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JITTER ANALYSIS OF MQTT PROTOCOL FRAMES IN MOBILE ROBOT CONTROL SYSTEM

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Abstract: *The paper presents a control system of the mobile handling robot which uses Internet of Things concept. Then a problem with jitter in communication between devices is shown. Based on the analysis a method which reduces the problem is proposed. It uses two instances of message broker. The first one for very important messages and the second for other information. Finally, the conclusions of the usability of the proposed method are presented.*

Keywords: Mobile robot, Internet of Things, Communication protocols, Control.

1. Introduction

Internet of Things is a relatively new concept in which objects can exchange information over the Internet (Chooruang, 2016 and Pingle et al., 2016 and Kazala et al., 2015). Access to the data is possible from any place, which is covered by the Internet network. Such idea can be used during the design of control systems of various mechatronic devices. On the basis of this idea has been developed in preparation for the European Rover Challenge competition and for projects (Dudek, 2016 and Straczynski, 2016) a mobile handling robot FUMAR shown in Fig. 1.

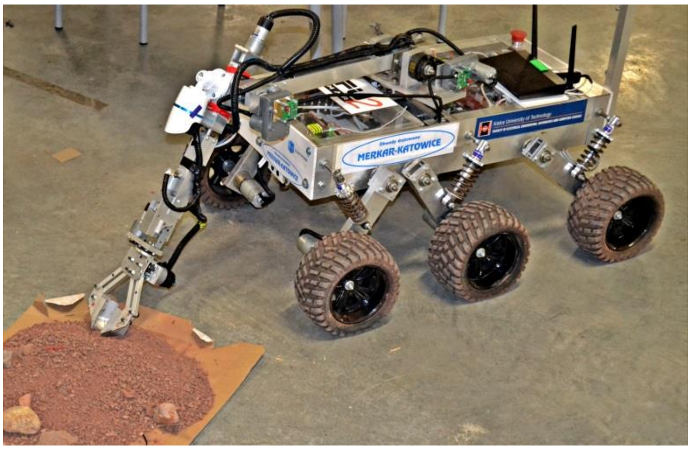

Fig. 1: Mobile robot FUMAR.

During testing of the robot control system, some problems were encountered related to the implementation of the MQTT protocol brokers which were used in the robot. They caused delays in the transmission of messages. The purpose of the paper is analysis of delays in the transmission of messages in robot control system. The relationship between occupancy level of the broker and the message sending time were investigated. Method of improving the system based on the introduction of a hierarchy of messages and double the broker has been presented. Finally the conclusions of the usability of the proposed method are presented.

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2. Mobile robot architecture

Mobile robot analyzed in the paper consists of six not steerable wheels powered by DC geared motors and platform with mounted a manipulating arm. The design of the robot is shown in Fig. 1. The robot arm has six degrees of freedom. To move each of arm links, DC motors equipped with gearboxes are also used (Dudek et al., 2016). For measuring the position and velocity determination, magnetic absolute encoders from AMS are used.

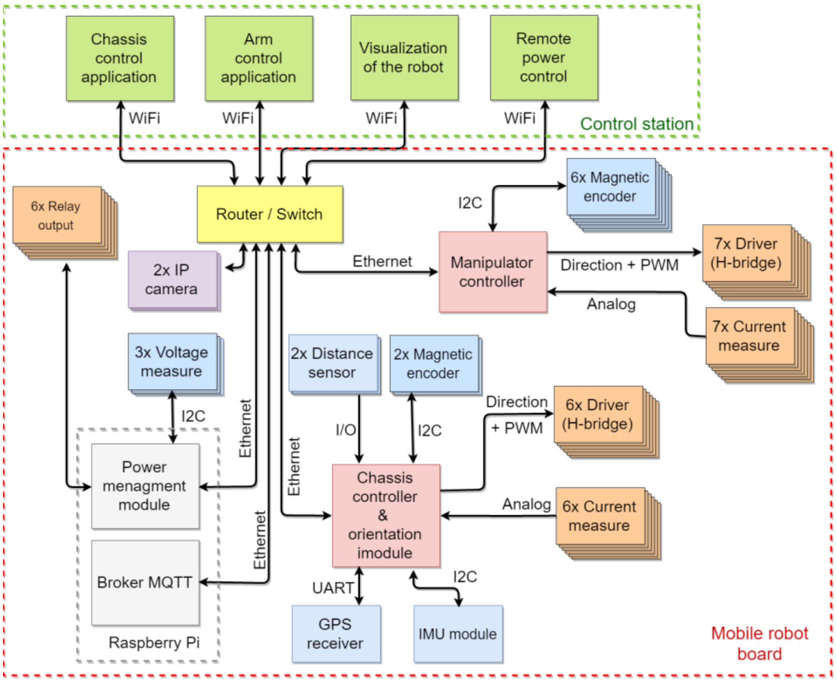

Fig. 2: Robot control system.

To ensure the greatest possible reliability and scalability, modular control system was developed. It enables redundancy of individual subsystems. In order to be able to control from a distance, the communication system is based on the idea of the Internet of Things. In the system, Ethernet and MQTT protocol are used which utilizes publish-subscribe communication model. Hardware architecture of the control system of the robot is shown in Fig. 2.

As the main onboard computer, single board computer Raspberry Pi with Ubuntu Mate operating system is used. It handles MQTT message broker. In addition, the computer which acts as a supervisory module allows disabling the other subsystems and monitoring the status of the lithium-polymer batteries. Other modules are managed by TM4C1294 microcontrollers from Texas Instruments, equipped with modern and efficient ARM Cortex-M4F core.

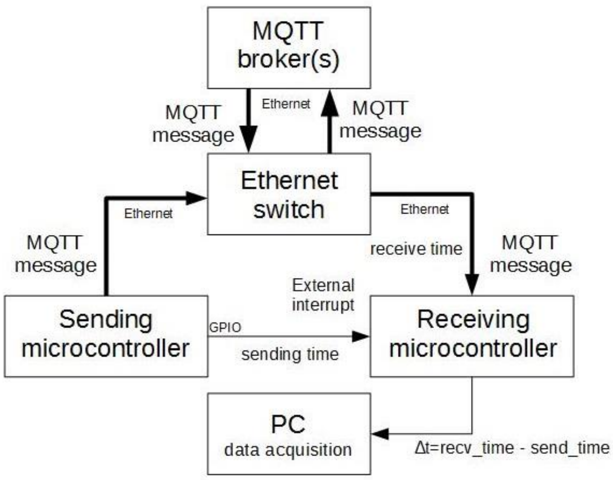

Fig. 3: Configuration of the broker test system.

3. Analysis of the impact of occupancy of broker on the data transfer time

One of the main problems in designing systems based on MQTT protocol is a fact that they use TCP/IP stack. Typically, in order to optimize the throughput, it employs Nagle algorithm which performs aggregation of frames (Nagle 1984). This is particularly undesirable in the systems which often exchange small portion of information. Nagle's algorithm should be disabled when additional latency is unacceptable. In subsystems which are based on microcontroller and LwIP TCP/IP stack implementation it can be forced to immediately send frames with use of tcp_output() function. This solution makes that each frame contains one MQTT protocol message. A bigger problem is in the case of MQTT brokers because it is not always possible turning off the Nagle algorithm. Initially, in the robot control system, popular open source MQTT broker called Mosquitto were used. To analyze latency in communication between two devices a special measurement unit shown in Fig. 3 were prepared.

During testing, it was noticed that the Nagle algorithm is enabled in the Mosquitto broker instance. The effect of MQTT frame aggregation caused by the algorithm is shown in Fig. 4. This broker does not allow to disable this mechanism using the configuration file. Therefore, it was decided to use Erlang MQTT broker (EMQ) that does not use this algorithm.

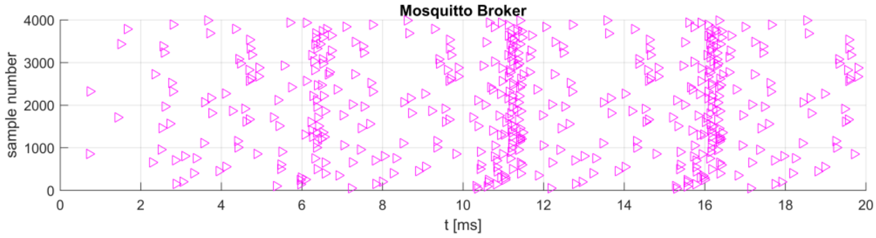

Fig. 4: Frame aggregation effect for Mosquitto broker.

Each of mechatronic communication systems contain at least few priorities of transmitted messages. The robot communication system, presented in this paper, has different kinds of MQTT protocol frames. They can be divided into high priority control messages and normal priority information messages. In order to minimize the transmitting time for high-priority messages, instead of a single instance of the broker, the two broker system was introduced. The first instance of the broker processes only most important MQTT topics, while the second one forwards others. Proposed priorities are presented in Fig. 6. Reducing occupancy of main broker through separation of messages positively affect the speed of high-priority packets. Results of the experiment are shown in Fig. 5.

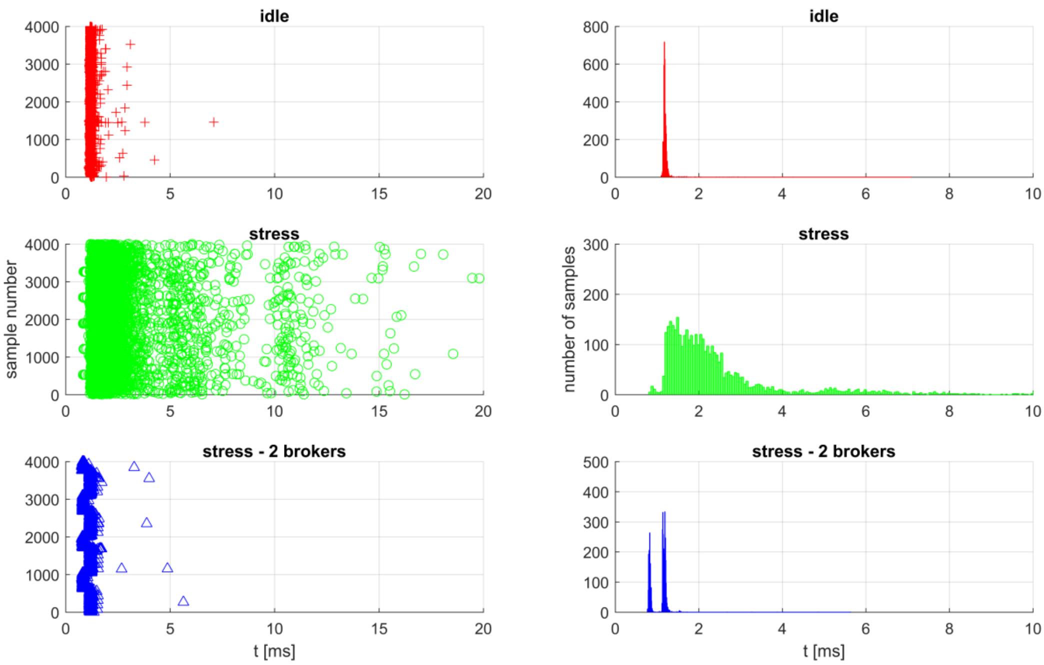

Fig. 5: Analysis of high priority frames end-to-end time.

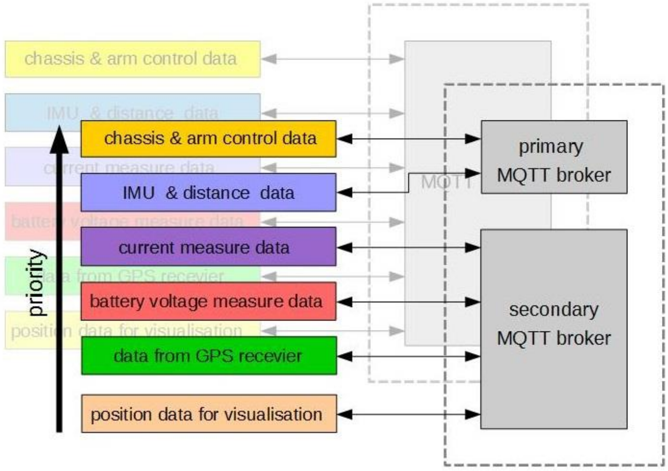

Fig. 6: Proposed priorities in two broker robot communication system.

Fig. 5 idle shows the times of transmission of priority frames in the absence of information frames for one broker configuration. Fig. 5 stress presents the same configuration with lots of information frames. Stress – 2 brokers shows configuration with two brokers with the same amount of information frames. It is clearly evident that the two brokers configuration even with a heavy load provides a low jitter of priority frames.

4. Conclusions

The use of IoT technologies in control systems of robots and other mechatronic devices, greatly simplifies the exchange of information between modules and between the operator and the controlled device. Using MQTT protocol enables the development of modular and scalable control systems. It can be easily integrated with the Internet network and used in systems consistent with the concept of Industry 4.0. For small installations with few transmitted messages, the control system can use a single broker. However, in the case of systems in which there is an intensive exchange of data and information transferred have different validity, the use of a single broker is not effective. This is due to the occurrence of delays in the transmission of the priority information. The solution to this problem is to use two or more brokers, each support information with different priority. Additional improvement can be obtained by assigning operating system priorities to broker processes. However, this does not give a significant reduction of a jitter of transmitted messages. In the future it will be possible to set priorities for each of the MQTT topics in the broker since it is planned to extend the MQTT protocol. Currently, there are implementations of brokers that use priorities, but efficiency of these solutions, particularly in multi-core systems is smaller than the use of separate brokers.

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