broad cast the gateway info to the clients. Sensor devices decode the gateway address information and attach the one of available gateway. If many gateways are available in the network, sensor device IOT platform attaches only one of the gateways. In other side, sensor devices also transmit gateway info message for getting one of the available gateway address dynamically. Frequent transmission of advertise message, it impacts on gateway performance. In other side sensor node also frequently sending gateway info request to gateway, impacts on sensor node power and bandwidth.

B. *Will Topic and will message feature*

Will Topic and Will messages are useful whenever sensor device is abnormally disconnected from the gateway. Subscribers subscribe Will topic with MQTT-Server. Whenever sensor devices abnormally disconnected with the Gateway, MQTT Server delivers the will message to the Subscribed will topic for appropriate action. Whole sequence process as shown in **Fig-04.**

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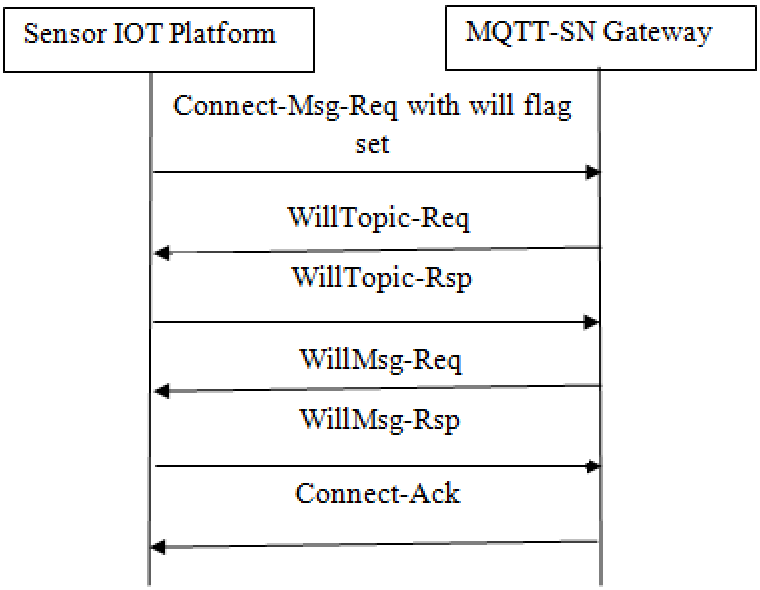

Fig 04: Will Topic and Message Sequence

C. ***MQTT-SN Registration procedure***

In the MQTT Protocol Architecture, topic name length is two bytes, it takes a length of topic name string up to 65535,it is too long topic name for MQTT-SN protocol. It is not affordable for the power and bandwidth constrained sensor devices. To resolve this issue, MQTT-SN protocol provides registration procedure. Whenever Sensor device initiate connect req, registration request to the gateway, gateway responds with short topic id forthat long topic name. Sensor node uses short topic id for publish procedure. Registration procedure as shown in **Fig-05**

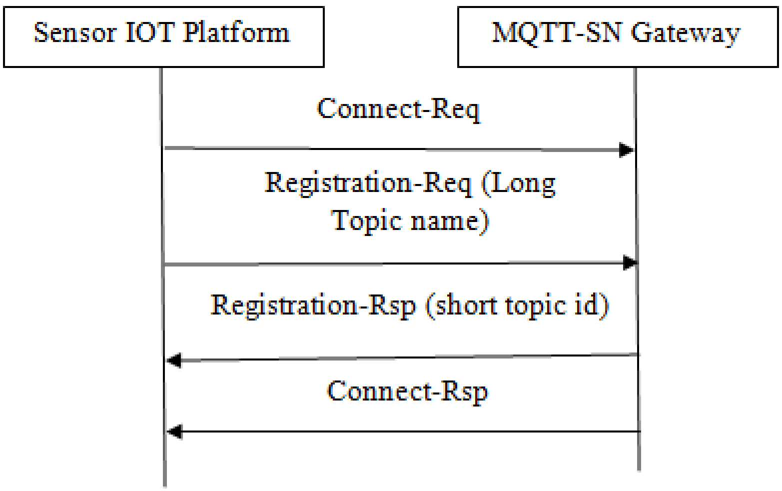

Fig 05: Registration sequence

D. ***Sleeping Client procedure***

In MQTT-SN protocol sleeping client procedure is useful ,when no data is being send to Gateway, Sensor device goes into sleep state and inform to gateway status of sensor device. Due to this power is saved in the sensor device.

E. *Publish and Subscribe procedures are remaining same as MQTT protocol, but short topic id used for publishes messages instead of long topic name.*

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F. ***IOT protocol stack***

IOT Protocol stacks as shown in Fig-06 for the Sensor device, Gateway and MQTT-Server.

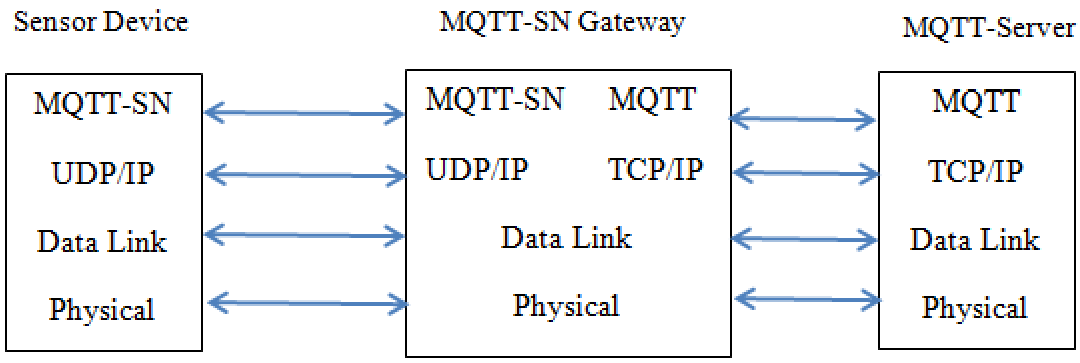

Fig -06: IOT Protocol stack

G. ***MQTT-SN architecture***

In the MQTT-SN protocol three types of components are available 1.MQTT-SN Clients 2.MQTT-SN Gateways, 3.MQTT-SN Forwarder and MQTT-Server.MQTT-SN architecture as shown in Fig-07

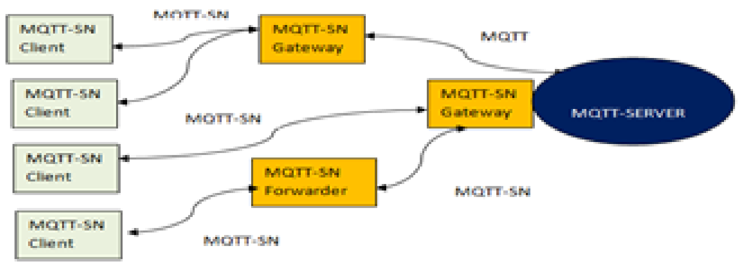

Fig 07:MQTT-SN Architecture

MQTT-SN Gateways are divided into transparent gateway, hybrid gateway and aggregating gateway.
Transparent Gateway: In this structure, each MQTT-SN client connects with MQTT-Server separately.
This is simple implementation in Gateway. But Number of MQTT-SN clients increases ,more number of MQTT-Connections are required in the gateway.
Hybrid Gateway: In this structure, some of the MQTT-SN clients are grouped and for this group only one MQTT-Connection initiated by the gateway**.** Moderate complexity is involved in the Gateway**.**
Aggregating Gateway: In this structure all MQTT-SN clients are grouped into one group and gateway initiate only one of MQTT-Connection with MQTT server. But more complexity involved in the gateway implementation.

H. ***MQTT-SN QOS table***

In MQTT-SN protocol, application designer can choose right QoSmodel as per application requirement dynamically. Different typesof QOS models are as shown in Table-01

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QOS Model	Description
QOS-0	The message is delivered at most once, or it is not delivered at all
QOS-1	The message is always delivered at least once. If the sender does not receive an acknowledgment, the message is sent again with the DUP flag set until an acknowledgment is received.
QOS-2	Publish payload messages are delivered exactly once
QOS-(-1or 3)	Initial connection need not be required, directly publish the message using predefined or short topic ids.

Table-01: MQTT-SN QOS models

I. ***MQTT-SN Topic Management***

Topic is a logical addressing entity in MQTT-SN and MQTT protocols. Subscriber can subscribe required topics for particular type data. Whenever MQTT Server received data on the topic publishes the data to the subscribed topics of subscribers.
Topic name is any time of string in the MQTT.But it is not standardized, application can chose desired topic name as per requirement.
For ex Topic Name:/Hall/Room1/Temperature, :/Hall/Room1/Humidity
Wild card topic also supports
For example: /Hall/Room1/# →from the /Home/Room1/ all types of data received from /Hall/Room1/
But in the lossy network and frequent transmission of data, a long topic consumes bandwidth. To resolve this issue MQTT-SN Client can send register message with long topic name to the gateway, gate returns the short topic id.

J. ***MQTT-SN QOS message flows***
In MQTT-SN protocol, three message sequences are available based on the QoS model
A. ***QOS-0 Message Sequence flow***

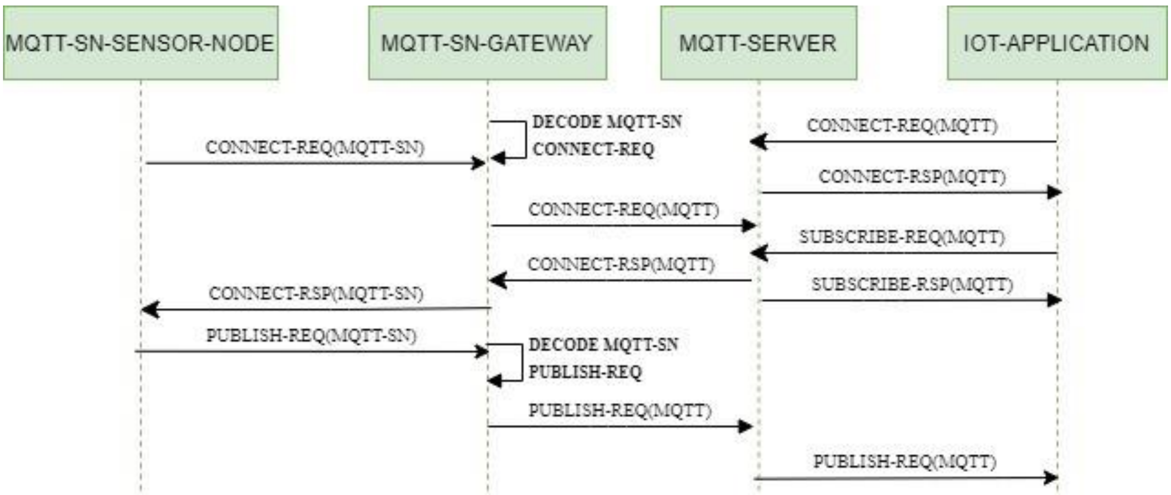

Fig-8 QOS-0 Message Sequence flow

B. **QOS-1 Message Sequence flow**

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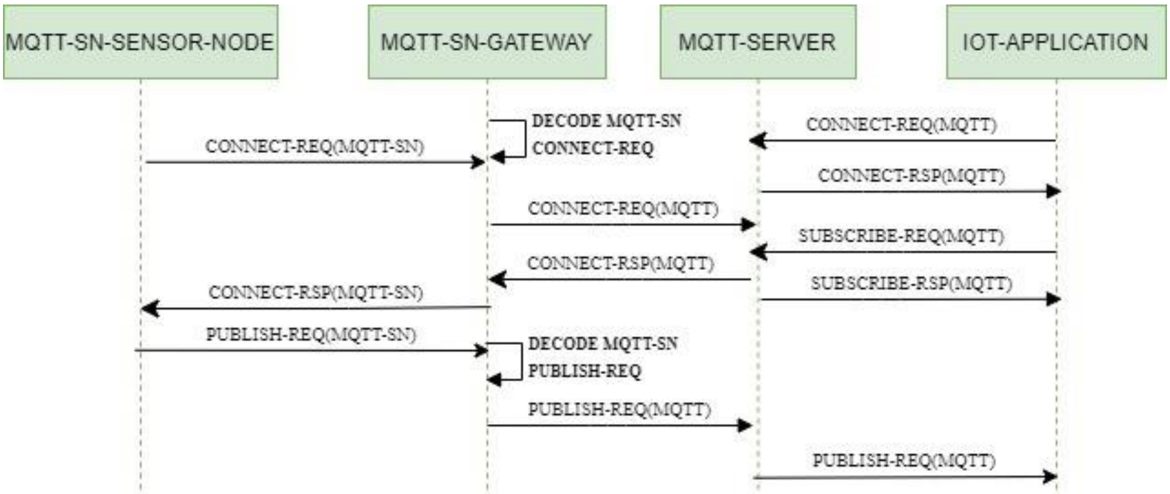

Fig 09: QOS-1 Message sequence flow

C. ***QOS-2 Message sequence flow***

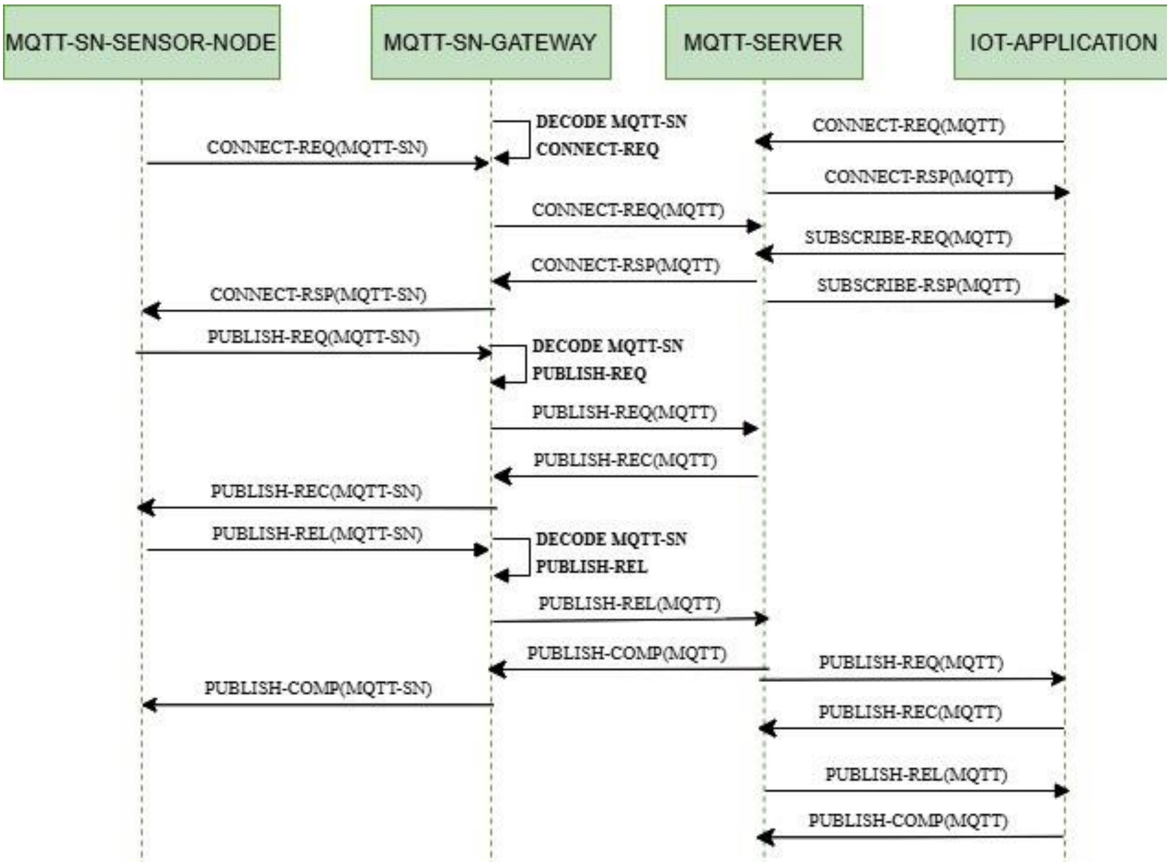

Fig 10:QOS-2 Message sequence flow

IV. IOT APPLICATION DEVELOPMENT PROCESS

MQTT Subscriber/MQTT-SN subscriber subscribe to the required sensor data through the topic name.MQTT Server receives the sensor data to that particular topic ,MQTT server publishes the

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sensor data to the subscribed topics.MQTT Subscriber receives the sensors data, decode it and store the sensor data in the SQL lite data base for further processing.MQTT Subscriber Application development process diagram as shown in **Fig-11**

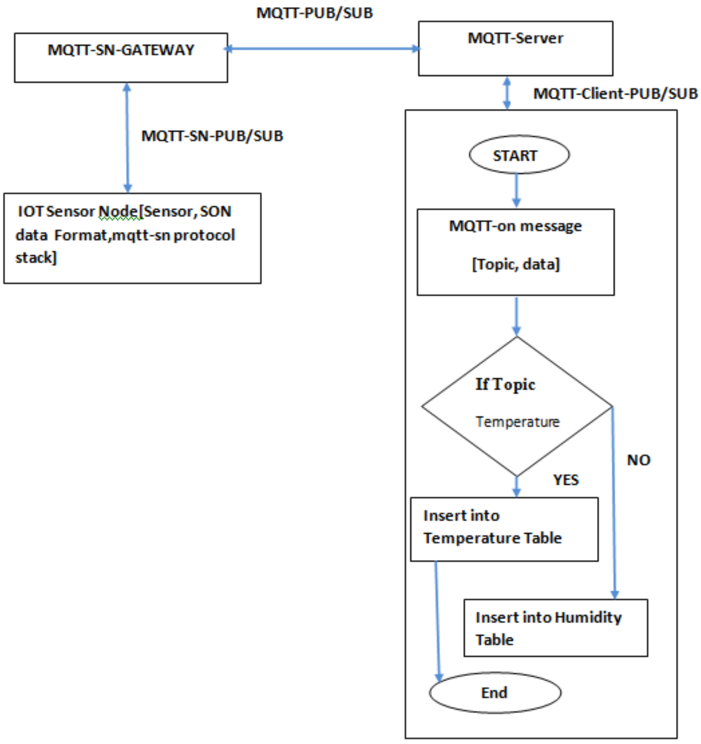

Fig 11: MQTT-Subscriber Application IOT Diagram

V. EXPERIMENTAL SETUP HARDWARE AND MESSAGE OVERHEAD, END TO END DELAY ANALYSIS

A. *Practical Sensor Platform*

DHT22 Sensor device connected to the ESP8286 low cost IOT platform .MQTT-SN stack software designed and developed to the Ardunio platform. Sensor Node software flow diagram mentioned in [4] by the same authors.

B. *Gateway software deployment*

Gateway MQTT-SN protocol software developed and deployed in the Raspberry Pi+B Hardware.

C. *MQTT Server*

MOSQUITTO MQTT server deployed in the desktop computing system and also cloud MQTT Server used for this project.

D. *Simulation of MQTT-SN clients*

C and Python based MQTT-SN clients, Android MQTT, MQTT mosquito publisher and subscriber frame work used for this simulation.

E. *Message overhead analysis for MQTT-SN, MQTT and COAP*

A. MQTT

A complete MQTT message publishing procedure involves the following steps/traffic exchange:

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- Since the MQTT protocol relies on TCP, a new TCP connection must be established at the beginning of each MQTT session. This is a 3-way handshake involving both ends (packets #1-#3). In other words, within each MQTT session an underlying TCP connection is present.
- TCP connection establishment is followed by an MQTT connection establishment procedure, involving:
  - an MQTT connect message sent by the client (#4) and the respective TCP ACK message sent by the broker's TCP end-point (#5)
  - an MQTT connect ACK message sent by the MQTT broker (#6) and the respective TCP ACK message sent by the client's TCP end-point (#7)
- MQTT connection establishment is followed by the MQTT PUB procedure, which includes the MQTT communication credentials, the topic and the IoT payload information (#8)
- MQTT message publication is followed by the release of the MQTT connection, through the MQTT Disconnect Message sent by the client's MQTT end-point (#9).
- Following the FIN/ACK flags included in the TCP part of the MQTT disconnect command; the underlying TCP connection is released through a bi-directional TCP messages exchange (#10-#12).

In Table-02 shown the exact overhead per message, including the MQTT, TCP and IP overheads. Notice that the payload in our experiments (the [{"bn":"testdev-","n":"temp","u":"C","v":20.0}] string message) is 47-bytes long.

Procedure	MQTT OVERHEAD (Bytes)	TCPOVERHEAD (Bytes)	IPOVERHEAD (Bytes)	Total Overhead (Bytes)
TCP connection establishment (#1-#3)	**-**	**40+40+32=112**	**3×20=60**	**172**
MQTT connection establishment (#4)	**115**	**32**	**20**	**167**
MQTT connection establishment TCP ACK (#5)	**–**	**32**	**20**	**52**
MQTT connection ACK (#6)	**4**	**32**	**20**	**56**
MQTT connection ACK TCP ACK (#7)	**–**	**32**	**20**	**52**
MQTT message publication (#8)	**144**	**32**	**20**	**196**
MQTT disconnection (#9)	**2**	**32**	**20**	**54**
MQTT disconnection (#9)	**2**	**32**	**20**	**54**
Total overhead	**265**	**400**	**240**	**905**

Table-02-MQTT Message Overhead Calculation

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In total,905 bytes are consumed for a single 47 bytes payload transmission,i.e almost 95% of bytes Exchanged are non-payload related. Assuming a 500KB NB-IoT data plan, this stands for roughly 550 messages per month or equivalently up to 18 messages per day,i.e less than hourly status update.

B. COAP protocol

Since CoAP is based on the UDP/IP transport protocol, there is no need for connection establishment/release and TCP acknowledgements. Hence, the CoAP POST command is encapsulated in a single UDP/IP message (packet #1). In the capture we also view a CoAP ACK message which is used to notify the client about successful message transmission. This is an optional feature of CoAP, so such a 2-way communication is not mandatory. The following table shows the overhead for each layer

Procedure	COAP OVERHEAD (Bytes)	UDP OVERHEAD (Bytes)	IPOVERHEAD (Bytes)	Total Overhead (Bytes)
CoAP POST (#1)	**183**	**8**	**20**	**211**
CoAP ACK (#2) (*optional)	**6***	**8***	**20***	**34***
Total overhead without Confirmed CoAP	**183**	**8**	**20**	**211**
Total overhead with Confirmed CoAP	**189**	**16**	**40**	**245**

Table-3-COAP Message over head calculation

In total, for non-confirmed COAP,211 bytes are consumed for a single 47 bytes payload transmission, Hence the overhead is significantly reduced compared to MQTT.The overall message length has been reduced more that 4 times. Assuming a 500 KB NB-IoT data plan, this stands for roughly 3,370 messages per month or equivalently up to 80 messages per day,i.e approximately 3 status updates per hour.

C. MQTT-SN protocol

MQTT-SN stands “in-between” MQTT and CoAP, since it borrows the 2-way communication nature of the TCP-based MQTT protocol, but at the same time uses UDP/IP as the underlying transport mechanism. So, we expect some overhead savings due UDP usage.

- Recall that in standard MQTT, each time the client needs to publish something, the full topic name should be included in each message. This could be a long name, consuming a significant amount of bytes. In our example, the topic name is channels/8f3de729-6a42-48d5-a266-20db9c7bda35/messages/244629b1-389e-4b33-8a82-/ which is 92-bytes long. MQTT-SN introduces “topic registration”, where the long topic name could be mapped to a 2-byte integer, and afterwards this 2-byte field could be used in each publish message, instead of the whole string representation.
- In standard MQTT when the client is put to deep sleep (for energy consumption purposes) the one end of the TCP connection fails and the whole session is broken. Hence, after the node wakes up, the session needs to be restored from scratch. MQTT-SN introduces the asleep mode, during which the connection stays active. To achieve this, in MQTT-SN, the client does not establish an end-to-end TCP connection with the MQTT broker. Instead, an intermediate entity called the MQTT-SN Gateway, is responsible for translating UDP packets arriving from/destined to the client to MQTT packets destined to/arriving from the MQTT broker.

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Procedure	MQTT OVERHEAD (Bytes)	UDP OVERHEAD (Bytes)	IPOVERHEAD (Bytes)	Total Overhead (Bytes)
MQTT-SN connection establishment (#1)	19	8	20	**47**
MQTT-SN connection ACK (#2)	3	8	20	**31**
MQTT-SN Topic Registration (* needed only once) (#3)	98	8	20	**126**
MQTT-SN Topic Registration ACK (* needed only once) (#4)	7	8	20	**35**
MQTT-SN Message Publication (#5)	54	8	20	**82**
MQTT-SN Disconnect to Sleep Mode (#6)	4	8	20	**32**
MQTT-SN Disconnect to Sleep Mode ACK (#7)	2	8	20	**30**
Total overhead	**187**	**56**	**140**	**383**

Table-4-MQTT-SN Message (with registration) over head calculation

Second scenario

Procedure	MQTT OVERHEAD (Bytes)	UDP OVERHEAD (Bytes)	IPOVERHEAD (Bytes)	Total Overhead (Bytes)
MQTT-SN (re-)connection establishment (#1)	19	8	20	**47**
MQTT-SN (re-)connection ACK (#2)	3	8	20	**31**
MQTT-SN Message Publication (#3)	54	8	20	**82**
MQTT-SN Disconnect to Sleep Mode (#4)	4	8	20	**32**
MQTT-SN Disconnect to Sleep Mode	2	8	20	**30**

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ACK (#5)				
Total overhead	**82**	**40**	**100**	**222**

Table-5-MQTT-SN Message (with out registration) over head calculation

In total for MQTT-SN and assuming an IoT payload of 47 bytes, the overhead for the case where topic registration is also included is 383 bytes, whereas for the case where registration has already been performed is only 222 bytes, significantly lower than MQTT and similar to COAP.

D. The following table summarizes the key findings, under the following assumptions

- IoT Payload: 47 bytes
- NB-IoT monthly data plan: 500 KB

Protocol	OVERHEAD (BYTES)	TOTAL ALLOWED MESSAGES PER DAY
MQTT	**905**	**18**
MQTT-SN First Connection	**383**	**43**
MQTT-SN Communication after first connection	**222**	**75**
CoAP	**211**	**80**
MQTT	**905**	**18**

Table-06- Message overhead analysis for MQTT-SN,COAP,MQTT

E. QoS impact on performance of MQTT-SN protocol

There is a simple rule when considering performance impact of QoS. It is: "The higher theQoS, the lower the performance." Let us evaluate performance corresponding with higherQoS. Suppose the time taken for sending a PUBLISH message is Pt. If QoS is used, the total time taken to transfer N number of messages will be Npt. Now in case of QoS 1, the PUBACK message (that is reply for the PUBLISH message) will flow from server to client. This is a2-byte message and might take a lot less time than Pt, hence call it mt. So the time taken for transferring n messages will be **N(Pt + mt).** And for QoS 2, the PUBREC, PUBREL and PUBCOMP messages would be flowing. Hence the n number of messages would take approximately **N(Pt + 3mt).** So if 10 messages need to be transferred from client to server andPt is 1 second and mt is 0.4 seconds, a QoS 0 message would take 101 = 10 seconds, QoS 1message would take 10(1 + 0.4) which is 14 seconds and QoS 2 message would take 22seconds.

F. MQTT-SN Message percentage Losses

Message payload in bytes to published to the MQTT-Server using Python MQTT-SN script	Source to destination message loss calculation at QOS-Level-0 (%)	Source to destination message loss calculation at QOS-Level-1(%)	Source to destination message loss calculation at QOS-Level-2(%)
1000	1.00	0.24	.0.18
2000	1.40	0.41	0.2
3000	1.60	0.60	0.22
4000	1.80	0.78	0.24

Table-07 Message percentage losses

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VI. PRACTICAL SIMULATION RESULTS

A. *Case-01: End to End IOT Application Logs (Mosquito MQTTServer deployed in the Local computer)*

1.SensorNode Logs:

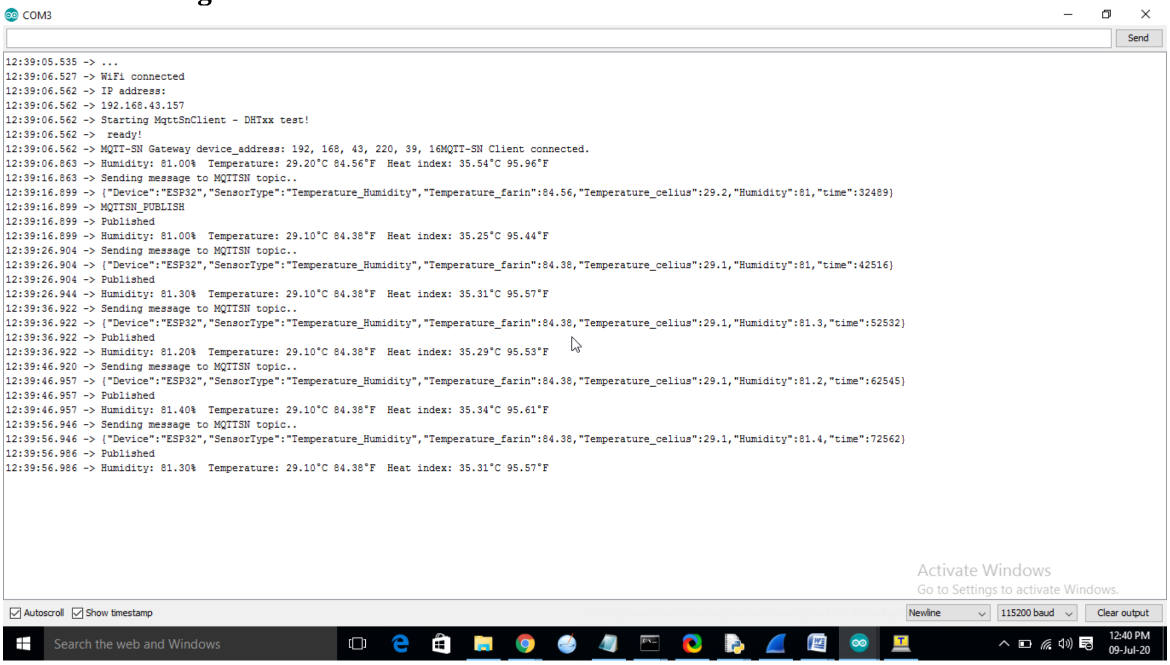

Fig: 12-Sensor Node Logs

2.Gateway Logs:

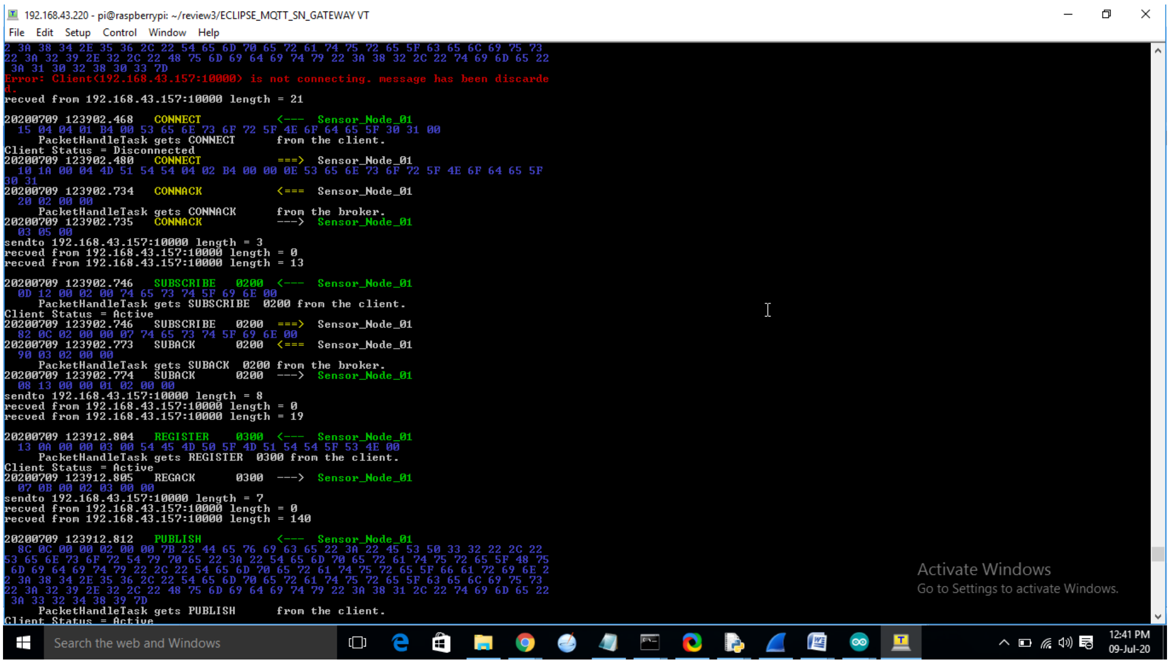

Fig:13-MQTT-SN Gateway Logs

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3.MQTT-Server Logs

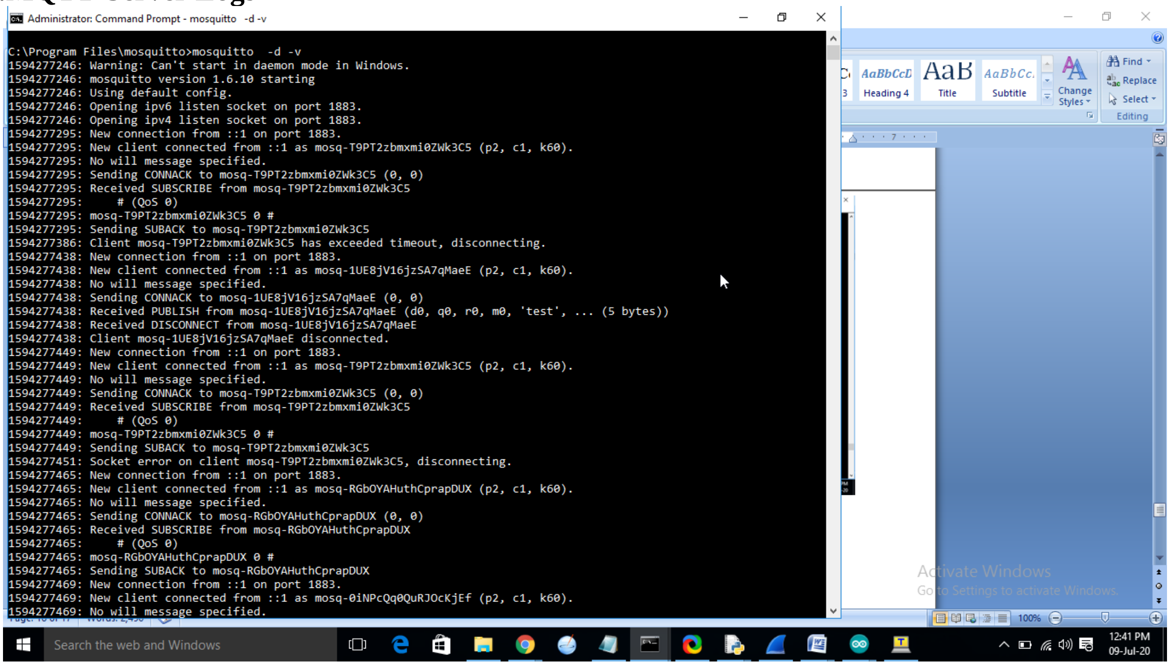

Fig:14-MQTT Server Logs

4.IOT Application Logs

IOT Application is starting
Connected with result code 0
Subscribing topic
MQTT Data Received...
MQTT Topic: TEMP_MQTT_SN
data Received type <class 'str'>
data Received
{"Device":"ESP32","SensorType":"Temperature_Humidity","Temperature_farin":84.2,"Temperature_celius":29,"Humidity":79.4,"time":32117}
Enter DHT22_Temp_Data_Handler
SensorID :ESP32
SensorType :Temperature_Humidity
Temperature_farin : 84.2
Temperature_celius : 29.0
Humidity : 79.4
Data_and_Time : 09-Jul-2020 12:45:38:926518
MQTT Data Received...
MQTT Topic: TEMP_MQTT_SN
data Received type <class 'str'>
data Received
{"Device":"ESP32","SensorType":"Temperature_Humidity","Temperature_farin":84.2,"Temperature_celius":29,"Humidity":81.2,"time":42147}
Enter DHT22_Temp_Data_Handler
SensorID :ESP32
SensorType :Temperature_Humidity
Temperature_farin : 84.2
Temperature_celius : 29.0
Humidity : 81.2
Data_and_Time : 09-Jul-2020 12:45:48:952169

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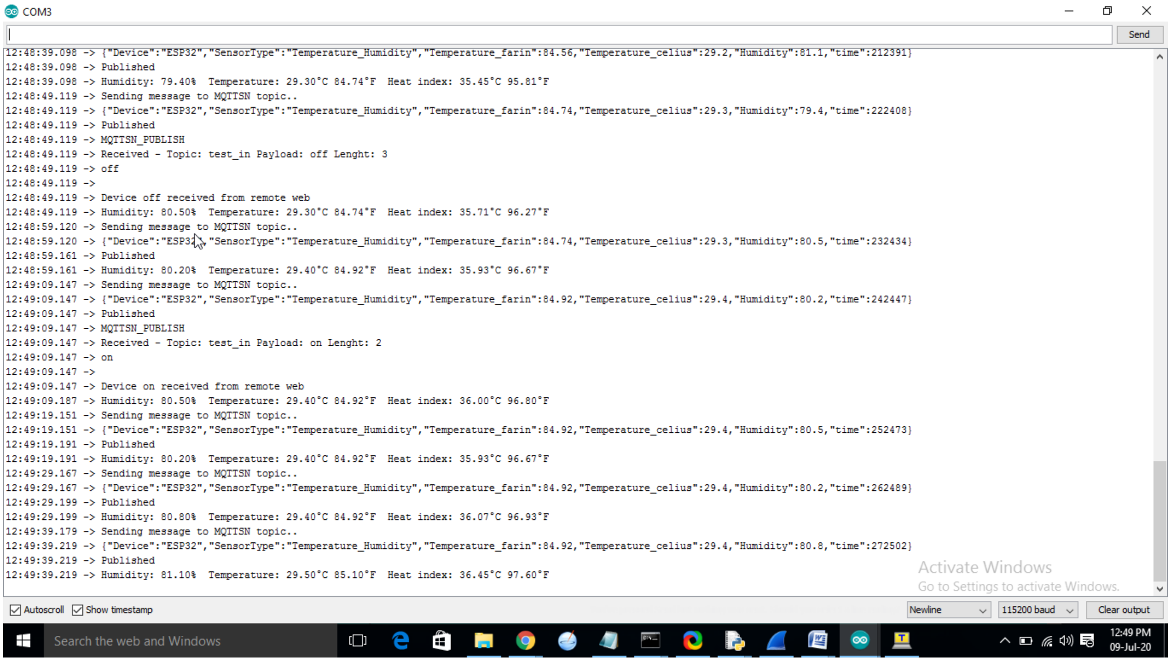
B. ***Case-02: End to End IOT Application Logs with Cloud MQTT Server***



5.Sensor Node Logs

Fig:15-Sensor Node Logs(With Cloud MQTT Server)

6.Gateway Logs

Fig:16-Gateway Node Logs(With Cloud MQTT Server)

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7.Cloud MQTT-Server Logs

```
2020-07-09 07:51:09: New connection from 223.228.98.199 on port 15738.

2020-07-09 07:51:09: New client connected from 223.228.98.199 as Sensor_Node_01 (c1,
k46080, u'rolyobzn').

2020-07-09 07:51:09: No will message specified.

2020-07-09 07:51:09: Sending CONNACK to Sensor_Node_01 (0, 0)

2020-07-09 07:51:10: Received SUBSCRIBE from Sensor_Node_01

2020-07-09 07:51:10: test_in (QoS 0)

2020-07-09 07:51:10: Sending SUBACK to Sensor_Node_01

2020-07-09 07:51:17: Received PINGREQ from mosq-diSdByB2kRTbQGZ6iS

2020-07-09 07:51:17: Sending PINGRESP to mosq-diSdByB2kRTbQGZ6iS

2020-07-09 07:51:53: Socket error on client <unknown>, disconnecting.

2020-07-09 07:51:55: New client connected from 223.228.98.199 as cloudmqtt-ws-ui-
0.3054179418283789 (c1, k60, u'rolyobzn').
```

Fig: 17-Cloud MQTT Server Logs (With Cloud MQTT Server)

8.IOT Application Logs

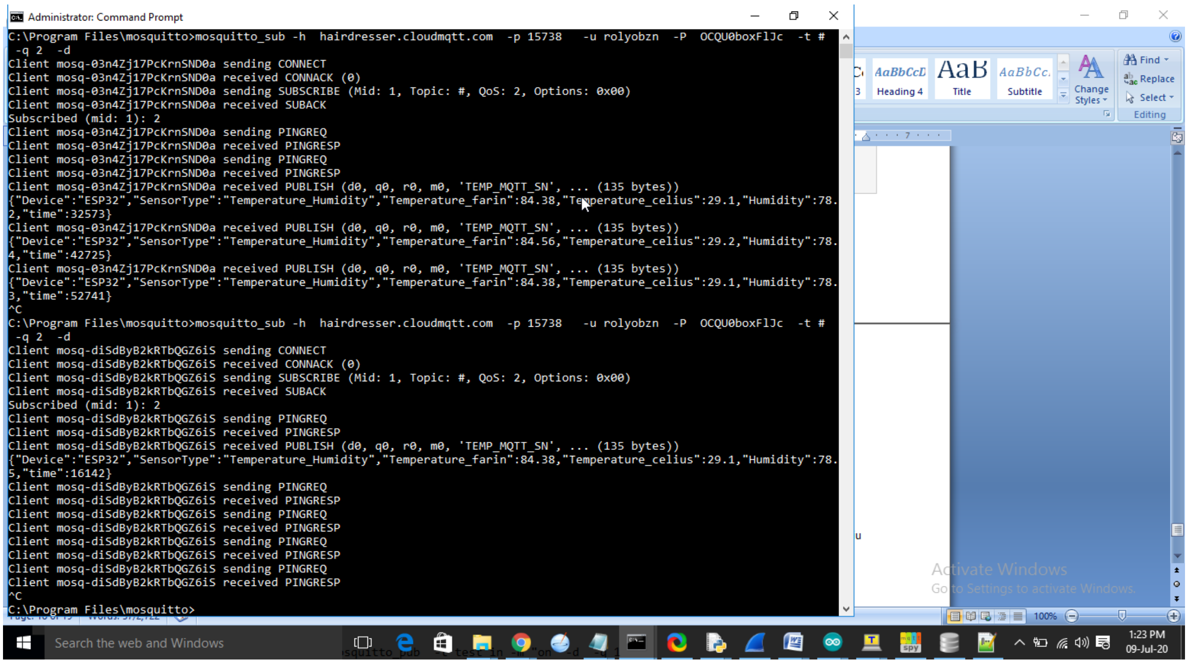

Fig: 18-IOT Application Logs(With Cloud MQTT Server)

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9.MQTT-SN-QOS-0,QOS-1,QOS-2 Wire shark Logs

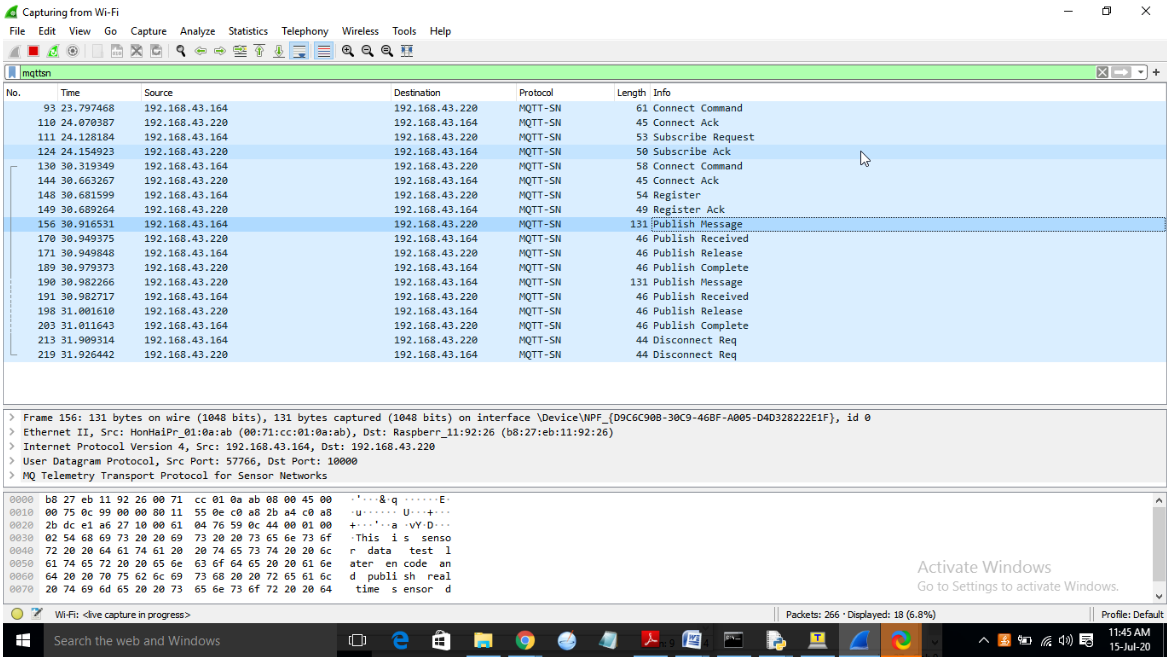

Fig: 19-MQTT-SN-QOS-02-Wireshark Logs

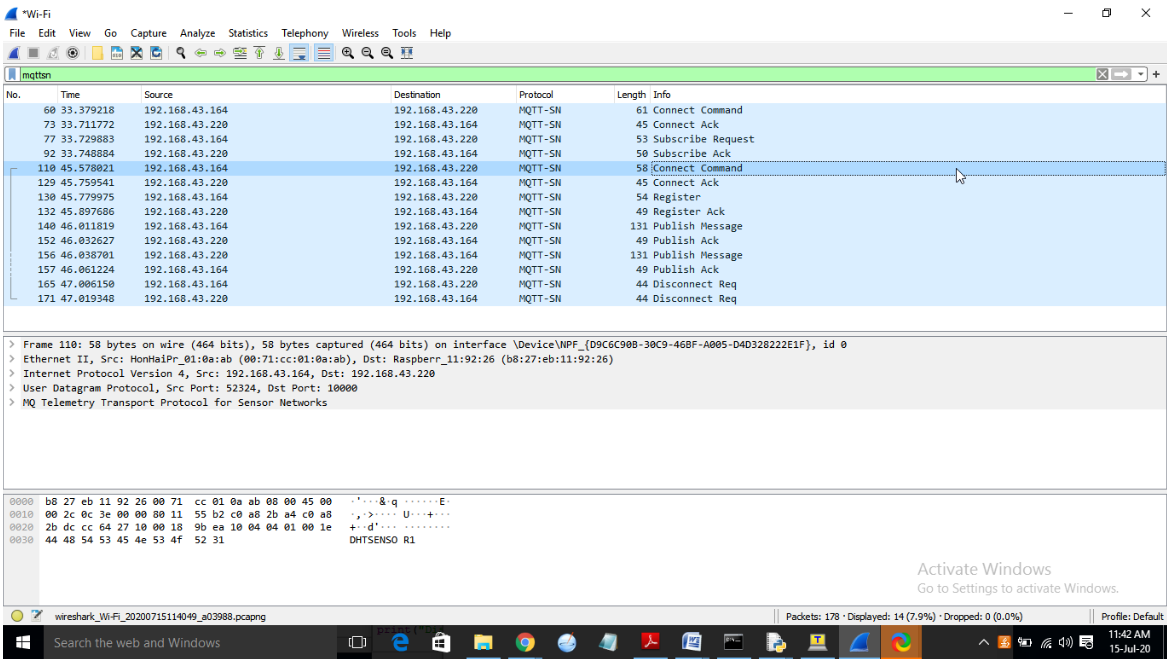

Fig: 20-MQTT-SN-QOS-01-Wireshark Logs

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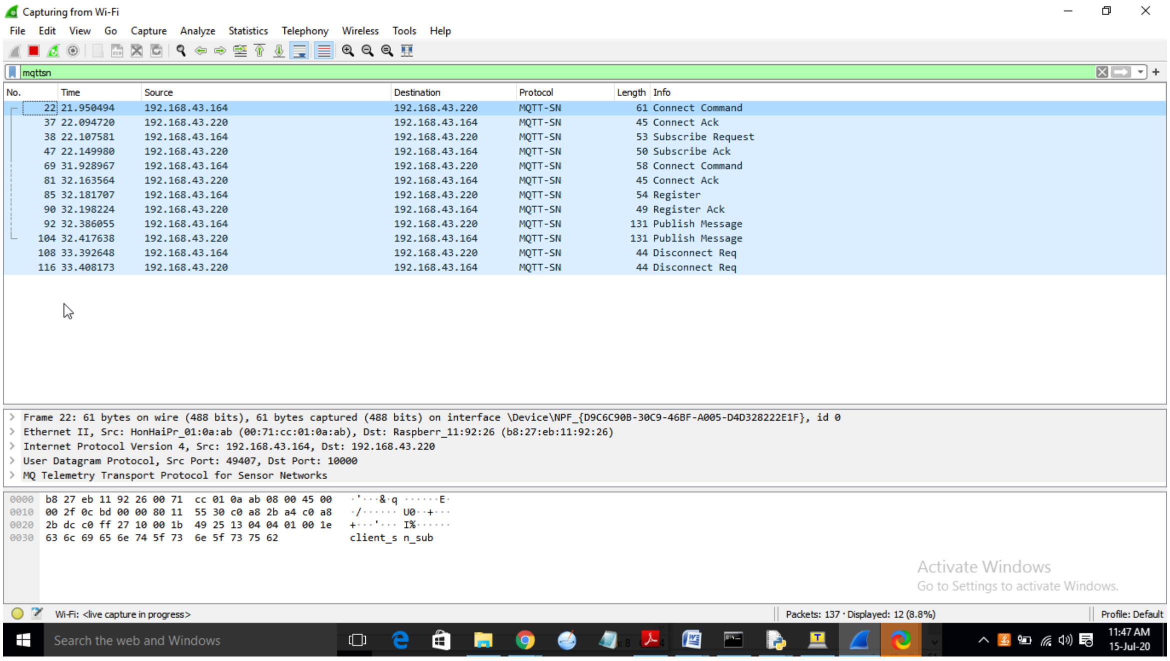

Fig: 20-MQTT-SN-QOS-0-Wireshark Logs

10.MQTT-Application Received Sensor Data

Practical temperature and humidity sensor data received as shown in Fig-21

id	Device	Sensor Type	Temperature_farin	Temperature_celius	Humidity	Date_n_Time
1	ESP32	Temperature_Humidity	84.56	29.2	51.2	09-July-2020 09:19:03:308728
2	ESP32	Temperature_Humidity	84.56	29.2	51.2	09-July-2020 09:19:13:316439
3	ESP32	Temperature_Humidity	84.56	29.2	51.2	09-July-2020 09:19:23:416277
4	ESP32	Temperature_Humidity	84.56	29.2	51.4	09-July-2020 09:19:33:460665
5	ESP32	Temperature_Humidity	84.56	29.2	51.5	09-July-2020 09:19:43:458445
6	ESP32	Temperature_Humidity	84.56	29.2	51.7	09-July-2020 09:19:53:467951
7	ESP32	Temperature_Humidity	84.56	29.2	51.9	09-July-2020 09:20:03:453599
8	ESP32	Temperature_Humidity	84.56	29.2	51.8	09-July-2020 09:20:13:470940
9	ESP32	Temperature_Humidity	84.56	29.2	51.9	09-July-2020 09:20:23:493006
10	ESP32	Temperature_Humidity	84.56	29.2	51.8	09-July-2020 09:20:33:522815

Fig: 21-MQTT-Application Received Sensor Data

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11.End to End Delay versus Number of messages

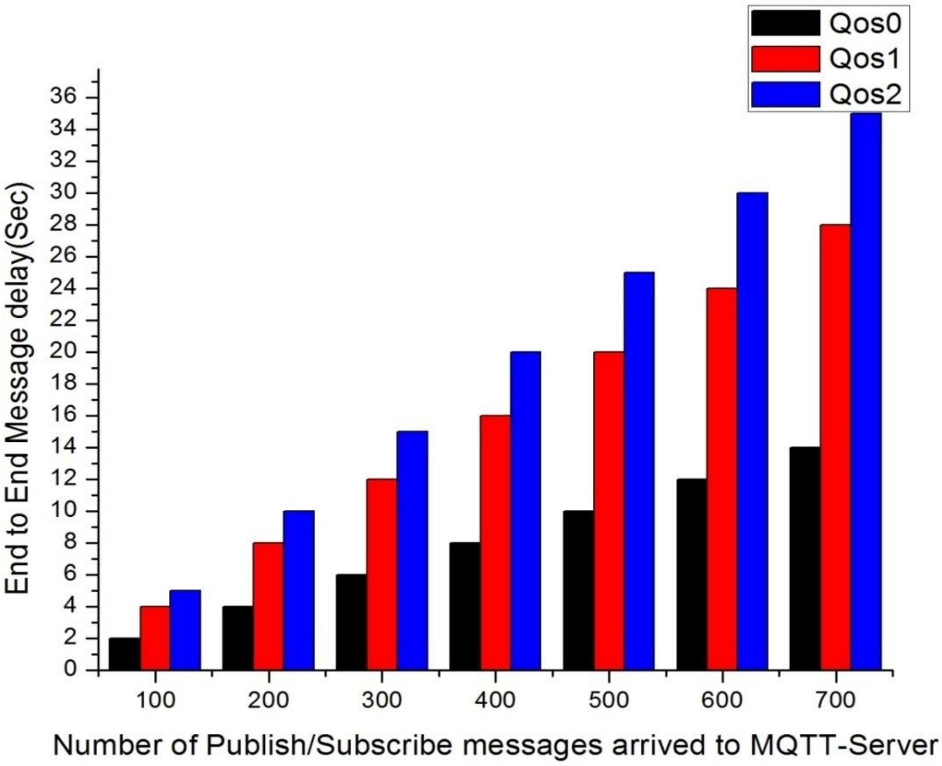

Fig: 20-Number of publisher/subscriber arrived to MQTT-Server

12.End to End Delay versus message size

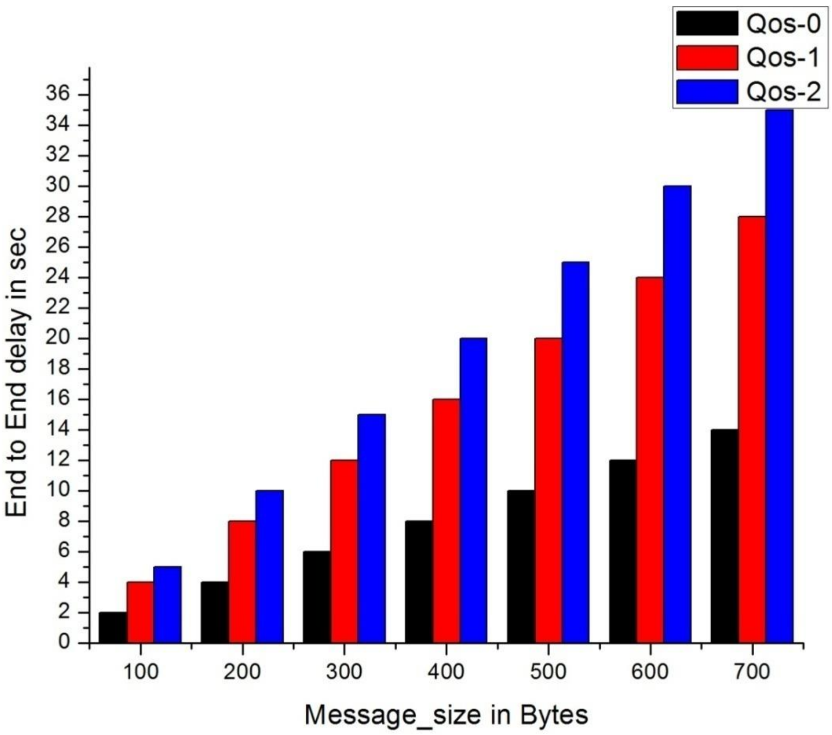

Fig-21 MQTT-SN Message Size in Bytes

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13.Temperature Sensor data graph

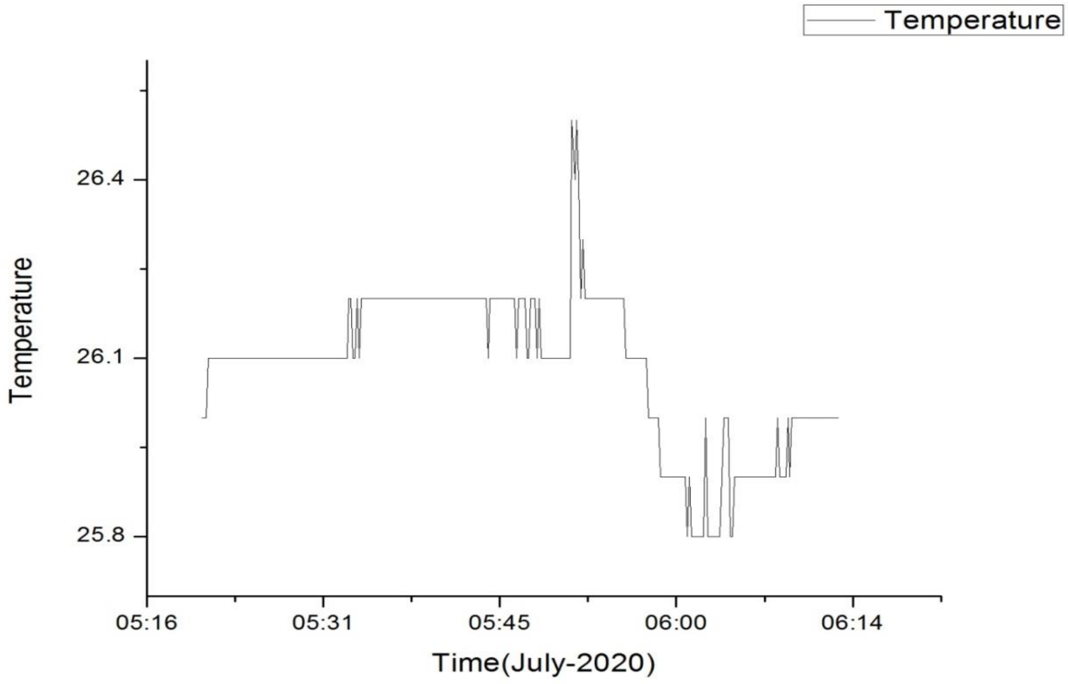

Fig-22-Temperature Sensor data

14.Humidity Sensor Data graph

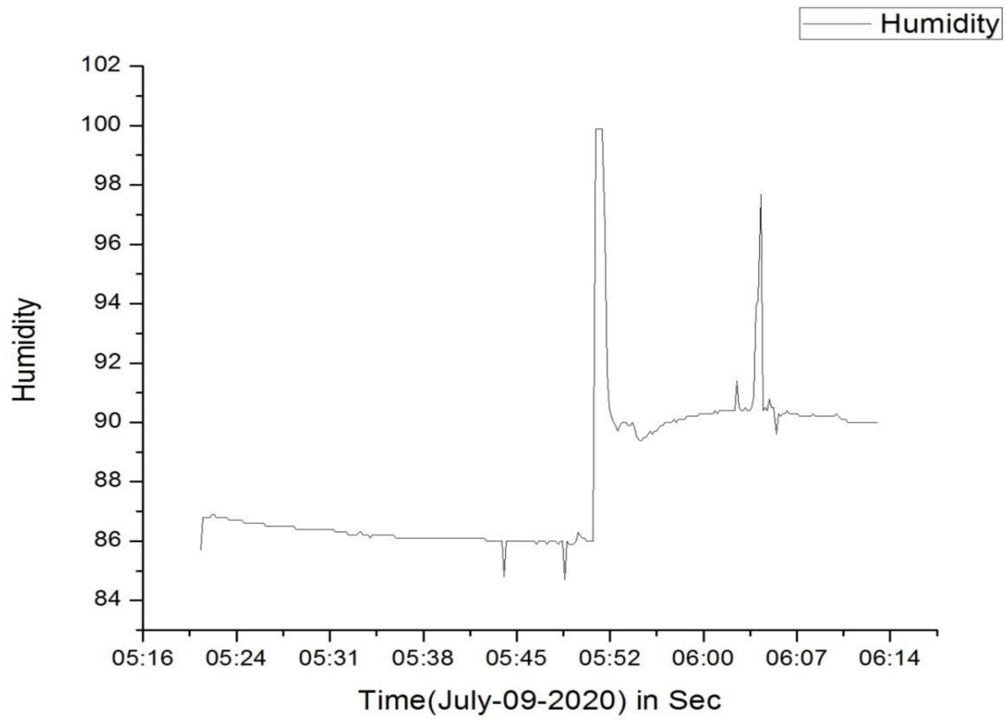

Fig-23-Humidity Sensor data

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VII. CONCLUSION

In this paper we discussed end to end message delay calculations for different types MQTT-SN QoS , MQTT-SN gateway integrated with local mosquito MQTT Server and Cloud MQTT Server. Simple MQTT IOT application developed for receiving of Sensor data from the MQTT-Server. Infuture wewill implement this setup and different Qos Models for the practical IOT applications.

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