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MEASURING THE LATENCY, OVER 4G LTE, FOR A TELEOPERATED ROBOT USING COMMERCIAL REMOTE DESKTOP SOFTWARE

Florin FLORESCU, Ioan-Emil POPESCU, Cristian MOLDOVAN, Erwin-Christian LOVASZ

Abstract: *The paper deals with measuring the response latency for a teleoperated robot, using commercial RD (Remote Desktop) software, over 4G - LTE. The proposed method is developed to determine if a real-time control can preserve the benefits for connectivity but also increase the security of the system.*
Key words: *measuring latency, teleoperated robot, RD software.*

1. INTRODUCTION

Teleoperated robots are becoming a new way of how things are getting done, the last years marked by a pandemic disease have forced the companies to increase the usage of remote work. By looking on how the internet has developed we can see that the information has become available all over the word, the amount of data has grown exponential, according to Cisco global cloud index (2016-2021) the prediction that by 2021 the worlds data volume will reach almost 19.5 zettabytes, we anticipate that a major player in the world of cyberspace will be taken by the smart cities, homes, cars or industrial Internet of Things [1].

The undeniable advantages over the work of human operators make them an efficient solution for performing tasks and characteristics such as speed and accuracy of execution related to easy operation have determined that the cost price, relative to the stages of technological development, is relatively low.

Studying how to interact with the environment, humans are using mainly visual information, a teleoperated robot that manipulates objects needs force-torque information, information regarding the progress of processes and the state of the environment in terms of sound information. The "perception" of the environment depends on the variety of sensors needed in the robotization processes, we will have to consider the possibility of adapting the sensor systems to the robot itself, also how to enter the data obtained is important, so several devices such as input / output are used to reduce the degree of loading with data from / transmitted by the human operator [2]

The communication channel used for data transmission is via the internet [3] where unlike other, direct radio or cable applications, there is the problem of losing data packets causing time delays that can have very high values. The performance of teleoperated systems can deteriorate dramatically and become unstable.

Ideally the teleoperated system would be completely transparent, so that the operator would feel that it is in direct interaction with the remote part and the relationship between stability and performance is explicitly defined considering the presence of delays on the communication line [4].

The paper proposes a study on how to measure the latency, over 4G LTE, for a teleoperated robot using commercial RD software.

2. LITERATURE REVIEW

The research topics aim to determine if a teleoperated systems is efficient and what kind

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of methods are used to command a robot from distance.

Teleoperation is being used more and more, research in the field of teleoperation of vehicles using artificial intelligence (AI) and 5G mobile communications networks has allowed some vehicle driving functions to be moved to cloud services [5, 6], being a much more efficient choice than implementing a machine learning solution.

Commanding a teleoperated humanoid robot using cloud services [7], controlling a KUKA-KR6 industrial robot via an Android mobile application [8], teleoperating an endoscope during minimally invasive surgery using Arduino Uno and a device eye movement tracking [9] or the use of a Raspberry Pi to monitor and control the robotic arm via a web application [10] demonstrates the usefulness of operating a remote robotic system.

The design of a control system of a robotic arm having 2 degrees of freedom (2DOF) using as a method the visual feedback and the angular position of the elements [10], eliminating from the equation the need to know the lengths of the elements [11, 12], proved to be more efficient and reliable than developing a system for controlling a robot humanoid by the method of capturing the position of the human operator using KINECT or speech and hand gesture recognition. [13, 14, 15].

The development of cloud robotics solutions [16] can reduce the efficiency requirements of the computers used. At the same time, in addition to the advantages of a computer system with much increased processing power, sufficient RAM, multiple developed applications, a new problem arises, that of the security of operating systems used [17], cases such as interruption of communications or hacking attacks. requires constant attention. Teleoperation of the robot [18], in conditions of maximum safety, can become dangerous in case of partial or total compromise of the operating systems or applications used at their level.

The issue of operational safety, as well as those related to efficiency and effectiveness in use, are still debated. The use of communication networks (especially mobile - LTE or 5G) raises problems regarding the degree of their load as well as the stability of transmission / reception [19, 20, 21, 22, 23].

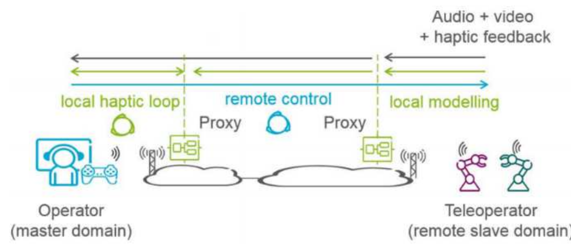

Fig. 1. Illustration of an "internet of skills" architecture

Keon Jang et al. [24] research the throughput of 3G and 3.5G while driving with high-speed trains and cars. A big difference was seen between stationary and mobile measurements, by which lower throughput over UDP and TCP, higher jitter and packet were verified when the vehicles were moving and stationary by comparing data.

Parichehreh et al. [25] has conducted measurements in order to compare 3 different types of congestion control algorithms in the LTE uplink. The results show that device packet losses have been observed.

However, for having all-time access to network it is recommended connecting to the best network available by using multiple sim-cards of different providers [26].

3. MEASUREMENT SETUP

For the measurement setup we describe the hardware and software used to measure the latency, over 4G LTE and compared with Wi-Fi and local, using commercial remote desktop applications (RD) software like TeamViewer, AnyDesk and Chrome remote desktop.

Hardware – a notebook – HP, i7 generation, IPS display, operating system: Windows 10 Home a PC – i5 generation, operating system: Windows 10 Professional, a monitor-Philips, 2ms response time, a webcam Logitech- V-UBC40 with 30 frames per second, Arduino UNO, LDT (Light Dependent Phototransistor), multicolor LED – RGB, a Breadboard, wires and a box.

The Arduino UNO was connected to the notebook by using a USB connector, the same as the camera, the LED and the LDT are connected to Arduino UNO through the breadboard. The camera and the LED are placed in a box where should be no light, for the measurements to be precise, the LDT is placed on the notebook or monitor screen using sticky tape.

Software – the tool used to measure latency was developed for Arduino UNO [27], C++ language, the results are shown on a serial monitor, measuring the total latency of all involved components. The application can gather data from the environment, light switch, and convert into measurable delay (us, ms). The calibration of the system must be realized every time, before the measurements are taken, so the values of the data are reliable.

The TCP/IP protocol has been configured to IPv6. Likewise, the number of addresses of IPv4 are almost depleted, the importance of new topology of network was required, the IPv6 is design to update old IPv4.

As a security enhance is to be seen when the IPv4 scanning time for identifying all the devices is only 45 minutes and scanning the entire IPv6 it is impossible for now, maybe using quantum computing is a solution but not for now [28]. The large space of IPv6 is enhancing the security of the servers and devices.

However, the idea is to change both the server address and the client to maintain the privacy and security and protect against targeted network attacks so the brute force scans cannot pose any threat to addressless server.

For the RD software we chose TeamViewer, AnyDesk and Chrome remote desktop. The measurement was made by using Vodafone RO as LTE telecom provider with unlimited traffic and an RDS router for local Wi-Fi access.

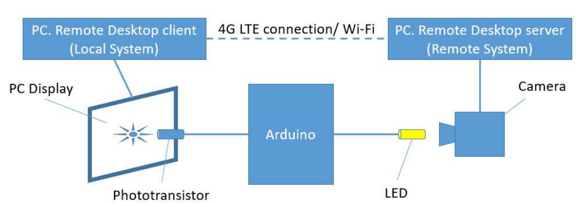

Fig. 2. Measurement setup

The measurement process has as center piece the Arduino, as shown in Fig.2. Connected to the Arduino are an LED and a Phototransistor. To perform the measurement,

- the LED is lit and the milliseconds timestamp is recorded t_{LED}.
- the LED state is “seen” by the camera connected to the Remote PC, which is running a RD application.
- the Remote PC is connected to the Local PC via the RD application.
- on the Local PC the LED is displayed and its state is perceived by the Phototransistor connected to the Arduino timestamp t_P is recorded and the loop is closed.

To calculate the system’s latency we just subtract the timestamps t_{LED} and t_P as shown in (1)

$$latency = t_{LED} - t_P \qquad (1)$$

We conclude that this measurement setup provides sufficient precision in order to extract meaningful information, the obtained measurements are in the millisecond range.

4. RESULTS

A large latency can cause gaps between the human operator and the robotic system. The video stream can be delayed and that can generate problems. We present the results of latency measured using Arduino UNO capabilities.

The connections for measuring the latency are made over 4G LTE, Wi-Fi or on local notebook in order to compare the results and find out if commercial RD are suitable for teleoperate, in real-time, a robotic arm.

The results obtain by measure the total latency over local and Wi-Fi network, of all involved components, while connecting trough RD applications are shown in Table 1.

Table 1

Comparing latency local and RD connections over Wi-Fi.

Connection /delay	Min	Average	Max
Local	273ms	411ms	831ms
Lan – Wi-Fi – TeamViewer	303ms	476ms	897ms
Lan – Wi-Fi – AnyDesk	365ms	578ms	958ms
Lan – Wi-Fi – Chrome remote desktop	350ms	470ms	905ms

For the analysis of data from the Table 1 we integrate the results in Figure 2, all data show that delay measured from using RD applications are different and the latency over Wi-Fi network is not very big compared with local measurements. The goal is to obtain latency under 300ms so the human operator has a real-time experience.

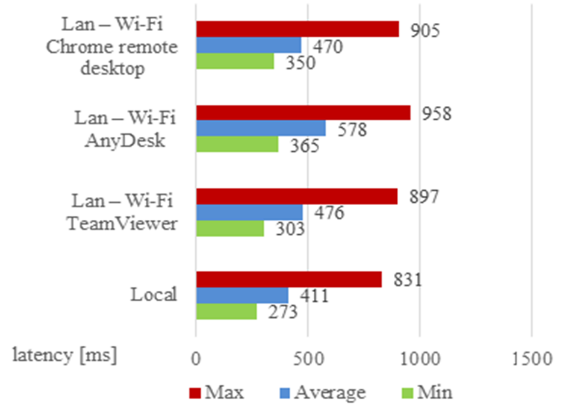

Fig. 3. Comparing the latency of RD applications over Wi-Fi.

The results obtained by measuring the total latency over local and 4G LTE network while connecting trough RD applications are shown in Table 2 and compared in Figure 3.

Table 2.

Comparing latency local and RD connections over 4G LTE.

Connection /delay	Min	Average	Max
Local	273ms	411ms	831ms
Lan – 4G – TeamViewer	317ms	443ms	877ms
Lan – 4G – AnyDesk	312ms	475ms	873ms
Lan – 4G – Chrome remote desktop	318ms	557ms	984ms

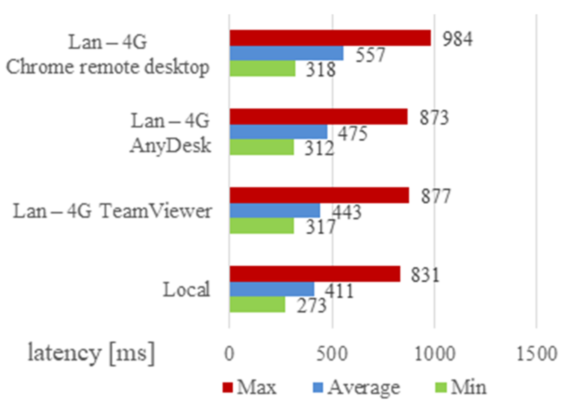

Fig. 4. Comparing the latency of RD applications over 4G.

Our measurements provides a clear understanding, the data obtain from the Wi-Fi and 4G LTE network are showing that the RD TeamViewer is in average 33ms faster over 4G LTE compared to Wi-Fi, on the other side we are seeing that AnyDesk application is 103ms faster over 4G LTE and Chrome remote desktop is slower by 87ms.

5. CONCLUSIONS

We observe, by comparing the latency of RD applications over 4G and Wi-Fi networks, that a teleoperated robot using commercial RD software is suitable, notably with 4G LTE. In most cases the latency measured in 4G is smaller than over Wi-Fi network.

Obviously, Arduino UNO is not a calibrated device. The clock of the device drifts slightly, for a future study if we need more precision it is recommend to use a real-time clock. Considering this is a glass-to-glass test, we are measuring the total latency of all involved components. For getting comparable results, the only variable that must be exchange in this chain should be the video-camera.

Analyzing all information related to teleoperated system we can say that it is possible to obtain a real-time teleoperated system, with the right hardware, over 4G LTE network. Securing the communication, make a better privacy and reducing the costs will require a new technology, 5G, for making it possible.

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MĂSURAREA LATENȚELOR, ÎN REȚELE DE TIP 4G LTE, PENTRU UN ROBOT TELEOPERAT FOLOSIND SOFTWARE COMERCIAL DEDICAT CONTROLULUI DE LA DISTANȚĂ.

Abstract: *Într-o lume unde lucrul de la distanță a devenit un lucru normal un nou tip de sistem, sistemul teleoperat, cunoaște o nouă etapă de dezvoltare. Operațiuni de acces de la distanță în medii periculoase, controlul de la distanță a autoturismelor aflate în mișcare sau efectuarea de operații chirurgicale de la distanță unde cunoștințele medicale pot fi folosite în orice loc de pe pământ pot face o reală diferență. Lucrarea este dedicată studiului măsurării latențelor pentru un robot teleoperat, folosind software comercial dedicat controlului de la distanță, în rețele de tip 4G LTE. Metoda propusă are ca scop de a determina dacă un control în timp real poate păstra beneficiile conectivității dar de asemenea și cum se poate crește securitatea sistemului.*

Florin FLORESCU, Ph.D. student, Politehnica University of Timisoara, Faculty of Mechanical Engineering, Mihai Viteazu Street, No. 1, 300222, Timisoara, Romania, florin.florescu@student.upt.ro.

Ioan-Emil POPESCU, Ph.D. student, Politehnica University of Timisoara, Faculty of Mechanical Engineering, Mihai Viteazu Street, No. 1, 300222, Timisoara, Romania, ioan-emil.popescu@student.upt.ro.

Cristian MOLDOVAN, Ph.D. Eng, Politehnica University of Timisoara, Faculty of Mechanical Engineering, Mihai Viteazu Street, No. 1, 300222, Timisoara, Romania, cristian.moldovan@upt.ro.

Erwin-Christian LOVASZ, Ph.D. Proffesor, Politehnica University of Timisoara, Faculty of Mechanical Engineering, Mihai Viteazu Street, No. 1, 300222, Timisoara, Romania, erwin.lovasz@upt.ro.