Evaluation of the MQTT Protocol Latency over Different Gateways

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ABSTRACT

The modern world of information and technology has progressed hugely in the past decade. There is no doubt that internet of things (IoT) technologies have developed gradually and evolved the last ten years in drastic ways. IoT combines the useful to pleasant with is implementation in the industry, it is from this concept comes the idea of the industry 4.0. Managing huge amount of data and its uncertainty is very important challenge in the industry field; accordingly, providing the quality of service is a striking requirement that ensures it is operating accurately. This paper deals with the estimation of latency in transferring data from the field to the Cloud based on lightweight protocol MQTT over different gateways, we implemented the IoT tool Node-RED in the gateway for simulation.

KEYWORDS

Industry 4.0, MQTT broker, MQTT Latency, IoT Gateway, Fog Computing,Groov edge opto22; Siemens IoT2040.

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1 INTRODUCTION

The goal of progress in computer science is to make it inseparable from our everyday experience while making it disappear. This evolution implies the transition to the third era of computing which is ubiquitous computing [1]. There is a wide variety of expressions used to describe this era, many of which are associated with a specific goal; the most widespread expression is the Internet of Things [2]. The latter has changed the way people communicate, and express themselves, many studies have been devoted to concretize this paradigm, and to make it real.

The emergence of internet of things has allowed a convergence of industry to industrial internet of things. Nowadays, several companies whose activity is the industry are facing severe competition from their worldwide counterparts in terms of product price function, quality, cost, lead-time, etc. For this reason, they are interested more and more in the Internet of Things. This last allows machine-to-machine communication without the intervention of human and promises to bring greater speed, efficiency, and advanced computing in the field of industry. [3][4] Many protocols have a very important role for satisfaction of quality of services in IOT; this last has several layers, and each layer uses the protocols that can be satisfy many factors in terms of performance. We focused our study on application layer and his famous protocol MQTT [5]. Actually, delivering data requires flexibility, scalability and geographic coverage, although there is not a universally solution for delivering it in safe, and timely manner to the very different applications involved. Latency is one of the keys and indicator that determine the performance of services [6]. So, test the latency of protocol MQTT over different gateways is an obvious and required, that's permits to determine the quality of services on application layer. The paper is structured as follows. In section 2 a brief overview of some terminologies: IOT and his protocols, IOTT 4.0 is provided. In section 3 the considered scenario is highlighted; the experimental setup and results are shown. Finally, concludes the paper

2 INVOLVES TECHNOLOGIES

2.1 Internet of things

For the sake of understanding how the IOT works, grasping the architecture seems very important. This last can be divided into four layers; The perception layer that attribute to physical device, the network layer which permits to send the data produced by the perception layer to the middleware layer in addition, the middleware layer processes data, warehouse, computing and storage using services like cloud Computing and fog computing. Finally, the Application Layer provides the services requested by customers providing the system output information to the user that requests that information. [2][7].

2.2 Fog Computing

Fog computing is a new paradigm of computational and storage that's extend the cloud computing to the edge of the network. The main value of fog computing is reacting quickly to changes in the streaming data that is coming from the end user. Although, fog devices can request certain computations to take place in the cloud servers. Moreover, they can interact with other fog devices located in different areas. The cloud computing, unlike the fog computing, typically takes place in a backend data center, with data being distributed from more or less centralized resources to consumers on the edge of the network. [8][9].

2.3 MQTT

The application layer is responsible for presentation and for data formatting. The application layer in the internet stack is based on HTTP. Some of the well-known standard protocols that's aim to interconnect the things and end-user applications to the Internet of Things are MQTT (Message Queuing Telemetry Transport), CoAP(Constrained Application Protocol), XMPP (Extensible Messaging and Presence Protocol) and WAMP (Web Application Messaging Protocol). [10]

MQTT (Message Queuing Telemetry Transport) introduced by IBM is another example of web messaging application protocol, whose effectiveness is becoming increasingly popular in popular applications such as Facebook social messaging.
Now, its application for applications based on M2M communications in IoT is widely investigated. The operating principle of the MQTT protocol is usually focused around the model publish/ subscribe. The protocol works over the TCP protocol, with a sufficiently simple communication mechanism to better respond to the strong constraints of sensor networks connected to the Internet. [10]

From the architectural point of view, the sensor nodes are publishers who all connect to a central entity called broker. Each message is published at the broker in the topic. Subscribers can subscribe to several topics. Whenever a new message is published in one of the items of interest, it will be immediately distributed to interested subscribers. In the figure below, an example of the M2M communication architecture in MQTT is illustrated. [11] [12]

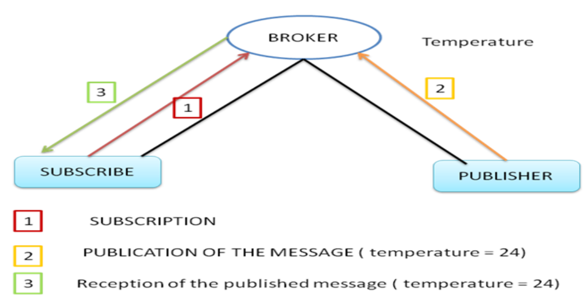

Figure 1: the M2M communication architecture in MQTT

The efficiency of the MQTT protocol has been approved for certain applications such as: medical and industrial applications. It has even been shown to be a good solution for mobile applications in constrained environments as it has a low memory footprint, low power consumption, and better distribution of information to recipients.

2.4 Industry 4.0

The field of industry and intelligent manufacturing are facing the new paradigm "industry4.0". The Industry 4.0 concept was born by applying the ideas of CPSs and IoT to the industrial automation domain, in order to create smart products, a smart production, and smart services [13]. The idea of Industry 4.0 was adopted in 2011 for developing German economy, as a next industrial revolution [14], where new technologies must be compatible with legacy and old systems. The Industry 4.0 must also assure the interoperability between technologies from different vendors, ensuring scalability and real time interaction protocols for large scale systems [15]. Industrial companies offer nowadays several solutions of factory equipment, connecting machines from distinct vendors and divers time periods that conform to different standards [16], Moreover, the concept Industry 4.0 is achieved, when the systems of factories and the infrastructure deploy the IT network and electronics for automated production [17], which complicate furthermore the system, that has to overcome in the same time different challenges. These challenges include, security, standardization of protocols, interoperability, Fog/Cloud Computing, Latency and Quality of Service. In order to overcome some of these challenges, the intelligent gateways play a vital role by offering a transparent operation between the IT and the Machine worlds. The IoT gateway links different objects to the internet in the industrial environment and able to operate as a join interface among different networks and support different communication protocols [3].

3 EXPERIMENTAND ANALYSIS

In order to test the latency communication, we adopt the End-to-end delay or one-way delay (OWD) technique, by considering the Publish and Subscriber of the MQTT scenario. The Publisher and the Subscriber are consecutively the source and the destination. The Publisher records a timestamp on the packet and sends it to the Subscriber using the MQTT protocol. In the reception, the subscriber notes the receiving time and calculate the End-to-end delay. The delay end-to-end can be defined according to different component, as described in [13]:

$$L = d_{end-end} = Tq + Tpr + Te + Tt + Tr + Tprg$$

Where Tq is the queuing delay, Tpr is processing delay, Te is the channel link establishment delay, Tt is the transmission delay (includes header transmission time Th and payload transmission time Tp), Tr is the routing delay (for multiple hops), and $Tprg$ is Propagation delay.

In this paper we defined the Latency L as a time interval between the Publish in the broker and the subscribe from the same broker, as represented in the figure 2, hence the Latency can be presented as follow:

$$L = T2 - T1 = d_{end-end} = Tq + Tpr + Te + Tt + Tr + Tprg$$

In order to send data through the cloud, we opted for the architecture Publish/Subscribe; In this regard we used the protocol MQTT over different situation and we calculate Latency between Subscriber and Publisher.

Case 1:

- ➢ The subscriber is placed in the PC in University Abdelmalek Essaadi in Tetouan
- ➢ The MQTT Broker is placed at the campus of the University of Cartagena in Spain
- ➢ The quality of services used is QOS0
- ➢ For reason to simulate the fog computing the broker and the publisher are placed at the same city Cartagena in Spain

Case 2:

- ➢ The Publisher is placed at the Center of formation professional of San Juan Bosco university in Cartagena Spain.
- ➢ The subscriber is placed in University Abdelmalek Essaadi in Tetouan
- ➢ The MQTT Broker is placed in different location on the internet.
- ➢ The quality of services used is QOS0

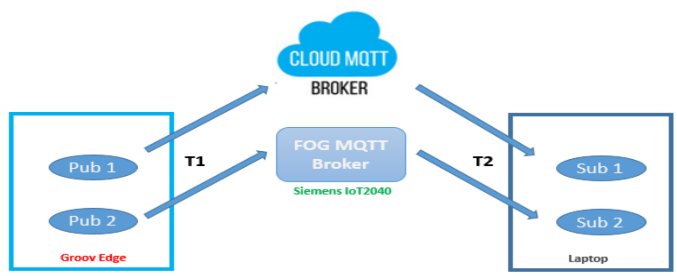

Figure 2: Publish and subscribe for the two different Brokers

Table 1: Routes from the Publisher and the Subscriber through different MQTT Brokers

	Cloud Broker FromGermany	CloudBroker From Ireland	Cloud Broker fromVirginia (USA)	SiemensFOG MQTT Broker
Average of Hops	**35**	**53**	**45**	**26**
Average of Latency	**161.5ms**	**66.5ms**	**137ms**	**60.5ms**

Before testing the communication latency of the MQTT protocol, we had recourse to the Tracert command, in order to have an overview about the total hops between the source and destination, that are publisher and subscriber through the broker; To calculate the total latency between source and destination, we calculate the sum of delay and number of hops between publisher and broker, and the sum of delay number of hops between broker and subscriber .We illustrate the results Tracert CMD in the Table 1.

According to the relevant analysis of the table, we see that the broker at the level of FoG (Siemens) allows having less latency than those located in the cloud, due to the fact that FoG is closer to the end user than cloud, and number of hops is low compared to the cloud.

Although, as we can see in the cases Canada and Virginia (USA), even the number of hops through the broker in Canada are low than the others from Virginia, the Latency through the Broker in Canada is higher than Virginia. The number of hops to the cloud does not determine the latency exactly; several

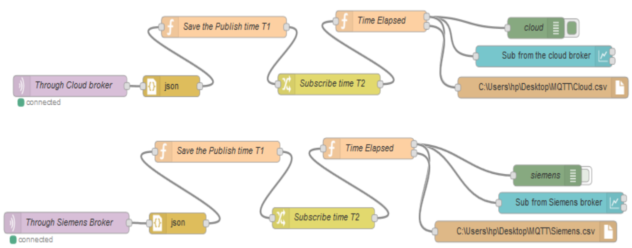

Figure 3: A node-RED Flow in the Client Computer, subscribing from the Cloud broker and the Siemens IoT2040 FOG Broker

Afterward, we used Node-RED the Internet of Thing tool to calculate the latency of the MQTT message in two different scenarios, as we described in the previous part. The publisher is placed in the industrial gateway Groov Edge from opto22, and the subscriber is in a laptop in Abdelmalek University of Tetuan. In the figure 3, we illustrate the code to calculate the time elapsed between the publish and the subscribe through the broker place in the IoT2040 and in the cloud. The obtained results are stored in a file in order to plot the latency over a period of time as shown in the Fig4, and Fig 5.

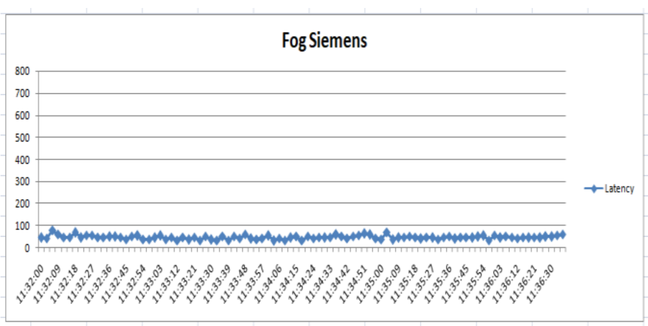

Figure 4: Latency of the packet Timestamp form the Groov Edge Publisher to the Laptop Subscriber, over the Siemens FOG IoT2040 Broker

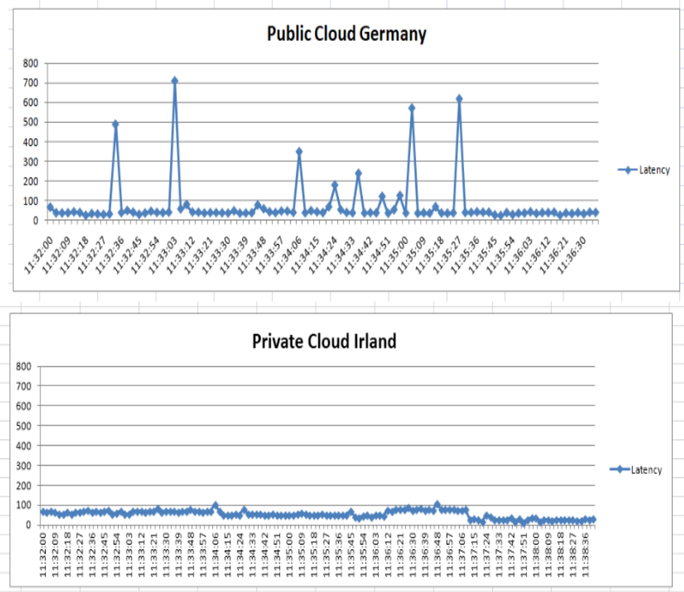

Figure 4: Latency of the packet Timestamp form the Groov Edge Publisher to the Laptop Subscriber, over the cloud Broker.

The graphs in Figure 4 and Figure 5 represent the variation in the latency over time of the two servers placed consecutively in the FOG and the Cloud.
We can see clearly that the latency increases when the broker is placed in the cloud server and it is less stable compared to the Fog server. However, the result of the experiments shows us that the private cloud servers give satisfactory result of latency compared to the public cloud servers. The pikes showed in the graphs are due to the congestion and retransmission of the network.

Table 1.Comparison Average of latency of Tracert and Node-ReD

Tools	*Fog broker*	*Cloud Broker*
Tracert	***60.5ms***	***121.66ms***
Node-Red	***84.19ms***	***127.96ms***

The table 2 illustrates the result of the average comparisons between the latency test tools, namely the Tracert command and the Node-Red. As can be seen, the results show that there is an increase in latency when the test is done by nod-red compared to the test done by the Tracert Command. This can be explained by the fact that nod-red adds the header for packet transmission.

4 CONCLUSIONS

This paper gave us an opportunity to study deeply and evaluate the famous protocol MQTT in term of latency, in the industry field. His architecture publish/subscribe allowed us to test intercontinental latency estimation.

The experiment test the latency over different gateways of MQTT broker, have showed that latency is linked to several parameters that define its performance; the experiment proved that's latency decrease when the broker is placed on the Fog server compared to the broker placed on the cloud server; that mean, whenever the server is close to the end user the latency decreases and gave more performance for transmission of the message; Although, the number of hops between destination and source in case of the cloud server do not determine the performance of latency -decreases of number of hops do not necessarily gave a good latency -.

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