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Temperature and Saturation level monitoring system using MQTT for COVID-19

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***Abstract*—In today's data driven world, seamless transfer of data is of paramount importance. The process of data assimilation and transfer demands high accuracy and security. During the outbreak of pandemics like COVID-19, continuous monitoring of temperature and saturation levels by the health officials is necessary. The information exchange between the patient and the health officials should be initiated instantaneously without any delay. For uninterrupted and accelerated data transfer, Message Queuing Telemetry Transport protocol can be deployed. MQTT has demonstrated good mobility, reliability, scalability, interoperability, power saving and security and hence can be considered as an alternative for wireless data transfer during situations wherein social distancing and self-isolation are mandatory.**

***Keywords*—Topic, Broker, Raspberry – Pi, Temperature, Saturation, Publisher, Subscriber**

I. INTRODUCTION

Message Queuing Telemetry Transport (MQTT) is a messaging protocol which can be deployed in bandwidth constrained environments. It supports discontinuous transmission and reception. The standard protocol structure includes a fixed 2 byte header, a variable header and a payload which is diminutive in bandwidth. MQTT requires zero administration and can be easily scaled up based on the requirements. From green computing perspective, sustained battery backup and energy conservation are the key takeaways.

MQTT supports networking of servers with a myriad variety of clients. For networking and scheduling between server and client, MQTT deploys publish/subscribe messaging. The source publishes a message under a particular topic. The subscribers who have procured access by subscribing to the particular topic, receive the message. There can be multiple receivers at the receiving end, with a single source at the transmitting end. This system also houses a broker which performs the functionalities of a router. The broker can be considered as the pivot around which data transfer occurs (based on the subscription). The figure below represents the function of publisher, broker and subscriber.

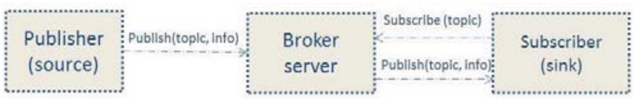


Fig.1 MQTT Elements

Broker has the autonomy to filter messages (also discard messages) based on the recipients list. During situations of signal distortion or disruption of services, the broker works in adherence with the last will and testament principle. The broker will inform the subscribers of the topic about the error encountered and will dispatch the last will message to all the subscribers of the topic. If there is any network turbulence, the broker will hoard the data and transfer the stored data after the connection is revived. MQTT supports Asynchronous mode of communication by deploying PUSH and POP methodology.

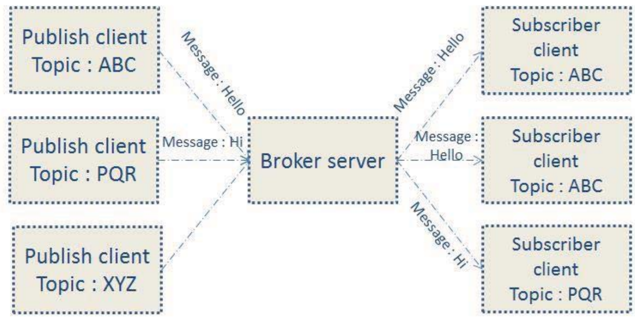


Fig.2 Characterization of Topic

There are three levels of Quality of Service (QoS) defined in MQTT. They are QoS0, QoS1 and QoS2.
QoS0 mimics the fire and forget principle wherein auxiliary messages are not preserved for retransmission. This method eliminates the concept of duplicate creation. The command set has only PUBLISH command.

QoS1 accommodates guaranteed delivery. The setbacks seen in QoS0 with respect to retransmission of messages during network failure are corrected here (using the concept of duplicate creation). The duplicates created can be used for retransmission during network failures. The command set includes the command set of QoS0 and PUBACK command.

QoS2 also accommodates guaranteed delivery. The stored messages can be reclaimed and retransmitted. The command set includes PUBLISH, PUBREC, PUBREL and PUBCOMP commands.
Advantages of MQTT protocol:

- Unbiased data distribution with enhanced sensing and computing capabilities.
- Exalted scalability and data security through broker authentication.
- Reduced overhead and bandwidth.

- Suitable for resource constrained client environments.

This paper consists of seven sections. The second section discusses about the related work, the third section describes the existing methods, the fourth section enumerates the proposed methodology, the fifth section interprets the experimental results, the sixth section describes about the conclusion and the seventh section explains about the future advancements.

II. Related work

After a detailed examination of papers and articles on MQTT, temperature and saturation monitoring using MQTT was designed.

The authors in the paper have discussed about the design of Message Queuing Telemetry Transfer (MQTT) protocol through pub – sub mechanism and the optimization of system parameters like battery consumption, energy efficiency, security, mobility, transmission efficiency, latency and transfer rate. The influence of delay, node failure and congestion on data transfer has been highlighted by the authors [1].

The authors have proposed a methodology to integrate MQTT with telemedicine. Using a LED based detector, the pulse rate of the patient is captured. After adequate signal conditioning, the amplified signal is converted to its digital form and is transmitted to the server. Based on the subscription, the patient data published can be viewed. This data can be used for treating patients through telemedicine [2]

The concept of MQTT has been exemplified by the authors in [3] for tracking carbon emissions. LDR, DHT11, and LM35 are the sensors which have been deployed in this mission. The output of these sensors is processed using Atmega 328 microcontroller. The processed data is wirelessly transmitted to the target subscribers by deploying of ESP8266 modules.

The authors in [4] have devised a methodology to measure/control the atmospheric conditions and febricity using MQTT protocol. This paper also includes a fire alarm system. The implementation houses three modules with two modules exclusively for temperature control and one module dedicated for monitoring the flame sensor. The Arduino modules interact with the MQTT broker through Wi-Fi. An application called Dashboard application for MQTT is used to oversee the variations.

The authors of this paper have laid great emphasis on the elements influencing MQTT broker design and performance. CPU utilization and Memory management concerns for Raspberry Pi 2 Model B broker have been evaluated and enumerated. The major outcome of this paper is the demonstration of increased scalability, optimized memory usage and reduced CPU usage of Raspberry Pi 2 module (implemented using C) [5]

The authors in [6] have implemented MQTT for temperature control in a warehouse using ESP8266 and WiFi. The data collected is shared to the Baidu intelligent cloud server using MQTT.

The authors in [7] have used MQTT box for temperature monitoring. Connection to brokers through TCP, web socket and TLS protocols has been shown. The use of MQTT load test for viewing the progress has also been demonstrated.

III. Existing Protocols

The sub structuring for the wireless transfer of data captured from sensors and actuators, has been done by the use of IoT protocols. AMQP, CoAP, XMPP and DDS are the most popular IoT protocols. This section explains each of these protocols in brief.

A. Advanced Message Queuing Protocol (AMQP)

This protocol works on pub – sub principle and includes the exchange section broker and the queue section broker. Exchange section apportions the messages to the queue section. Subscribers who endorse themselves with a specific topic gain access to the information shared in the particular queue.

B. Data Distribution Service (DDS)

DDS endorses broker less architecture and provides high reliability and QoS.

C. Extensible Messaging and Presence Protocol (XMPP)

Messaging based applications use XMPP to switch between publish/subscribe and request/receive modes. XMPP assures efficient transfer of messages with minimum latency. High power consumption and Poor Quality of Service (QoS) are major setbacks seen here.

D. Constarined Application Protocol (CoAP)

This protocol has revolutionized the web application domain. CoAP uses User Datagram Protocol (UDP) while the other IoT protocols use Transmission Control Protocol (TCP). CoAP supports reliable communication with four modes namely confirmable, non - confirmable, piggyback and separate.

In most of the IoT protocols, there is a tradeoff between data transfer rate and latency. Unlike the other protocols, MQTT promises high data rate with minimum latency. Hence MQTT is the preferred choice for real time wireless data transfer for health care application.

IV. Proposed System

MQTT endorses the Publish - subscribe model in contrary to the present day client- server model. The present day model endorses the concept one - to - one communication between targets. MQTT hides the publisher from other clients. The identities of the Subscribers and the Publishers is masqueraded by the broker Mosquitto (performs the authentication of the clients). This paper discusses about the deployment of MQTT to screen patients based on the measured temperature and saturation values. Temperature and Saturation level measurements are fed into the MQTT client (Raspberry-Pi module) and later published on to the cloud. These values are also shared with the health officials and relatives who have obtained access to the data by subscribing to it. The messages are sorted by the broker by exploiting the concept of Message filtering (topic based filtering). If the Temperature and Saturation level of person ABC is published under topic ABC, only those health officials and relatives who have subscribed to topic ABC can access the information shared. Similarly, if the Temperature and Saturation level measurement of person PQR is published under topic PQR, only those health officials and relatives who have subscribed to topic PQR can access the information shared. The information shared in topic ABC is accessible only to its subscribers and the information in shared in topic PQR is accessible only to its subscribers. Thus data privacy and confidentiality is maintained.

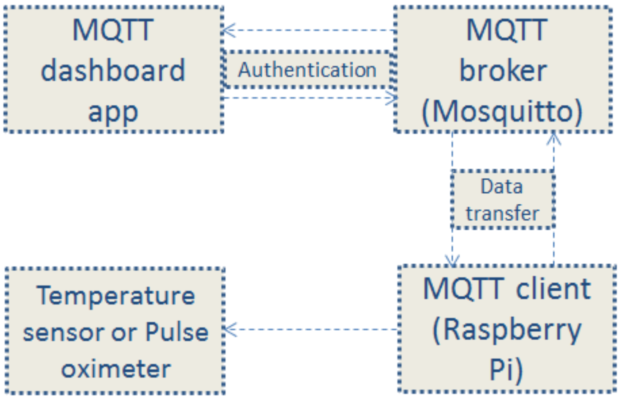


Fig.3 Block diagram of the proposed system

MQTT necessitates the presence of a connection between a client and a broker and not between clients. Connection between the client and broker can be instigated by the broker through the use of CONNECT command which houses a Client ID, Clean session flag and the user credentials for authentication as shown below:

Connect (host, port= 1883, keep alive =60, bind_address= “ “)

Publishing action can be instigated by the client only after establishing a successful connection with the broker. The topic name, QoS level, Payload, Packet Identifier and DUP flag are the fields which are present. After receiving publish and subscribe commands, the published message will be guided to the respective subscriber. When a subscription request is received, the Mosquitto broker checks the subscription and initiates the data transfer through the MQTT Dashboard application. Health officials and relatives can access the Temperature and Saturation level measurements and decide the next course of treatment.

V. Experimental Results

Transfer of the temperature and saturation values with Quality of Service 2 (QoS 2) has proved that lossless data transfer can be achieved with minimum delay. The temperature measurements are published under the topic ’topic’ and saturation values are published under the topic ‘test’.

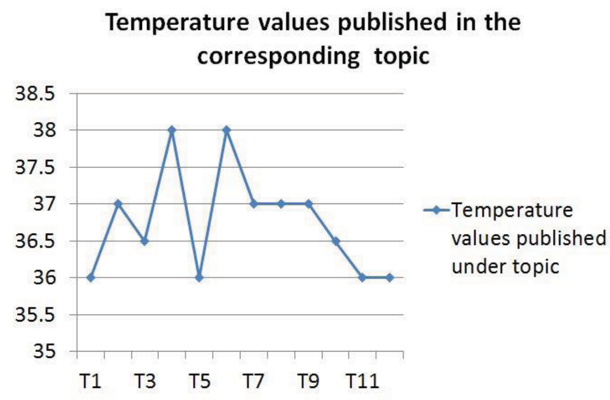


Fig.4 Temperature values obtained through MQTT dashboard application

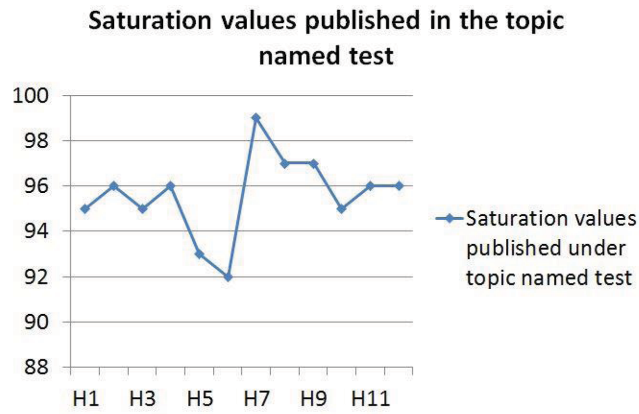


Fig.5 Saturation values obtained through MQTT dashboard application

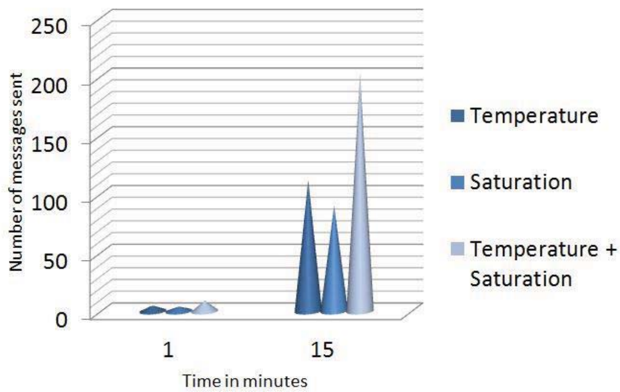
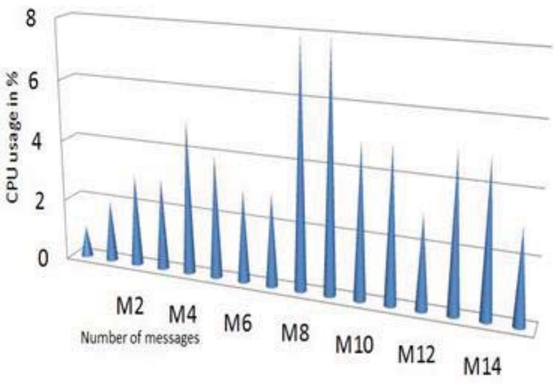


Fig.6 Graph depicting the relationship between the number of publishers and data transfer rate

From the graph it can be found that, as the number of publishers increase, the data transfer rate also increases.

Consider the scenario where nine messages are transmitted per minute with two publishers. In a fifteen minute interval, the number of messages anticipated is one hundred and thirty five while the number of messages received is close to one hundred and eighty seven . Hence we can substantiate that MQTT supports accelerated data transfer.



	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11	M12	M13	M14	M15
1	2	3	3	5	4	3	3	8	8	5	5	3	5	5	3

Fig.7 CPU utilization for messages with uniform payload

The graph shown above denotes CPU usage for a uniform payload (15 messages). The CPU usage depends on the data transfer rate. It is also affected by the nature of data being sent and the other tasks which are being executed parallely.

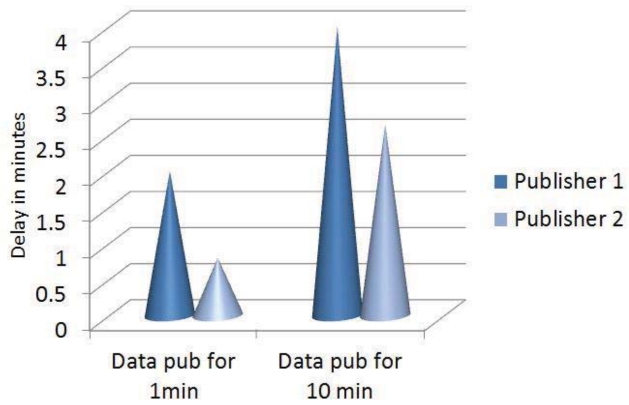


Fig.8 Graph depicting the relationship between the number of publishers and delay

It can be seen that the observed delay and the number of publishers are related inversely. From the graph it is evident that as the number of publishers increase, the delay encountered decreases resulting in conservation of energy and bandwidth.

VI. Conclusion

The deployment of MQTT protocol for temperature and saturation level monitoring in the current pandemic situation has displayed convincing outcomes. The research work conducted has shown that MQTT protocol performs better with increased number of publishers providing higher data transfer rate and enhanced security. Hence the use of MQTT in transferring temperature and saturation values will make a positive impact on the lives of health care workers and people who are in quarantine by endorsing telemedicine and promoting social distancing.

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