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Evaluation of MQTT Protocol for E-Learning

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Abstract-----In this paper, we aim to apply the Internet of Things (IoT) technology to the E-learning system and create e- learning system that uses available learning resources all over the world. There many application protocols in IoT, this paper will focus on the use of Message Queue Telemetry Transport (MQTT) to the proposed e-learning system. MQTT will be evaluated for the e-learning application. The evaluation will be carried out using network simulation for different e-learning scenarios. The study is carried out by means of simulation using OMNET++ and we develop simulation model by using INET framework. The study found that the average end to end delay (mean) will be increased, when packets received and sent increase and the congestion will be increased in broker when the number of MQTT clients (publishers and subscribers) are increased resulting in stopped working broker before completing the time limit for these scenarios

Keywords---- IoT, e-Learning, MQTT, OMNET++, INET

I. Introduction

Internet of things (IoT) is a prevalent technology that provides communication and collaboration between the physical and virtual objects. As it develops, it grows in size and dimension impacting different aspects of our life such as the education. Based on the primary idea of IoT, all objects that obtained IP address will be able to interact with each other physically and virtually. The main structure of Interne of things is based on the data sensed by sensors, tags or actuators and sending it through a gateway to a cloud system. The interaction in the IoT includes Machine-to-Machine, Object- to Machine or Object-to-object types [1]. The goal of the Internet of Things is to enable things to be connected anytime, anyplace, with anything and anyone ideally using any path/network and any service [2]. The Internet of Things (IoT) is the prevalent phenomenon that supports creativity in many fields. The area of education (e-education) is one of these fields. As IoT can be joined with other IT technologies, it can offer a vast variety of the e-educational technologies which can change the future of the education systems. The future education centre will be equipped with smart objects. Students and teachers authenticate their validity of as users passing finger-prints and RFID ID Card in front of the reader, mobile checking in order to enter to the physical rooms or access to the automatic system management of the campus or the school. The IoT classrooms in the future include the sensors to validate the access of the educators and students. The smart whiteboards and desks will be furnished with the RFID or WSN devices that can physically detect the users [1]. This allows the educative objects, such as students, connected online to the labs, library, didactic materials, assessments, and educational messages and administrative tasks in an efficient manner (effective e-learning) in a large-size virtual classroom [1].

II. Related Works

Majid Bayani et al. [1] focused on the research associated to the benefits of the e-learning in the smart cities. In this paper a concise review of the benefits that Internet of things can bring up is explored. Internet of things is changing the scheme of actual educational system. IoT provides a very efficient communication between objects physically and virtually. Also, it makes a possible connections between the physical world and the Internet which before was not feasible. IoT enables the global connection of different points, centres, institutes, labs, libraries, entities, organisms, organizations, companies, agencies located around the world to the physical objects. A theoretical analysis was developed in order to study the main benefits of the IoT on the e-learning in the smart environment and communities. **O. Said and Y. Albagory [10].** They aim to apply the Internet of Things (IoT) technology to the E-learning environment and create a global learning system that utilizes available learning resources all over the world. They introduce a simple F-learning architecture consisting of smart classrooms and remote and virtual labs. They apply the Constraint Application Protocol (COAP) to the proposed F-learning system. Network simulator NS2 is used to compare the efficiency of the F-learning environment to a traditional E-learning one. The simulation results show that the F-learning system has lower packet loss and delay in addition to larger throughput compared with the traditional E-learning system. **D. Soni and A. Makwana** [11]. This paper focuses on describes the evolutions and the importance of MQTT in IoT. They indicate in the paper there are various brokers implemented for MQTT protocols but each one has some limitations and no one implements priority of data. This paper describes the importance of MQTT in IoT, the architecture of MQTT, deferent domains where MQTT is used, different brokers of MQTT, current issues in MQTT and future trends. The result show, MQTT simplicity and open source code make this protocol suitable for constrained environments like IoT which has low power, limited computation capability and memory, and limited bandwidth.

III. Background

1- Message Queue Telemetry Transport (MQTT)

MQTT is a messaging protocol that aims at connecting embedded devices and networks with applications and middleware. The connection operation uses a routing mechanism (one-to-one, one-to-many, many-to-many) and enables MQTT as an optimal connection protocol for the IoT and M2M. MQTT utilizes the publish/subscribe pattern to provide transition flexibility and simplicity of implementation as depicted in Figure (1). Also, MQTT is suitable for resource constrained devices that use unreliable or low bandwidth links. MQTT is built on top of the TCP protocol. It delivers messages through three levels of QoS. The specifications provide three elements: connection semantics, routing, and endpoint [3].

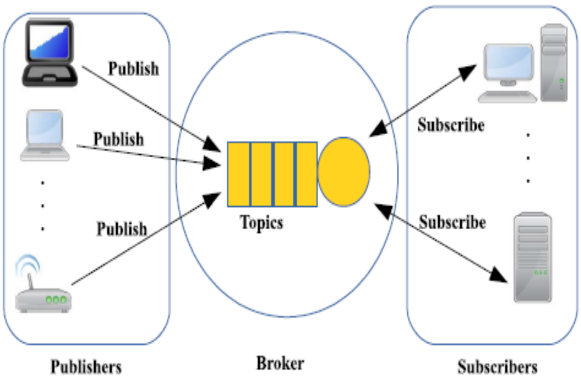


Figure (1): The architecture of MQTT [3]

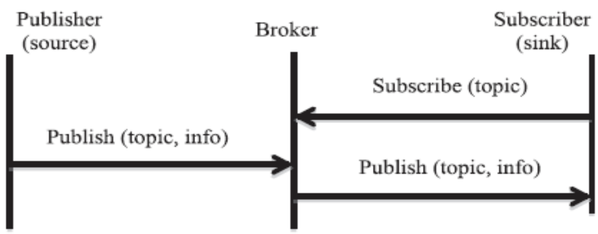


Figure (2): Publish/subscribe process use by MQTT [3]

MQTT simply consists of three components, subscriber, publisher, and broker. An interested device would register as a subscriber for specific topics in order for it to be informed by the broker when publishers publish topics of interest. The publisher acts as a generator of interesting data. After that, the publisher transmits the information to the interested entities (subscribers) through the broker. Furthermore, the broker achieves security by checking authorization of the publishers and the subscribers. Therefore, the MQTT protocol represents an ideal messaging protocol for the IoT and M2M communications and is able to provide routing for small, cheap, low power and low memory devices in vulnerable and low bandwidth networks. Figure (2) illustrates the publish/subscribe process utilized by MQTT and Figure (3) shows the message format used by the MQTT protocol. The first two bytes of message are fixed header. In this format, the value of the Message Type field indicates a variety of messages including CONNECT (1), CONNACK (2), PUBLISH (3), SUBSCRIBE (8) and so on. The DUP flag indicates that the massage is duplicated and that the receiver may have received it before.

0	1	2	3	4	5	6	7
Message Type				UDP	QoS Level		Retain
Remaining Length (1~4 bytes)							
Variable Length Header (Optional)							
Variable Length Message Payload (Optional)							

Figure (3): MQTT message format [3]

2-Basic IoT Structure in E-learning

A Basic System Architecture of IoT is illustrated in Figure (4). As Figure (4) displays, the basic IoT architecture is divided into three layers: application, network and perception layers [6, 7].

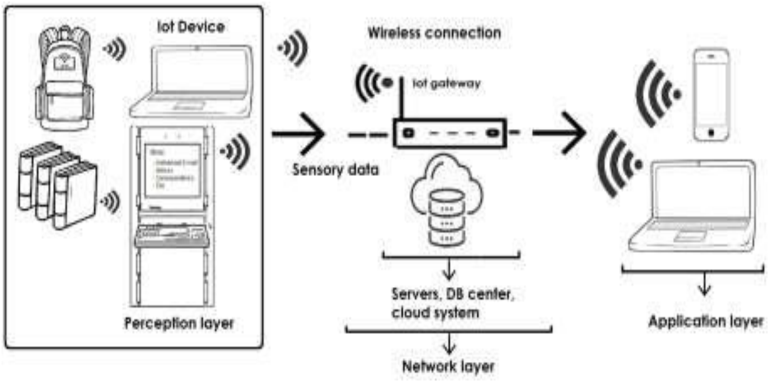
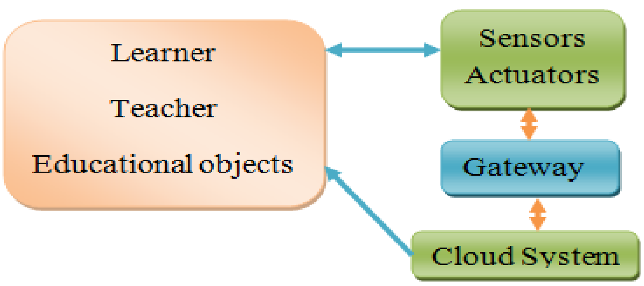


Figure (4): A Basic Architecture of IoT in Education [6]

The application layer provides services to user applications using an interface. The network layer is in charge of providing connection between nodes and gateway. The gateway point is considered as an intermediary between the application and perception layers, in order to obtain the data sensed from the sensor nodes in the perception layer and send information to a cloud system. Moreover, the perception layer includes the physical objects or sensors that can sense an event or object action. A small sensing system in this layer is responsible for sensing (WSN) and storing the data sensed. Figure (5) has demonstrated a basic IoT educative structure where IoT devices detect the events, object tracking or any data in the perception layer. The sensory data will be sent to the gateway, stored in a small cloud system. The data after processing could be used for further decisions.



[لاداعي لهذا الرسم] Figure (5): A Basic IoT Educational Architecture

IV. Method & Tools

1- A simulation model

In OMNeT++, the most important elements beside events are modules. There are two different types of modules: (1) simple modules; and (2) compound modules. Simple modules are implemented in C++ and represent the active components of OMNeT++ where events occur and model behaviours are defined. Compound modules are a composition of other simple or compound modules, and are used as containers to structure a model. Unlike simple modules, compound modules are not written in C++. However, they use NEtwork Description (NED), a simple language to describe the topology of the simulation model. The .ned file(s) can either be loaded dynamically or compiled static into binary of the INET framework. The actual simulation model in OMNeT++ is called 'network' which is a compound module. To configure a network one can either specify the parameters for modules in .ned files or in the omnet.ini configuration file. The advantage of using the configuration file is to define simulation runs with various parameter values. This is particularly useful when we run simulations from a script or batch file. OMNeT++ provides two types of simulation data outputs: scalar and vector. A scalar has one single value of the simulation output (e.g., the number of packets received). However, vectors store series of time-value pairs over a certain period such as response times during the simulation. One can add a new statistic by modifying simple modules to log the data of interest and recompile the framework. These statistics are stored in files at the end of simulation and can be analysed later using plove and scalar programs provided by OMNeT++. We develop simulation model by using INET Framework. The following INET Framework modules are used: 'StanderdHost' which is acted the publisher, broker, and subscriber network, 'ChannelControl' for keeping track of the station position and to provide an area for station movement and 'FlatNetwork Configurator' for configuration of IP addresses and routing tables for simple networks. Each of the modules that we use in the simulation was imported from a .ned file. We also develop a compound module by containing the following four elements described below.

1) **Parameters:** Module variables which are used to configure submodules.

2) **Submodules:** Instances of other modules. We can assign values to the parameters of submodules. We define a number of instances of the StanderdHost which are stored in an array called host. The number of instances is determined by a module parameter which allows us to develop simulation model with several stations by changing the numHosts parameter. We also define a variable called display for the modules to display in the GUI.

3) **Gates:** Connection points of a module.

4) **Connections:** Define a connection between two gates or submodules.

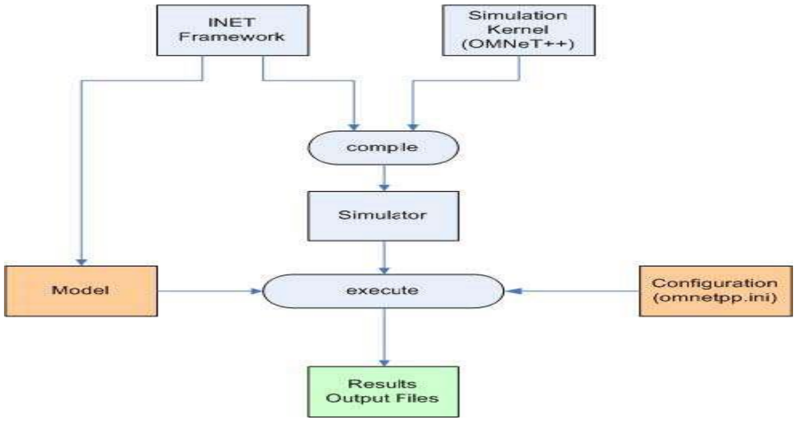


Figure (6): A framework for OMNeT++ with INET

To measure the performance of the present network we use thruputMeter modules. The module NodeBase was extended and used as its basis the StandardHost module implementation, which was modified further to include Thruput-Meter module. This module is placed between TCP and TCPApp layer. Modified structure of standardHost along with thruputMeter is show in figure (8) below.

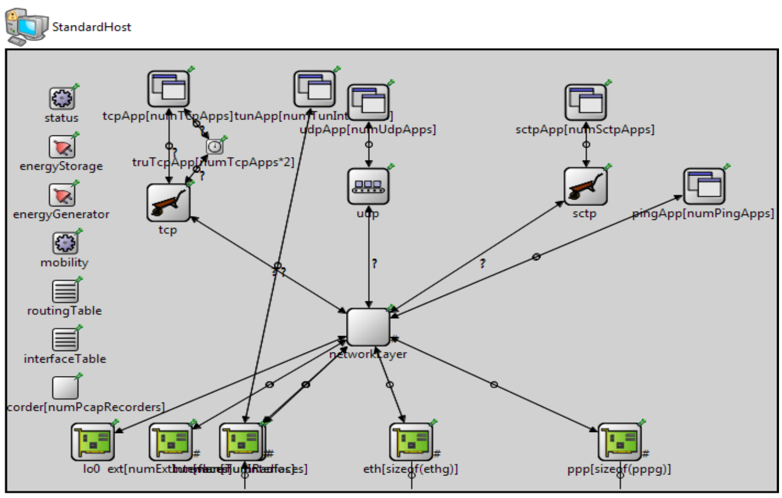


Figure (7): StandardHost with thruputMeter module between tcp & tcpApp

2-Implemented Scenarios

Different scenarios were carried out to get accepted results in order to agree all measurements and to conclude the effects MQTT application protocols. The radio medium used in all scenarios is Ieee80211ScalarRadioMedium and connected viaIPv4 router that supports wireless, Ethernet, PPP and external interfaces and internet cloud to allow data to be exchanged between motes. The e-learning proposed scenarios contain number of rooms which represent classrooms and anther rooms represent laboratory. Each room contains two camera, one sensor temperature, fire detection using in laboratory, number of desk, projector, number of laptop, board, and number of kit in laboratory. Table (1) illustrates the overall parameters that are utilized in all scenarios.

Table (1): simulation parameters

Parameter name	Value
Radio medium and Mac protocols	**IEEE 802.11 scalar radio medium**
Bandwidth	**2MHZ**
Access point	**3**
Bit rate	**2Mbps**
Packet size	**Depends on the traffic type**
Transport protocol	**Tcp**
Buffer size	**1MiB**
Time gap between packets	**Different for each a device**
Carrier frequency	**2.4 GHZ**
Node transmission range	**100m**

The figure (8) shows the nodes, the connections, and the transmitted data.

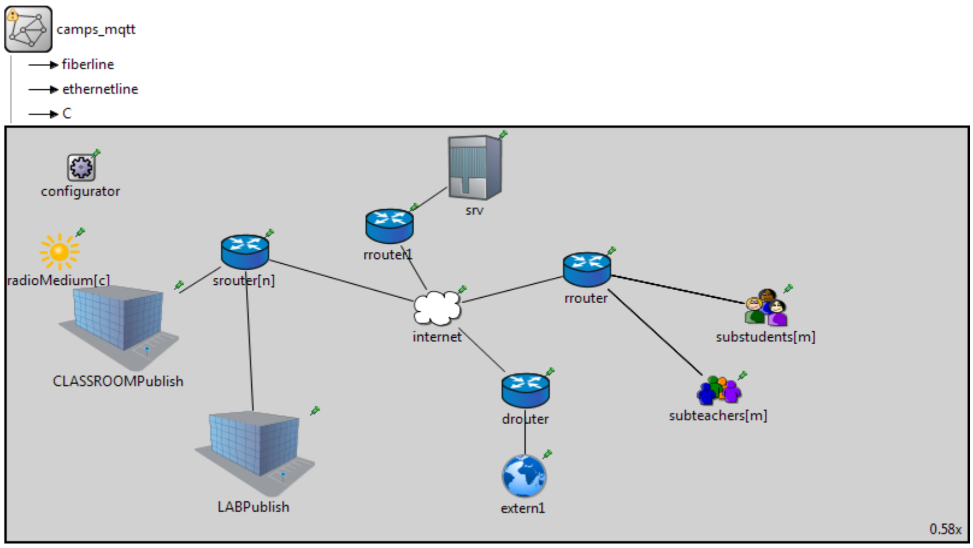


Figure (8): The proposed design of MQTT protocol

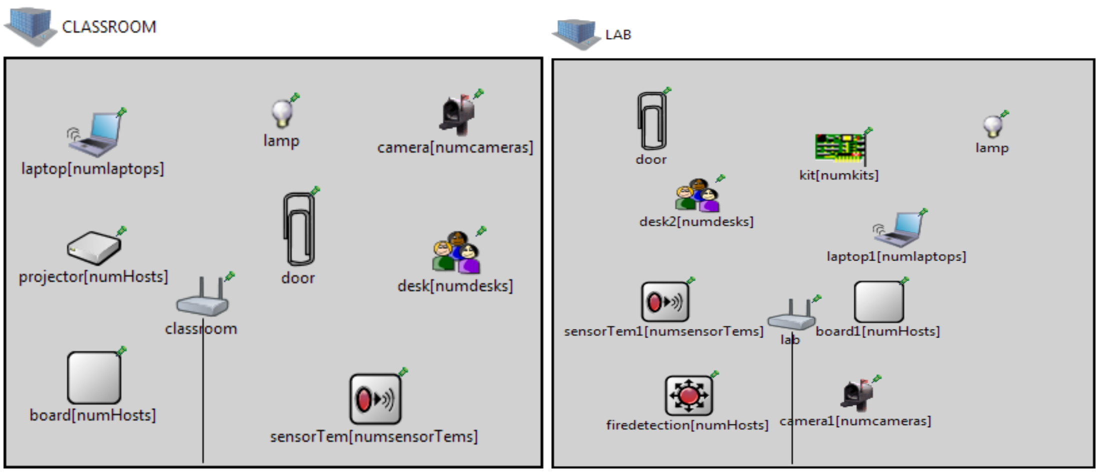


Figure (9): The compound module for classroom & laboratory

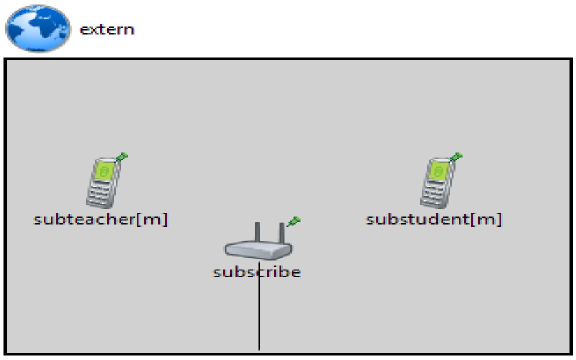


Figure (10): The compound module for Subscriber wireless

V. Results

The simulation results are stored in output files in OMNET++ for later analysis. The key performance metrics used to scale efficiency of evaluation MQTT protocol in e-learning are (end to end delay, send, receive, and throughput). Table (2) illustrates the number of publisher and subscriber that are used in all scenarios.

Table (2): The number of publishers and subscribers in all scenarios

Scenarios	Number of publishers	Number of Subscribers
First	44	22
Second	414	34
Third	940	46
Fourth	414	58
Fifth	558	96

1- Average End to End delay

This key performance metric is end-to-end delay to every packet received from a low layer and forwarded into a high layer at a network system. Typically, it can be calculated by:

$$\frac{\sum(arrival\_time - sent\_time)}{\sum number\_of\_connections}$$

Largest end to end delay mean appears in fifth scenario till 34 sec due to increase the number of subscribers and publishers in this scenario which lead to rise in number of packets are received and sent.

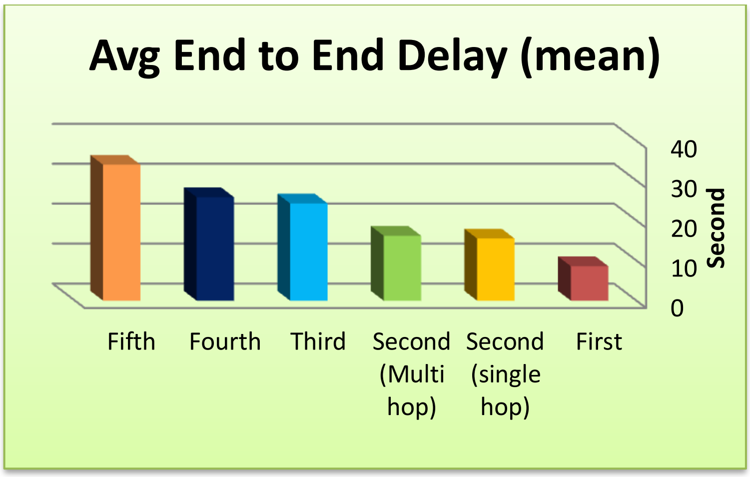


Figure (11): Average End to End Delay

2-Average send and receive

These are represented number of packet sent and received (bits/sec) in each scenario. The largest average send and receive are registered in the Fourth scenario, average send till 2355460.436 bits/sec and the average receive is till 387452.4287 bits/sec due to the increase in a number of subscribers which lead to rise in a number of packets are sent and receive.

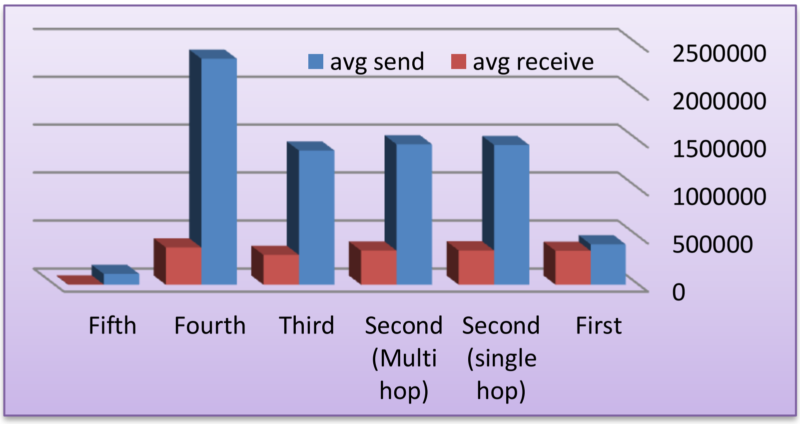


Figure (12): Average send and Average receive

3- Average throughputs

This key performance metric is measured through a total number of packets received correctly inside the interval at a network system. We will be measurement throughput by using thruputMeter module to evaluate the network performance. Typically, it can be calculated by:

Throughput (bits/sec) = (sum (number of successful packet) * (average packet_ size)) / Total Time sent in delivering that of data

Average throughput to all scenarios shows in the figures below. The largest average throughput is registered in the fourth scenario till 3124 packets/sec due to number of receive packet to time.

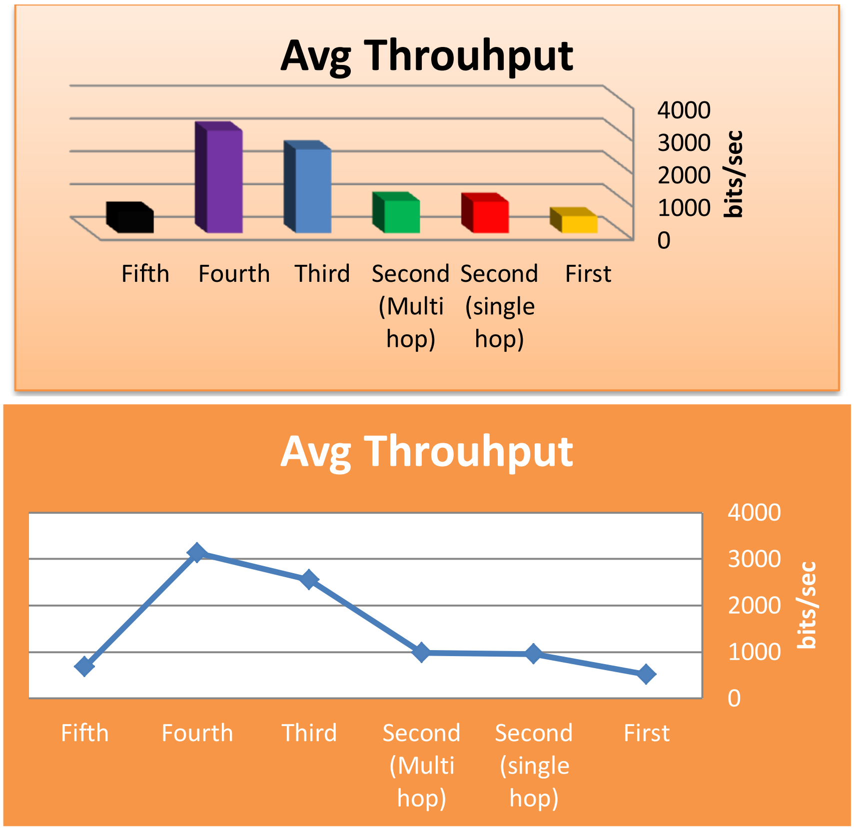


Figure (13): Average throughput

VI. Conclusion

This paper is interested with studying and applying MQTT protocol in the e-learning environment .we use OMNeT++ simulation with different scenarios .The results of the scenarios are collected in anf file in OMNeT++, we take the scalar file result. The proposed system will improve teaching and learning process in future. IoT will bring ease for both students and teachers. Students will learn better, and teachers will be able to perform their duties more efficiently. We are used for new technologies for education, like high-speed wireless networks which provide the bandwidth for audio and video streaming of lessons and wire networks. The simulation results show average end to end delay in different scenarios will increase when packets received increase and the congestion will be increased in broker when the number of MQTT clients (publishers and subscribers) are increased ,average send and receive will increase when MQTT clients are increased , and average throughput will be measured by using ThruputMeter models ,this models will put between Tcp and TcpApp, average throughput will be increased when increase number of packets received then it will starts to decrease and it starts to degrade for the wireless network.

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