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Application of the MQTT Protocol in Telepresence Robots

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Abstract – This paper presents the application of the MQTT protocol in the communication with telepresence robots. They are used for various purposes in education, medicine, nursing homes, etc. To ensure a good user experience, sending data from applications to telepresence robots needs to be fast and reliable. The MQTT protocol is open, fast and can be easily implemented. Its features make it ideal for data transmission in the communication with telepresence robots.

I. INTRODUCTION

Telepresence robots (TRs) are special type of robot used to provide a view in remote locations through proper control and movement in the environment. These robots often have a built-in teleconferencing system, camera, speakers, microphones and so on. Most of them also have wheels for movement in the environment in which they are located. This allows the user at the remote location to control the robot depending on its needs. TRs can also be operated by people at the location of the robot if remote people are unable to do that.

The benefits of using these types of robots are huge. There are a lot of use cases in which TRs can be used. According to one research of UNESCO Institute for Statistics (UIS), the number of children, adolescents and youth out of school in 2018 was 258 million. Of these, 59 million were primary school children, 62 million were lower secondary school children and 138 million were upper secondary school [2]. Due to the situation with the Covid-19 virus, this number is now significantly higher. With the proclamation of the pandemic on 11 March 2020 by World Health Organization (WHO), many schools and universities were closed. The educational process started online with the use of teleconferencing platforms. Given the situation, it is good that the educational process has continued. This was primarily due to the digitalization as well as new technological developments. This only confirms the need for investments in new platforms, tools and things that will be able to facilitate the educational process in the future [5] [30]. TRs can be used for this. Using them in education can help both children and teachers. They can help all children who, for some reason, cannot attend school. This way they would feel like they were really present in the classroom. This increases the sense of belonging and at the same time motivates the students. As mentioned earlier, TRs can also help teachers. They also face problems during the teaching process. This is especially pronounced now in a time of pandemic. One of the biggest problems they face is in terms of practical work and laboratory exercises. Although they can use computer cameras, they do not always provide a good view. This is where TRs can help. They can provide access, from different angles, to any place in the room, e.g. a large laboratory where practical work is performed. A better view can be made possible by moving the robot properly and zooming in using the camera. Using additional technology such as augmented and virtual reality can also enhance the TRs user experience [4]. This confirms the importance of using TRs in education [1] [3].

TRs can also be used in health care. According to one study of United Nations (UN) for the world population, there were 703 million elderly people that are on age 65 and over in the world in 2019 [6]. It is estimated that the number of elderly people will double by 2050 to 1.5 billion [6]. This imposes the need to develop new technologies and platforms that will help the elderly to perform daily activities. These technologies would certainly be of great help to caregivers who also face new challenges on a daily basis. TRs can have a huge positive impact acting as an assistant to caregivers [7]. With TRs, caregivers will be able to monitor the elderly remotely. Elderly people can communicate with their family members and their friends, which will reduce loneliness and maintain social interactions. TRs will especially help when people are in a nursing home, where the communication, support and inclusiveness are most important [8].

There are several use cases for TRs in medicine. They can be used as a communication tool between patients and their families and doctor, for remote health consultation, for contactless delivery of foods and medicines, for remote room disinfection [9] etc. These things are extremely important, especially now, in the period of the Covid-19 pandemic.

All of the above use cases only confirm the importance of using TRs. What is also important in TRs is the communication. Sending commands from a remote user to the TRs should be almost in real-time with low latency. This can be achieved using the MQTT protocol.

The rest of the paper is structured as follows: Section II presents the related work with MQTT and TRs. Section III describes the basics of the MQTT protocol. Section IV presents the application of the MQTT protocol in TRs. Section V is a discussion about the TRs and MQTT. Sections VI is a conclusion of our work.

II. RELATED WORK

Gonzalez-Jimenez in [10] describe the usage of TRs in elder telecare applications. They proposed the MQTT protocol for sending commands to the robot and also for exchanging sensorial data. Cymbalak et al. in [11] present a concept of extending the telepresence technology with physical interactions. They proposed integration of MQTT in overall communication model for sending coordinates, pressure data, body or instructions for arm movement with minimal delay. Kiselev et al. in [12] present an evaluation of using semi-autonomy features in telepresence systems. In their robot control architecture, they have used the MQTT protocol for communication with the client interface. Loza-Matovelle at al. in [13] proposed an architecture for integration of robots and sensors for the elderly in an ambient assisted living environment. In this architecture MQTT is used for communication between devices which contain sensor and actuators. Cortellessa et al. in [14] used the MQTT protocol for inter-process communication which allowed sharing data by using a publish/subscribe design pattern. Luperto et al. in [15] showed a framework which is centered around an assistive mobile robot for elderly people. They proposed the usage of MQTT protocol for communication purposes. The same authors in [16] show the main components of the system with mobile robot for at-home ambient assisted living of the elderly. In their system the robot interacts with other system components by sending commands and feedback through a MQTT channel using JSON messages. Melendez-Fernandez et al. in [17] present a web-based solution for robotic telepresence. They used MQTT protocol for establishing a bidirectional communication between clients and robots. MQTT is used for sending commands to the robot and transmitting sensory data. For this purpose, they used a MQTT Message Broker which implements the MQTT protocol and provides compatibility for TCP/IP and WebSockets.

The MQTT protocol is also used in automotive industry for data transmission, in transport and logistics, in telecommunications and in manufacturing industry. Car manufacturer company BMW uses MQTT to create fast, reliable and scalable platform for cars [19]. It uses this protocol in their car-sharing application. SAIC Volkswagen uses MQTT in their IoV platform that establishes the connection between cars, cars and people, cars and roads. It also implements in-car information services, intelligent transportation and vehicle control automation [20]. Matternet uses MQTT for real-time monitoring of autonomous drones [21]. The drones and the landing stations transmit MQTT messages that can be used to provide the flight status in real- time. In some of the IBM Telemetry use cases, the MQTT protocol is used for home energy monitoring and control and for home patient monitoring [22] [23]. CASO Design uses MQTT for creating smart kitchen appliances. This protocol helps them to enable remote management of the appliances and for pushing notifications for the end-users to inform them about unexpected situations [24]. German Railway uses MQTT to enable the communication between the trains and wayside monitoring systems [25]. Facebook Messenger has been using MQTT since 2012 [26]. It enabled fast messaging as well as optimization of battery and bandwidth. The transmission of messages took place in hundreds of milliseconds, instead of a few seconds like earlier. All of these use cases only confirm the benefits of using the MQTT. This protocol can be applied to improve the communication in TRs, both for sending commands and for proper exchange of data.

III. MQTT PROTOCOL BASICS

MQTT is a publish/subscribe protocol for the Internet of Things (IoT) [18]. It is located at the application layer of the IoT protocol stack. It is open, simple and can be easily implemented. These features make it useful for constrained devices which has limited memory and low processing power such as sensor devices and controllers. There are libraries for application development that use the MQTT protocol in several programming languages such as: C, Java, C#, JavaScript, etc.

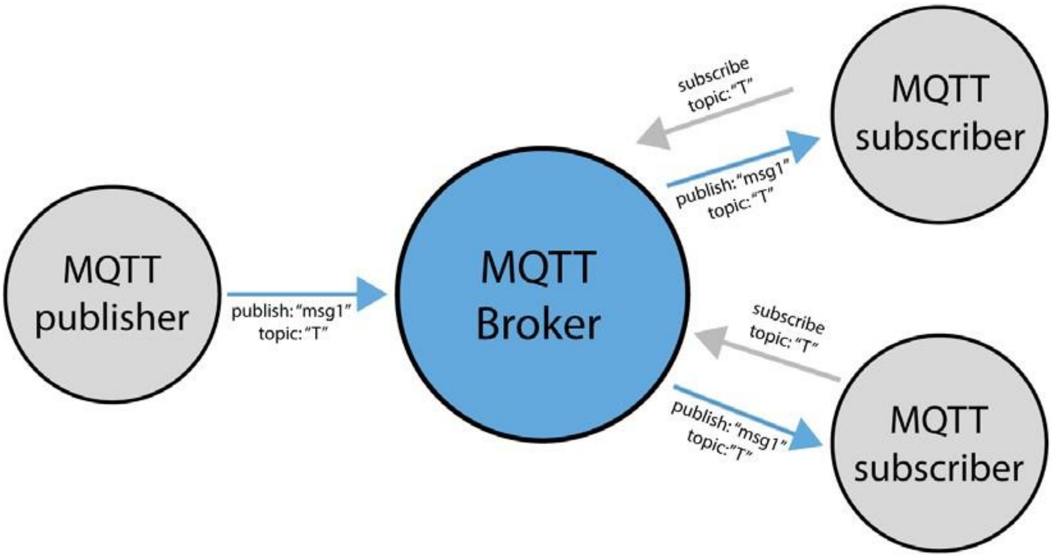

Figure 1. MQTT publish-subscribe model

In 2014 the version 3.1.1 of the MQTT became OASIS standard, while in 2016 it became ISO standard. The latest version of the protocol is MQTT

5.0. It became OASIS standard in 2019. It offers a number of improvements and new features that can help the clients.

This protocol implements the publish/subscribe model which is ideal for IoT communication (Fig. 1). It is client-server model with two types of clients. The first type are clients who send messages which are called publishers. The second type of clients are those who subscribe on a specific topic to receive messages. They are called subscribers. The central role in this communication is played by the broker. It receives all the messages from publishers and delivers them to subscribers according to the topic on which they have subscribed. These two types of clients do not communicate directly with each other. The broker is acting as an intermediary between them.

The topic is hierarchically arranged UTF-8 string which is the subject of the message. It can have one or more levels which are separated by the character "/". One example of MQTT topic is:

/home/bedroom1/temperature

This topic has three levels. Topic names are case sensitive, so the following topic is not the same as the previous:

/home/Bedroom1/temperature

MQTT has three Quality of Service (QoS) levels which guarantee delivery of messages. The QoS levels are:

- QoS 0 (at most once)
- QoS 1 (at least once)
- QoS 2 (exactly once)

MQTT v.3.1.1 has 14 different control packets (CONNECT, CONNACK, PUBLISH, PUBACK, PUBREC, PUBREL, PUBCOMP, SUBSCRIBE, SUBACK, UNSUBSCRIBE, UNSUBACK, PINGREQ, PINGRESP and DISCONNECT. The

latest version MQTT 5.0 has one packet more and it is the AUTH control packet. Every packet has a size between 2B and 256MB. It is ideal for networks for low bandwidth and high latency. According to [27] the average latency is around 0.3196 seconds. It is especially important for applications where we need to exchange data in real time. TRs are the ones that require communication in almost real time. This is especially true for the robot movement commands. In order for the robot to move smoothly, the commands sent by a client need to be delivered with low latency and almost in real time. In addition to the commands, the data itself should be sent quickly. This can be data from sensors placed on the robot, data from the environment, etc. According to its features, the MQTT protocol can significantly help to improve the communication in TRs.

IV. THE USE OF THE MQTT PROTOCOL IN TRS COMMUNICATION

TRs are usually located in a remote environment. Users send commands to the robot that receives the commands and responds accordingly. Commands are sent over the Internet. In order to have natural movements, it is important that the commands sent by remote users are sent in fairly real time. If this is not the case, then we would have a bad user experience. Users will try to move the robot, but due to the delay of the commands, they could not fully

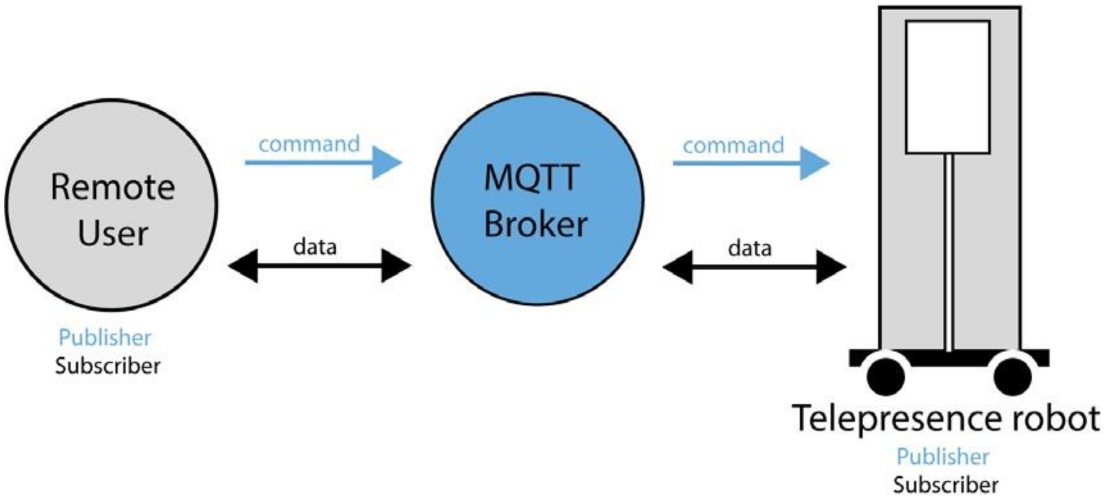

Figure 2. Communication of user and telepresence robot using the MQTT protocol

follow it. Since the user is not in the same room as the robot, he/she uses a network to send data/commands. Network issues can also be a problem for properly delivering commands to the robot. However, this is a general problem and the user is usually notified about this through the application he/she uses. There are TRs which have tablets or mobile phones attached to them, that serve to establish a connection with the robot. Basically, the commands that are send by the user to this mobile device are forwarded to the robot which executes them. Forwarding commands in this case must also be done quickly in order to ensure a good user experience. In addition to commands, we often need to send data from the robot to the users and vice versa (this may be data from sensor device located on the robot, data for objects located in the environment, some private data etc.). Adequate fast and reliable transport should also be provided for this data. This will also provide a good user experience.

According to its characteristics, the MQTT protocol can be applied for communication in TRs. As can be seen in Figure 2, the remote user and the telepresence robot communicate with each other using the MQTT protocol and MQTT broker as a central component of the architecture. To send commands, the remote user sends a message to the broker, on a topic on which the telepresence robot is subscribed. Once the broker receives the message, it forwards it to the robot that executes the command. Sending data can be in both directions, from the remote user to the telepresence robot and vice versa.

V. DISCUSSION

A very important thing in developing applications for TRs using the MQTT protocol is to determine the purpose of the application, in order to determine the data flow. Depending on the context of the application, the telepresence robot can have the role of publisher and subscriber. Same is for the client. The data and commands are sent through MQTT broker.

As mentioned before, that MQTT has three levels of QoS. To develop application, we need to determine which QoS level we will use. It all depends on the purpose of the application: whether we want the messages to be sent at most once (QoS 0), at least once (QoS 1) or exactly once (QoS 2).

Another important thing when we develop applications for TRs using the MQTT protocol is to pay attention to the security. Appropriate authentication and authorization mechanisms must be provided in order to allow only users who have the appropriate rights to send commands to the robot and to exchange data. If data are sensitive, then it is best to encrypt it or the transmission could be through covert channels suggested in [28] and [29].

VI. CONCLUSION

TRs can be used in a variety of fields. They can be used in education, medicine, homes, care centers for elderly, museums, etc. Therefore, it is important to implement appropriate mechanisms and protocols that will ensure reliable and fast data transfer. This can be achieved by implementing the MQTT protocol. It is open, simple and can be easily implemented. Sending messages with MQTT is done almost in real time. All of this makes it ideal for TRs communication. Our future research will be focused on developing applications for TRs using the MQTT protocol.

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