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IoT Protocols for Health Care Systems: A Comparative Study

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Abstract*— There have been great advances in the field of Internet of Things (IoT) recently. At the same time there are an ever growing request for healthcare systems to progress human health. The previous decade has witnessed the expansion of numerous Internet of Things based applications of healthcare in the application layer of IoT protocol set, there are number of network communication protocols for IoT like HTTP or novel protocols specified to the field of IoT such as CoAP or MQTT. In this paper, we make a comparative study between the network communication protocol Message Queue Telemetry Transport (MQTT) and the Hypertext Transfer Protocol (HTTP) to know the needs of a system, in particular the bandwidth requirements and the volume of generated data. The study is carried out by means of simulation, the comparative study based on the Throughput and end to end delay .To build the simulation environment we used OMNET++ network simulation framework and INET framework. In MQTT the average throughput in the first scenario is (79851.6bit/s) and then it started decreasing in the other scenarios when the number of publishers and subscribers increased until reaching (16786.9bit/s) and the average end to end Delay in first scenario is (0.281 second) and then started increasing in the other scenarios until reaching (0.386second), In HTTP the average throughput in the first scenario is (179.55bit/s) and then it started increasing in the other scenarios when the number of publishers and subscribers increased until reaching (216.8bit/s) and the average end to end Delay in first scenario is (2.256second) and then started increasing in the other scenarios until reaching (2.714second).

***Keywords*— HTTP, Healthcare, IoT, INET, MQTT, OMNET++**

I. INTRODUCTION

The Internet of Things (IoT) is a notion reflecting a linked set of anytime, anything, anyplace, anyone and any network. Internet of Things (IoT) can be characterized as a collective network infrastructure where virtual and physical objects are interconnected with each other. With the intervention of many developed technologies such as wireless body area network , wireless sensor network, , implanted and wearable sensor, IoT views its capabilities of fixing existing difficulties or problems in healthcare monitoring systems. It can help to enhance the quality of service (i.e.) displaying remote monitoring and push notification whereas decreasing healthcare costs. The IoT stocks suitable solutions for a large range of applications such as traffic congestion, smart cities, structural health, security, emergency services , and healthcare[1]. The (IoT) is one of the most hopeful approaches in improving the quality of human life. This is through healthcare monitoring and remote telemedicine support systems, which are able to deliver real time data collection, transportation and visualization through the Internet [2]. IoT provides immediate access to hospitals and doctors by measuring and processing vital signs of Patients. This helps in decreasing the death rate caused because of the heart failures and strokes. IoT based healthcare applications will have great impact on global economy by (2025). There are various applications of IoT in healthcare such as Glucose level sensing which monitor the blood sugar level using non-invasive techniques. Body temperature sensors that record and transmit temperature. Oxygen level measures oxygen percentage in blood using non-invasive method. Home monitoring is a method that can help health systems operate more carefully with patients and physicians. The existing remote monitoring solutions have higher cost and complexity. A newer advanced solution reduces the cost compared to traditional delivery models. Every year around17.3Million people die due to cardiovascular diseases and it will increase by(2030) [3]. The performance of the Network configurations is measured using simulation environment. We preferred OMNET++ Version 5.0 (Objective Modular Network Testbed) object oriented modular discrete event network simulation framework with INET framework for OMNET++.

II. IOT APPLICATION LAYER PROTOCOLS

In this section, we review three IoT application protocols that are used for message passing and that have been standardized by several standardization organizations. There are many application protocols:

1. *Hyper Text Transfer Protocol (HTTP):*

The HTTP is an application level protocol for distributed, collaborative, hypermedia information systems. The HTTP is a generic and stateless, protocol which can be used for many tasks beyond its use for hypertext, such as name servers and distributed object management systems, through extension of its request methods, error codes and header. A feature of HTTP is the typing and negotiation of data representation, allowing systems to be built independently of the data being transferred. The HTTP protocol is a request/response protocol. A client sends a request to the server in the form of a request method, URI, and protocol version, followed by a Multipurpose Internet Mail Extensions (MIME) -like message containing request modifiers, client information, and possible body content over a connection with a server. The server responds with a status line, including the message's protocol version and a success or error code, followed by a MIME-like message containing server information.

2. *Constrained Application Protocol (CoAP):*

CoAP is an application protocol used to equip constrained environments with HTTP (e.g. request/response) web transfer mechanisms. CoAP has been provided with a built in registration mechanism which makes the protocol also appropriate to pub/sub applications. One of the main design goals of CoAP was to minimize the message overhead and constrain the packet fragmentation[5].

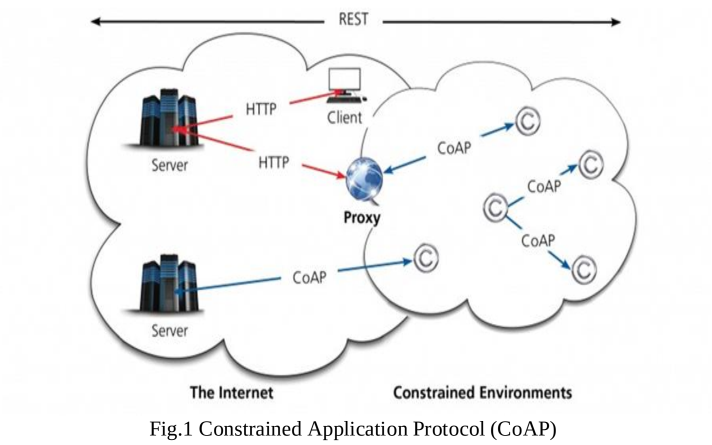

Fig.1 Constrained Application Protocol (CoAP)

3. *Message Queue Telemetry Transport (MQTT):*

It is a lightweight protocol appropriate for devices with bounded processing and memory capabilities, in order to send data over low bandwidth networks. MQTT defines three Quality of Service (QoS) levels for message delivery. With QoS 0, messages are delivered at most once (MQTT is as reliable as TCP); with QoS 1, messages are delivered at least once by means of acknowledgments (PUBACK or SUBACK); with QoS 2, messages are delivered exactly once[5]. MQTT based on the pub/sub model , where multiple clients can build a connection with broker in order to:

i) subscribe to specific topics and then receive the published messages rested to these topics.
ii) publish messages to topics.

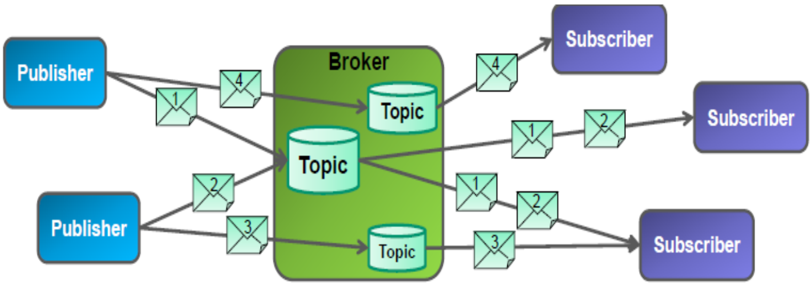

Fig.2 Message Queue Telemetry Transport (MQTT)

III. RELATED WORK

Number of Researchers has participate their efforts for developments of many IoT based healthcare applications. Researchers have worked on a reference model for IoT implementations. For example,

Y. Liao (2016) [2] In this paper, an analytical and precise in to out (I2O) human body path loss (PL) model at 2.45 GHz is derived relied on a 3D heterogeneous human body model under safety constraints.

P. Salunke and R.Nerkar (2017) [3] in this paper, It is impossible for the large population of elders to follow up the classical healthcare, This system is valuable for doctors who are suppressed with patient load and beneficial for rustic patients who have least arrival to healthcare facilities.

N.Manh Khoi and C. Ahlund (2015) [4] in this paper they specified numerous network related requirements of a remote health monitoring system, like low bandwidth consumption, specially upload bandwidth. In This paper they suggest and evaluate an architecture named IReHMo. IReHMo is capable of combining many types of home automation sensors and healthcare IoT devices in the sensing layer.

N. De Caro and W. Colitti (2013) [5] In this work, they have focused on CoAP and MQTT, two lightweight application protocols capable of satisfying most requirements of smartphone based assemble sensing applications in terms of performance. thus, they have compared and discussed in detail these two protocols from a qualitative perspective and then from a quantitative one.

T. Reschka and T. Dreibholz (2010) [7] In this paper, they describe the improvment of the TCP module, which is part of the INET framework for OMNeT++.

N. Bui and M. Zorzi (2011)[8] In this paper, they characterize how IoT can be the main enabler for distributed health care applications and, how health care is one of the most promising killer applications for the IoT.

A.Mohammad Rahmani and N. Kumar Thanigaivelan (2015) [9] here, they presented the concept of Smart eHealth Gateway, The gateway serves as a bridge for medical sensors and home,hospital building automation appliances to IP based networks and cloud computing platforms.

IV. METHOD & TOOLS

Fig.3 show the IoT healthcare network which include sensors, gateways, internet cloud, server and clients.

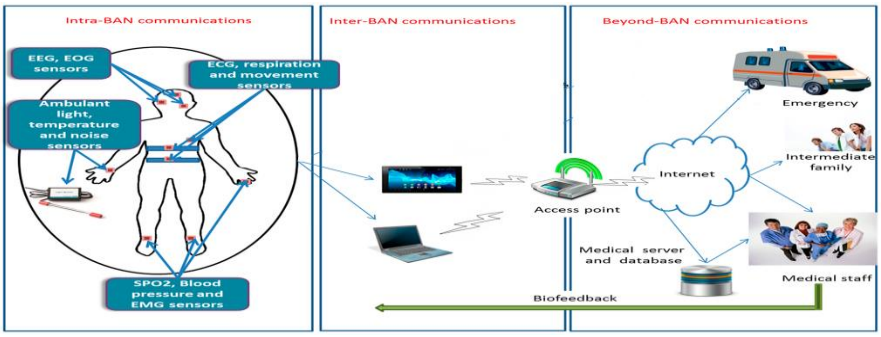

Fig.3 IoT Healthcare network.

As mentioned in the Introduction section we are using Simulation environment with OMNET++ and INET framework to carry out our experiment. The proposed design for health monitoring consist of telemedicine system with different line as shown in the fig. 4 below. The telemedicine system extend over network that include individual health monitoring systems that connects a medical Broker via the internet. The different lines in the system architecture are intelligent and provide some forms of analysis, real time diagnosis are often possible in some rare cases. The Medical Broker is developed to serve hundreds or more end users. The sensor nodes which are either implanted or worn on the body are designed to privately sample vital signs and transfer the sampled signs (data) through a wireless personal network implemented using ZigBee (IEEE802.15.4). we have implement four scenarios each scenarios includes subscribers, publishers and single Medical Broker and there is a compounds module that represent the patients rooms ,in fig.4 below shown The proposed design of the first scenario.

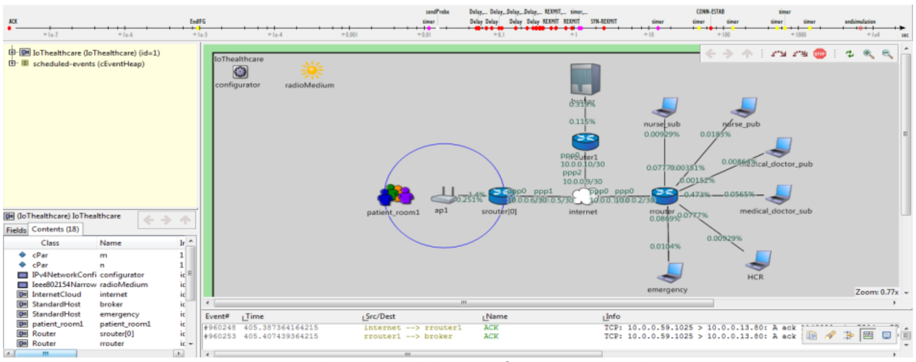

Fig.4 The proposed design of MQTT protocol.

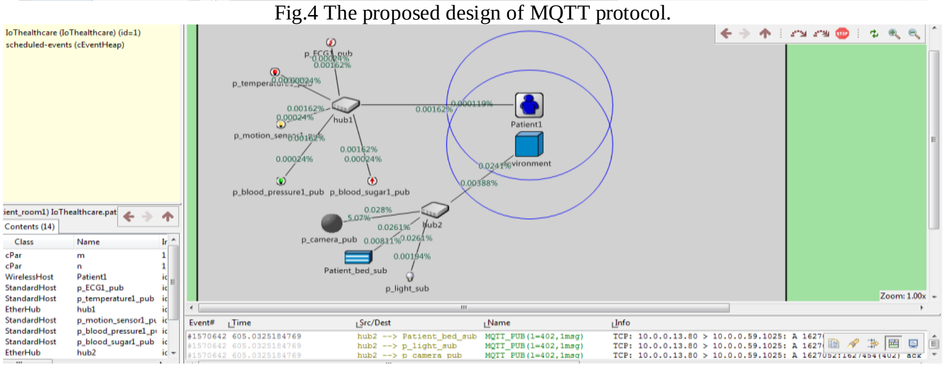

Fig. 5 compound module (patient room).

As shown in fig.4 and fig.5 above There is one compound module(Patient Room) in the proposed design, each Patient Room have several tiny sensor nodes which are placed in some important locations on the human body, resulting in a wireless sensor body area network (WBAN) that is capable of monitoring different vital signs, multiple sensor nodes that monitor temperature, blood pressure, sugar level, motion sensor , ECG and the environment object(Patient bed sensors, camera and light), these signs are transferred via Zigbee to the access point (AP) and then to the MQTT Broker via the internet cloud , HCR is the HealthCare Record databases. The sensor nodes on the patient's body publish the information to a specific topic in the Broker, then the subscribes subscribe to these topic and keep track of patients status. We have used the wireless host Modules nodes and standard host Modules. the MQTT App is added in the application layer of the Broker, publisher nodes and subscriber nodes.

V. HTTP IMPLEMENTATION

The HTTP implementation can deliver sensor data using HTTP GET method. To get a sensor value, the monitoring side has to establish an HTTP session with the home gateway, therefore HTTP packets can be exchanged. The HTTP protocol implemented in OMNET++ by using the INET framework httptools modules which has two source files one named as (http browser)for clients and the other named as(http server)for servers, the subscribers in MQTT converted to servers in HTTP and the publishers in MQTT converted to clients in HTTP, the simulation parameters is shown in table.1, Fig.6 show the HTTP implementation in the first scenario.

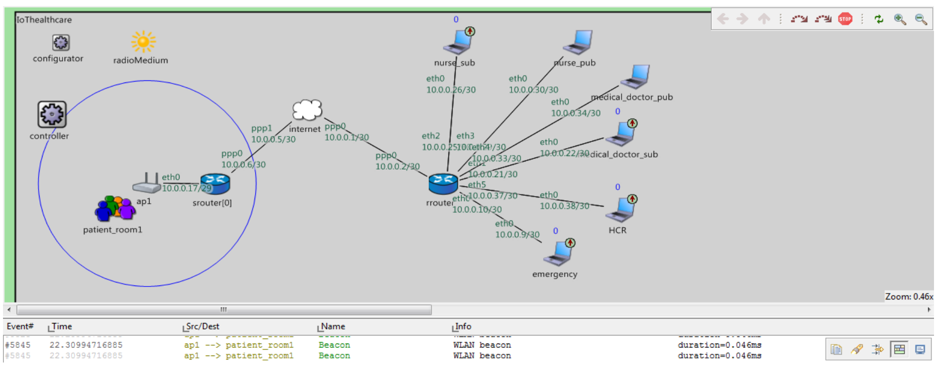

Fig.6 HTTP implementation.

The radio medium used is (Ieee802154NarrowbandScalarRadioMedium) the radio medium parameters configured in the INI file, Table. 1 show the radio medium parameters.

TABLE 1
THE RADIO MEDIUM PARAMETERS

parameter	value
Radio transmitter power	10mW
Radio transmitter bitrate	2Mbps
Radio transmitter header Bit Length	100b
Radio transmitter carrier Frequency	2.4GHz
Radio transmitter bandwidth	2MHz
Radio receiver sensitivity	-85dBm
Radio receiver SNR Threshold	4dB

The MQTT and HTTP simulation parameters of the simulation environment have been shown in Table.2.

TABLE 2
MQTT AND HTTP SIMULATION PARAMETERS

Device	Think time exponential(s)	Request length exponential (B)	Data rate(B/s)	Idle interval exponential (s)
Patients(gateway)	1	350	350	3
Environment(gateway)	7	650	92.85	3
Temperature sensor	1	1000	1k	1
Motion sensor	2	7000	3500	1
Blood pressure sensor	3	1000	3k	1
Blood sugar sensor	4	8000	2k	1
ECG sensor	5	12000	2400	1
Camera	6	4000	666	3
Patient bed	5	350	70	3
Light	3	150	50	3
Emergency	1	450	450	2
HCR	1	250	250	2
Medical doctor pub.	2	350	175	2
Medical doctor sub.	2	650	216.66	2
Nurse pub.	3	550	183.33	2
Nurse sub.	1	550	550	2

VI. RESULT

The average throughput have been calculated by using the thruputMeter modules, this module is inserted between TCPApp layer and TCP as shown in Fig.7.

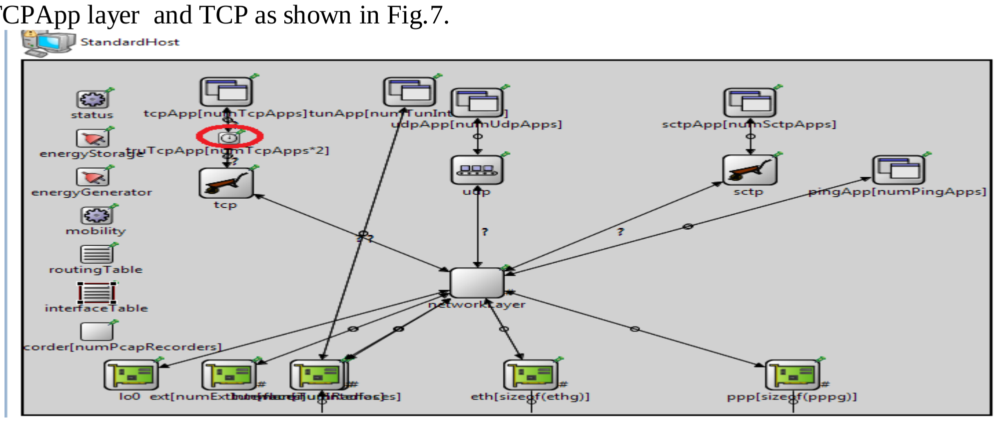

Fig.7 Standard Host with thruputMeter modules between tcp & tcpApplayer.

The results of the experiments are collected in anf file in OMNET++ and graphed in Excel. The Throughput of the network nodes is shown in fig.8 and fig.9 below, Throughput is number of bits transferred per second. The average throughput formula is shown in equation below.

Throughput = I / T ....(1)
Where:
I :- Data Rate .
T:- Time.

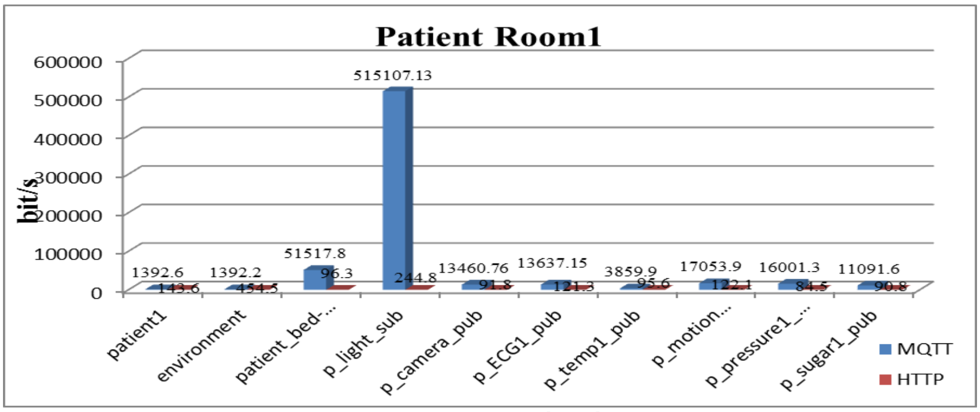

Fig.8 Patient Room1 Throughput

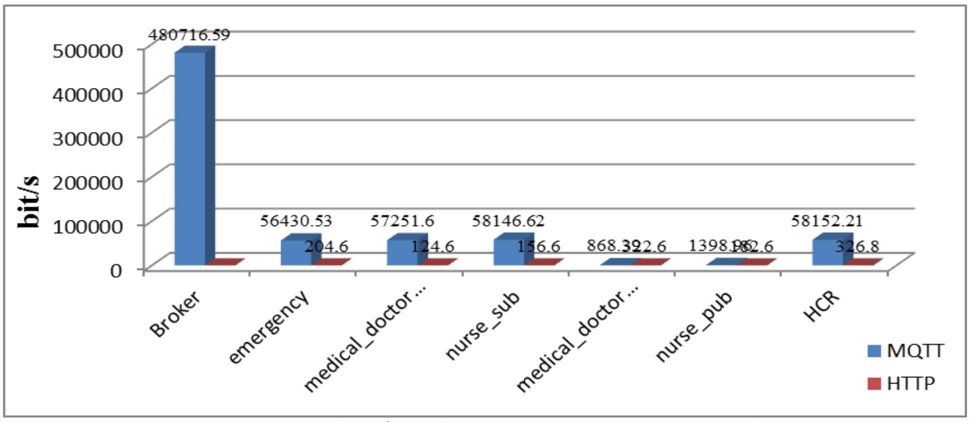

Fig.9 Average throughput for Broker, Doctors, Nurses, emergency and HCR.

End to end Delay (mean) or one way delay (OWD) indicates that the time taken for a packet to be transmitted across a network from source to destination. end to end Delay shown in fig.10 and fig.11 The end to end Delay can be calculated by the equation below.

D nodal= D proc + D queue + D trans + D prop…………(2)
Where:
D nodal : the average end to end Delay.
D proc : the processing delay.
D queue: the queueing delay.
D trans : the transmission delay.
D prop : the propagation delay.

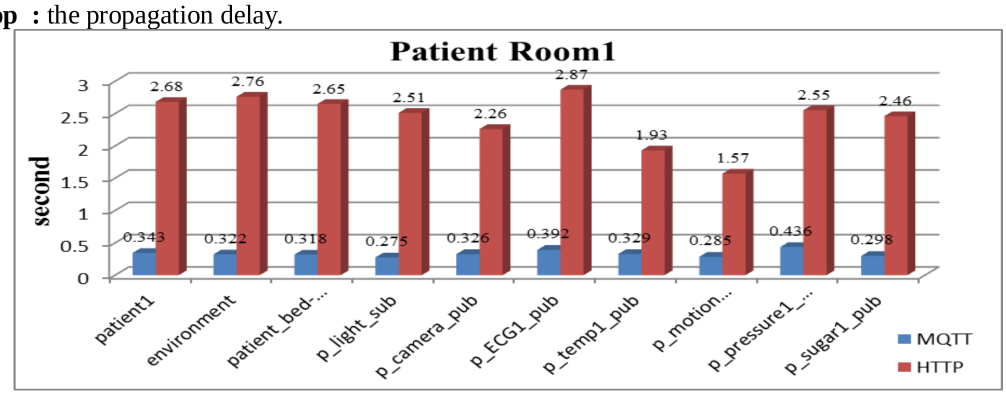

Fig.10 Patient Room1 end to end Delay.

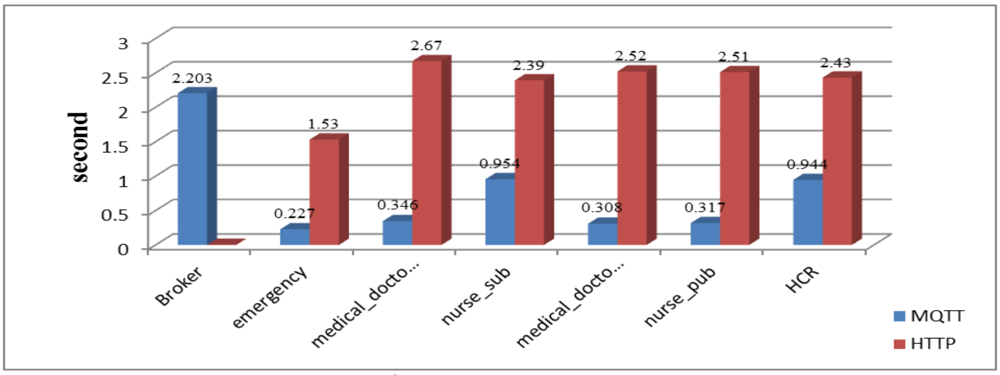

Fig.11 end to end Delay for Broker, Doctors, Nurses, emergency and HCR.

The average throughput and end to end Delay for MQTT, HTTP and the number of publishers and subscribers in all scenarios shown in Table.3 below.

TABLE 3
THE AVERAGE THROUGHPUT AND END TO END DELAY FOR MQTT, HTTP AND THE NUMBER OF PUBLISHERS AND SUBSCRIBERS IN ALL SCENARIOS

Scenario	MQTT Throughput(bit/s)	HTTP Throughput(bit/s)	MQTT End to end Delay(second)	HTTP End to end Delay(second)	Number of Publishers and clients	Number of subscribers and servers
Scenario1	79851.6	179.55	0.281	2.256	10	6
Scenario2	20935.44	209.7	0.297	2.351	18	8
Scenario3	30734.1	223.2	0.355	2.524	28	12
Scenario4	16786.9	216.8	0.386	2.714	38	16

From the table.3. above we have notice that when the number of publisher and the number of subscribers the average throughput decreased and the end to end Delay increased this happened because of the congestion occurred. The average throughput for all scenarios is shown below in fig.11.

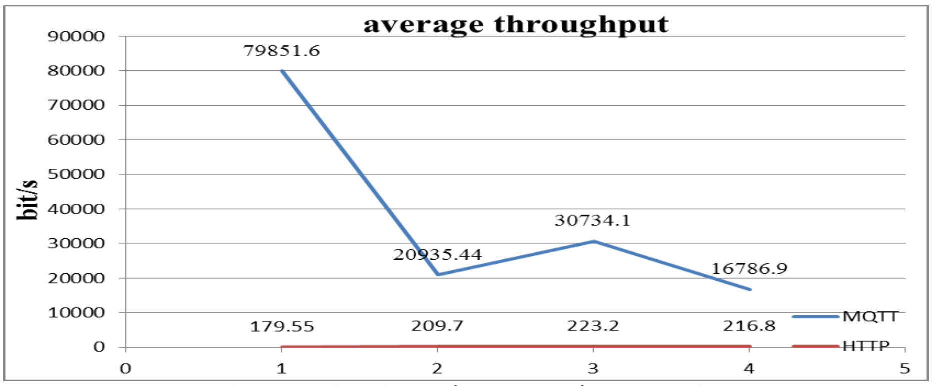

Fig.12 The average throughput in four scenarios for MQTT and HTTP .

From fig.12 we notice that when the average throughput is very effected by the number of publishers and the number of subscribers when is increased the average throughput decreased due to the congestion.Fig.12 below is show the average end to end Delay in all scenarios.

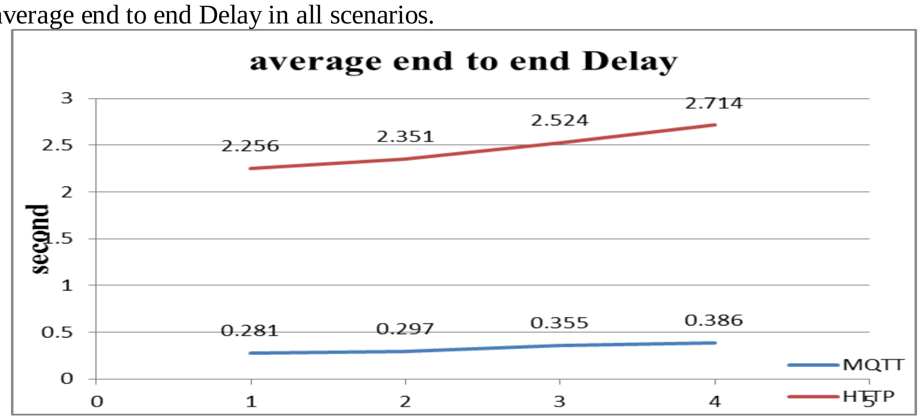

Fig.13 the average end to end Delay in four scenarios.

When we see fig.13 we notice that the average end to end Delay is increased when the number of publishers and subscribers increased.

VII. CONCLUSIONS

In this paper The IoT is used by healthcare to monitor physiological statuses of patients through sensors by collecting and analyzing their information and then sending analyzed patient's data remotely to processing centers to make suitable actions. Not only for patients, it also useful for normal people to check the health status by using wearable devices with sensors. we use and analyze the MQTT protocol and take four scenarios and evaluate the proposed design by using OMNET++ simulation environment and its INET frame work, from the results obtained its noticed that the efficiency of the Medical Broker decreased when the number of subscribers and publishers increased because of the congestion, the throughput in the Medical MQTT Broker in scenario1 is(480716.6 bit/s) and the end to end Delay is (2.203 second) and in the last scenario (scenario4) the throughput is(64608.03 bit/s) and the end to end Delay is (190.18 second). In fig.12 we notice that the MQTT protocol have throughput higher than the HTTP protocol throughput and the HTTP protocol have end to end Delay in fig. 13 higher than MQTT protocol end to end Delay so that we can consider that the MQTT protocol is better than the HTTP protocol.

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