Journal of Information and Technology
https://jidt.org/jidt
2024 Vol. 6 No. 2 Pages: 221-228 e-ISSN: 2714-9730

Comparing the Performance of LoRaWAN and MQTT Protocols for IoT Sensor Networks

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Abstract

IoT (Internet of Things) Sensor Networks are an important infrastructure in facilitating data collection from various widespread sensor devices. In this context, the selection of the right communication protocol plays a key role in determining the performance and efficiency of the network. Two commonly used protocols in IoT sensor networks are LoRaWAN and MQTT. The study aims to compare the performance between LoRaWAN and MQTT protocols for IoT sensor networks in various critical aspects such as differing in terms of the number of end devices, data transmission period, gateway radius distance, and power consumption, Data collected from sensors connected to LoRaWAN and MQTT gateways. The data includes Throughput, Packet Loss, and power consumption The results show that LoRaWAN is generally superior to MQTT in terms of Throughput and Packet Loss, especially at long gateway radius distances. LoRaWAN also has lower power consumption compared to MQTT, but MQTT also excels in Data Transmission Period and Number of End Devices in terms of Throughput and Packet Loss. The selection of the right protocol should be based on the needs and characteristics of the application to be implemented.

Keywords: IoT Sensor Network, LoRaWAN, MQTT, Throughput, Power Consumption.

1. Introduction

The Internet of Things (IoT) has grown rapidly in recent years, driven by advances in wireless technology and cloud computing [1]. IoT sensor networks play a crucial role in IoT, by collecting data from a variety of devices and environments [2]. To support efficient and reliable communication in IoT sensor networks, the right communication protocols are required.

LoRaWAN and MQTT are two popular communication protocols for IoT sensor networks[3]. LoRaWAN is a wide area network (LPWAN) protocol designed for long-distance communication with low power consumption[4]. MQTT is a lightweight messaging protocol designed for publish-subscribe communication[5].

Several studies have analyzed the performance of the LoRaWAN protocol and the performance of MQTT for IoT sensor networks. The research entitled "Analysis of LoRa with LoRaWAN Technology Indoors in Polytechnic of Malang Environment" [6] and the research with this title conducted a research "Monitoring and Analysis of the Quality of Network Performance of the Message Queue Telemetry Transport Protocol on G-Bot (*Garbage Robot*)"[7]. The results show that LoRaWAN and MQTT have their own advantages in IoT sensor networks.

Although several studies have analyzed the performance of LoRaWAN and MQTT for IoT sensor networks, further analysis is still needed to compare the performance of LoRaWAN and MQTT protocols for IoT sensor networks [8]. The reason for holding This study is to evaluate and compare the performance of the two, especially in performance metrics, such as throughput and packet loss, and power consumption.

With the development of IoT sensor technology and the increasing variety of protocol options, comparative analysis is essential to determine the most effective solution [9]. This research is expected to make a significant contribution to the understanding of the performance of LoRaWAN and MQTT protocols in the context of IoT sensors

2. Research Methods

This research will be carried out by following the stages depicted in the Flow Diagram Figure 1.

Receipt: 30-11-2023 | Revision: 29-06-2024 | Publish: 11-07-2024 | doi: 10.60083/jidt.v6i2.565

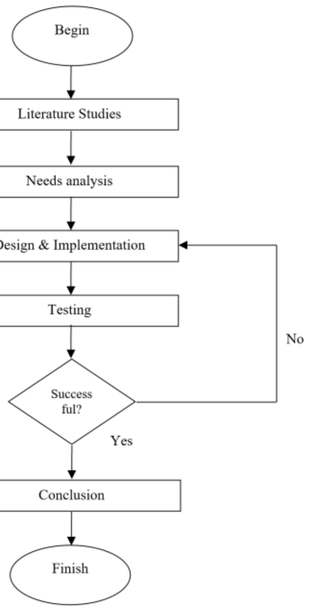

Figure 1. Flow Chart Research methodology

Conducting literature research first is a crucial step to gather relevant information and theories before entering the needs analysis stage**.** This helps researchers understand existing problems and potential solutions. The second stage of the needs analysis then helps the researcher determine the software and hardware required for the research. At this stage, the researcher will identify the functional and non-functional requirements of the system, as well as the necessary technical specifications. The implementation stage involves the deployment of pre-selected hardware and software. The system testing process is carried out to ensure that the developed system is functioning properly. This is done by conducting various tests, such as unit testing, integration testing, and system testing.

2.1. Design and Implementation

The implementation stage involves the deployment of pre-selected hardware and software. This section describes the design and implementation of tests used to compare the performance of the LoRaWAN and MQTT protocols on IoT sensor networks with parameters *throughput, packet loss* and power consumption[10]. The two protocols will be tested with simulations *Network Simulator* 3 or abbreviated as NS-3 to evaluate the performance and efficiency of each in terms of data transmission with a test paremeter of the number of end devices, gateway radius distance, data transmission period, The following Table 1 is the value for each parameter [11] [12].

Table 1. Simulation Parameters

Parameters	Value
Number of *end devices*	100, 200, 300, 400, 500, 600, 700, 800, 900, and 1000
Number of gateways	2 pieces
Simulation Time	600 seconds
Data Transfer Period	1 second, 10 seconds, 20 seconds, 30 seconds, 40 seconds, 50 seconds, 60 seconds, 70 seconds, 80 seconds, and 90 seconds
Gateway Radius Distance	1000 m, 2000 m, 3000 m, 4000 m, 5000 m, 6000 m, 7000 m, 8000 m, 9000 m and 10000 m
Power Consumption Duration Hours	1 hour, 2 hours, 3 hours, 4 hours, 5 hours, 6 hours, 7 hours, 8 hours, 9 hours, 10 hours

3. Results and Discussion

3.1. Definition of IoT Sensor

The Internet of Things (IoT) is a concept where everyday objects are equipped with the ability to connect and transfer data over the internet[13]. This allows these objects to collect, analyze and exchange data without the need for continuous human control[14]. In other words, IoT connects electronic devices, sensors, and other objects to the internet, allowing them to interact with each other and exchange data[15]. IoT has several key components, one of which is IoT (Internet of Things) sensor network [16] i.e. is a collection of sensors that are connected to the internet and work together to collect data from the surrounding environment[17] [18]. These sensors can detect things like temperature, light, pressure, humidity, or motion [19]. The collected data is then transmitted over the network to the data management center, where the data can be analyzed and used for various purposes [20] [21].

3.2. Definition of LoRaWAN Protocol

LoRaWAN1. Saveatrain.com Long Range Wide Area Network**,** is a wireless networking protocol designed for Internet of Things (IoT) devices that require long range and low power consumption [22]. The LoRaWAN protocol is designed to optimize power usage and communication reliability in IoT devices that often have limited resources [23]. It also allows the delivery of data from IoT devices to LoRaWAN gateways [24], which then forwards the data to a remote server, such as a cloud server, for further processing [25]. One of the key features of LoRaWAN is its ability to support many networks of low-power IoT sensors over a wide network, as well as its ability to adapt to changing environments, including interference that may arise in wireless environments [26] [27].

3.3. Definition of MQTT

MQTT (Message Queuing Telemetry Transport) is a lightweight, connection-oriented publish/delivery-based messaging protocol implemented on top of the TCP/IP protocol [28] [29]. designed to support communication between widespread IoT devices, such as sensors, actuators, and other devices and servers or applications that monitor or control them. In the MQTT model, there are three main entities: the publisher, the broker, and the subscriber[30]. The publisher is responsible for sending the message to the broker, the broker then forwards the message to all subscribers who subscribe to a particular topic or topics[31]. This allows for asynchronous communication between devices in the Internet of Things (IoT) and other applications or services [32]. By using MQTT in IoT sensor networks, users can easily collect data from various sensors, monitor specific conditions or parameters, and control devices based on the information received[33]. The protocol also allows for high scalability, allowing sensor networks to evolve over time without requiring significant changes in communication architectures [34].

This test was conducted using two identical IoT sensor networks, each using the LoRaWAN and MQTT protocols. Each network consists of one gateway and several end devices. The number of end devices varies from 10, 20, 30, 40, 50, 60, 70, 80, 90, and 100. Data transmission periods vary from 1, 10, 20, 30, 40, 50, 60, 70, 80, and 90 seconds. The distance of the gateway radius is varied from 1000 m, 2000 m, 3000 m, 4000 m, 5000 m, 6000 m, 7000 m, 8000 m, 9000 m and 10000 m, and finally the power consumption is varied from 1 hour, 2 hours 3 hours, 4 hours, 5 hours, 6 hours, 7 hours, 8 hours, 9 hours, 10 hours. For each combination of the number of end devices, the data transmission period, . Gateway radius distance, throughput and packet loss are measured. Throughput is measured by calculating the number of bytes received per second. Packet loss is measured by calculating the percentage of packets that are not received. Meanwhile, the power consumption of the end device is measured for each duration

3.4. Number of End Devices

Based on Figure 2, it can be seen that MQTT throughput is consistently higher than LoRaWAN across all number of end devices[35]. The throughput gap between LoRaWAN and MQTT is getting smaller with a larger number of end devices [36]. On a small number of end devices (10-20), MQTT throughput is higher than LoRaWAN with a difference of 20-15 kbps.The throughput on the LoRaWAN protocol has gradually decreased from 100 kbps (10 end devices) to 95 kbps (20 end devices). At a large number of end devices (60-100), the throughput on MQTT continues to decrease by 5-10 kbps compared to LoRaWAN [37]. The throughput on LoRaWAN experienced a slow gradual drop, reaching 55 kbps on 100 end devices.

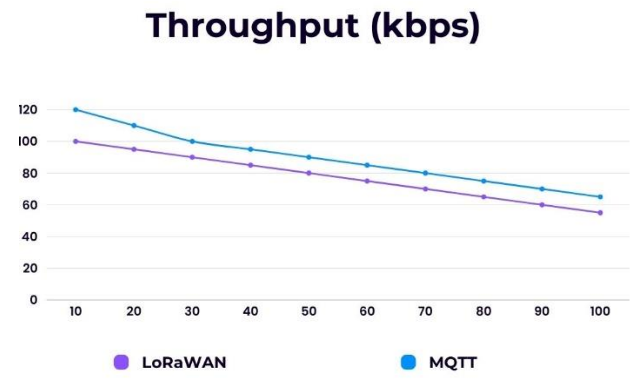

Figure 2. End *Device Throughput Graph*

After the test it is seen in Figure 3 that Packet loss on MQTT is consistently lower than LoRaWAN across all number of end devices. The packet loss gap between LoRaWAN and MQTT is getting smaller with a larger number of end devices [38]. In the small number of end devices (10-20), the packet loss in MQTT is lower than that of LoRaWAN with a difference of 0.3%. Packet loss on the LoRaWAN protocol has gradually increased from 0.5% (10 end devices) to 0.8% (20 end devices). In the number of many end devices (60-100), packet loss in MQTT continues to increase with a difference of 0.2-0.3% compared to LoRaWAN. Packet loss on the LoRaWAN protocol has experienced a slow gradual increase, reaching 3.0% on 100 end devices.

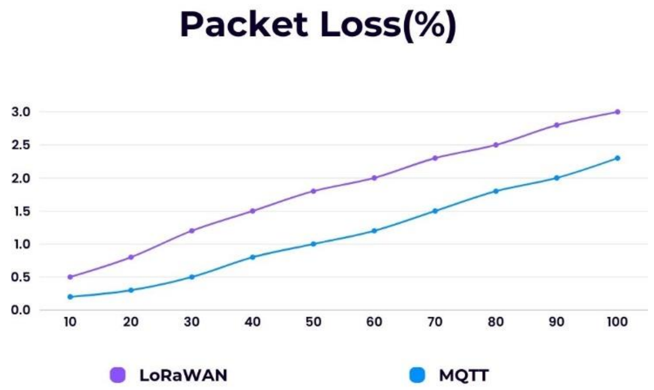

Figure 3. Packet *Loss End Device Graph*

3.5. Data Submission

Based on the tests that have been carried out in Figure 4, it can be seen that the throughput on the MQTT protocol tends to be higher than that of LoRaWAN [39]1. Saveatrain.com Throughput on the MQTT protocol consistently higher than LoRaWAN in all data transmission periods, The throughput difference between LoRaWAN and MQTT is smaller in longer data transmission periods [40]. In short data transmission periods (1-10 seconds) **MQTT** Throughput is higher than LoRaWAN with a difference of 10 kbps, at **LoRaWAN** The throughput has been gradually increased from 50 kbps (1 second) to 70 kbps (10 seconds). Over long data transmission periods (50-90 seconds) Throughput **MQTT** continues to increase with a difference of 5-10 kbps compared to LoRaWAN, while in **LoRaWAN** The throughput experienced a slow gradual increase, reaching 110 kbps in 90 seconds.

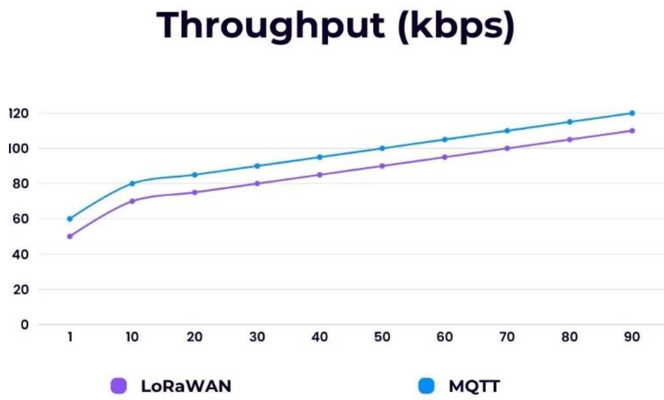

Figure 4. *Period* throughput graph

The test results in Figure 5 show that the packet loss on the LoRaWAN protocol is consistently higher than that of MQTT in a short data transmission period (1-10 seconds).[PubMed In short data transmission periods (1-10 seconds) Packet loss on the LoRaWAN protocol is higher than that of MQTT with a difference of 0.7%. Packet loss in MQTT has decreased gradually from 0.8% (1 second) to 0.5% (10 seconds). Packet loss in MQTT is consistently lower than that of LoRaWAN in medium data transmission periods (20-40 seconds) and long data transmission periods (50-90 seconds). In long data transmission periods (50-90 seconds), packet loss on the LoRaWAN protocol is stable at 0.1% in all data transmission periods.

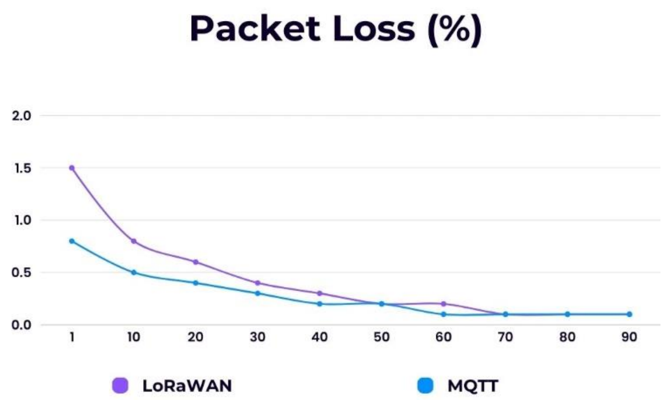

Figure 5. Period *Packet Loss* Chart

3.6. Gateway Radius Distance

Based on the tests carried out, it can be seen in Figure 6 that there is a significant difference between the throughput of the MQTT and LoRaWAN protocols at various gateway radius distances [41]. In general, MQTT throughput is higher than LoRaWAN at all tested gateway radius distances [42]. At a close gateway radius (1000 m), MQTT generally has higher throughput than LoRaWAN [43]. At a long distance of the gateway's radius (5000 meters or more), LoRaWAN throughput starts approaching or even exceeding MQTT throughput.

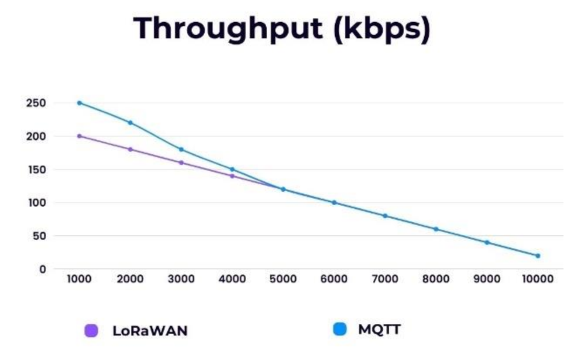

Figure 6. *Gateway* Reach *Throughput Graph*

Based on the test results, shown in Figure 7, it can be seen that there is a significant difference between the packet loss of the LoRaWAN and MQTT protocols at various gateway radius distances. In the generally, LoRaWAN packet loss tends to be lower than MQTT [44], especially at long gateway radii distances. At close gateway radii distances, both MQTT and LoRaWAN generally have low packet loss relatively low (< 3%). At long gateway radii distances, LoRaWAN packet loss is generally lower than MQTT.

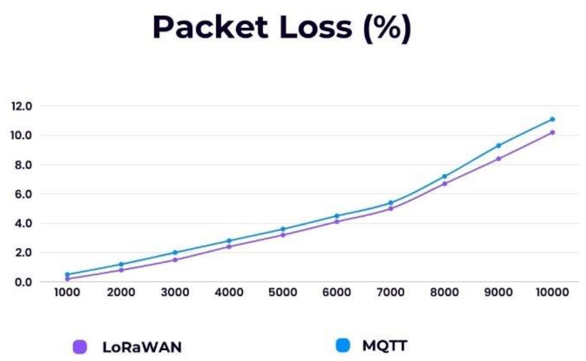

Figure 7. Gateway *Range Packet Loss Chart*

3.7. Power Consumption

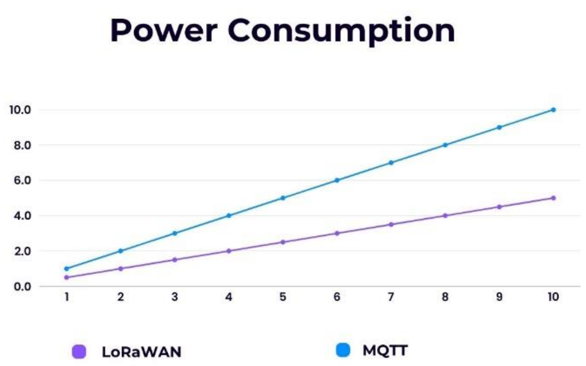

Figure 8. Power *Consumption Graph*

Based on Figure 3 of the results of the test, it can be seen that MQTT power consumption is consistently higher than LoRaWAN at all durations[45]. The power consumption difference between LoRaWAN and MQTT is getting smaller at longer durations [44]. At a short duration (1-2 hours) MQTT power consumption is higher than LoRaWAN by a difference of 0.5 mAh. The power consumption of the LoRaWAN protocol has gradually increased from 0.5 mAh (1 hour) to 1.0 mAh (2 hours). At long durations (5-10 hours) the power consumption on MQTT continues to increase by a difference of 2.5-5.0 mAh compared to LoRaWAN. Power consumption on the LoRaWAN protocol has experienced a slow gradual increase, reaching 5.0 mAh in 10 hours.

4. Conclusion

Based on the test results, it can be concluded that the MQTT Throughput results are higher at all end device counts, data transmission periods, and close gateway radius distances (up to 5000 meters), Throughput on the LoRaWAN protocol is higher at long gateway radius distances (more than 5000 meters). In terms of MQTT packet loss results are lower at all end device counts, data transmission periods, and close gateway radius distances (up to 5000 meters), packet loss on the LoRaWAN protocol is lower at long gateway radius distances (more than 5000 meters). Meanwhile, in the power consumption results of the LoRaWAN protocol end device, power consumption is lower at all durations than MQTT.

In testing a small number of end devices**,** MQTT is more advantageous in terms of throughput**.** A large number of end devices may be more advantageous for LoRaWAN in terms of Throughput and Packet **Loss**. In data transmission period testing**, MQTT** is advantageous for short data transmission in terms of Throughput**,** LoRaWAN is more advantageous for Long data transmission period in terms of Throughput and Packet **Loss**. In terms of gateway radius distance and its impact on Throughput and Packet Loss in IoT sensor networks, LoRaWAN is generally superior to MQTT. In the power test results, LoRaWAN is superior to MQTT.

Both have advantages and disadvantages that make them more suitable for specific scenarios on IoT sensor networks. Choose LoRaWAN if you need wide range, require low power consumption and have many end devices connected. And choose MQTT if you need high throughput for a short period of data transmission**.** has a short gateway radius. LoRaWAN and MQTT have advantages in different fields for IoT sensor networks. So in choosing a LoRaWAN or MQTT prostore, choose a protocol that suits the specific needs of your application.

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