17th Symposium IMEKO TC4, 3rd Symposium IMEKO TC19 and 15th IWADC Workshop
Instrumentation for the ICT Era
Sept. 8-10, 2010, Kosice, Slovakia

# A Cheap Wi-fi Instrumentation Remote Control Platform for Electric and Electronic Didactic Laboratory

Fabio LECCESE
Electronic Engineering Department, University of "Roma Tre"
Via della Vasca Navale 84, 00146 Roma, tel. +39 06 57337085, fax. +39 06 57337101
Italy
leccese@uniroma3.it

***Abstract*** **–** Remote control of instrumentations and the connected measurement techniques represent an interesting topic particularly appreciated in some sectors as industry, research and e-learning. The current technologies allow to fully control modern instrumentation that is already conceived for this aim, while it is harder to manage old instrumentation not specifically designed for this kind of control. At the moment the costs are strongly conditioned by the current architecture that uses a personal computer as local server to manage the local instrumentations making impossible a really common use of these technologies. In this paper a system for remote controlling instrumentations implementing IEEE 488 or otherwise, based on an economic Wi-fi architecture, is described.

***Index Terms -*** Remote measurements, instrumentation remote laboratory, e-learning, Wi-fi, IEEE 488 standard.

## I. INTRODUCTION

The advantages offered by Web-technologies and services are unaccountable for, first of all the economic ones. The possibility to connect from all over the world to carry out measurements or to drive actuators, open new possibilities to exploit laboratory instrumentations in the industry [1,2], in the research [3,4], medicine [5,6] and learning fields [7,8,9,10,11]. Regarding the last field of application, by keeping monitoring the opinions and learning process of the students during several years of activity, it has been possible to develop a benchmark that can be adopted as evaluation reference model for those who wish to manage a remote laboratory in the University environment[12]. All these activities use internet as the medium to send and receive information, so obtaining the remote control. The standard architecture is shown in figure 1 (left side), where the operator uses his own computer to drive a remote server placed in the remote laboratory, in order to realize the expected functionalities via internet. Normally the physical connection is realized by means of a LAN that connects the local server with the net by wire (standard RJ45), but with the increasing diffusion of Wi-fi and WiMAX telecommunication systems, the possibility to develop wireless remote control system is becoming increasingly popular. In fact, the application of wireless technologies has several advantages compared to the wired version. First of all, there is no need to cable all the building, which is a particularly difficult task, especially in case of old buildings with brickwork or concrete masonry walls. In fact using wireless access points it is possible to realize an internal wireless connection with only an internal/external interface to the outside connection. It is clear that the wireless architecture connection allows saving money compared to the wired one. The flexibility and the easy scalability of this type of connection are other important advantages. Moreover the WiMAX system could allow the direct internet connection of remote sensors and actuators placed very far from the access point (extending the classical Wi-Fi range) so allowing wide remote sensors architecture [13,14].

Currently all these applications use, as local server, a Personal Computer that implies high costs both for purchasing and for maintenance, but also for the energy consumption that is an aspect frequently disregarded in these applications but which is becoming really significant. In this article is presented a cheaper platform for remote control, based on Wi-fi technologies. A real application for controlling instrumentations (standard IEEE 488 or different) in the electric and electronic measurement laboratory of "Roma Tre" University is also presented.

## II. CLASSICAL ARCHITECTURE DESCRIPTION

It is possible to conceive the remote laboratory as divided into two principal parts, the local framework that includes all the equipments local side, and the wideband network that corresponds to the access network and the remote client/users. The local framework is generally composed of:

- a local server that receives commands from the client and delivers these inputs to the software driver that communicates with the instruments by standard protocols (IEEE 488 or RS232). Normally the server is a personal computer running on Microsoft operating system with internet information service (IIS) or Linux;

- IEEE 488 instrumentation such as function generators, oscilloscopes, multi-meters and so on; to drive this instrumentation the server uses normally a suitable GPIB (General Purpose Interface Bus) card;
- old instrumentation with high accuracy, absolutely still suitable for some significant measurement experiences, which, due to the old design, does not implement the IEEE 488 connection;
- the DUT (Device Under Test) that can be either a single circuit or a configurable circuit;
- in this last case, as well as for the old instrumentation case, suitable actuators are needed to reconfigure the circuit or to drive the instruments; to control the actuators it is necessary to use a specific microcontroller card suitably designed for this aim; the card can be internal or external to the PC.

The most common software used to drive the instrumentation, to collect data and to output the results, is LabVIEW. It is a graphical tool, widespread both in the industry and in the learning field, which allows us to design control circuits and systems, to carry on measurements and to design tests. By means of Dynamic Link Library (DLL), LabVIEW implements the GPIB control. In order to publish the information, LabVIEW has a WEB Publishing Tool, very easy to set up, that can be used to design and develop Internet-accessible remote panels for monitoring and control, distributed computing and collaboration frameworks. The client machine accesses a webpage and by means of a plug-in connects to the server machine. When the remote panel is created, an internal web server is started in LabVIEW and the remote panel may be accessed via web browser.

## III. THE PROPOSED ARCHITECTURE

The proposed architecture follows the classical one but the local server is realized with a specific economic card based on RABBIT 4400 microprocessor that replaces at the same time the personal computer, the GPIB card and the μController card, allowing us to save a considerable amount of money. Moreover in order to speed up and make the proposed application easier to use, expensive dedicated software or downloaded plug-ins are not needed. This structure offers the same performance obtainable by the previous one, but without using a pc as a server, eliminates a series of problems connected with it:

- the purchase of the hardware as PC, GPIB card, and, in case of driving actuators, a microcontroller that, sometimes, has a considerable cost;
- purchasing of the software, that can be the operating system like Windows, or software to manage the drivers and the instruments like LabVIEW;
- maintenance of the local server, both from hardware and software point of view: the hardware doesn't need particular attention but the constant operative status reduces life span of the server. On the other hand the operating system needs more accurate attention to avoid crashes, and to protect against hackers attacks that can exploit the server's public IP address to commit illegal actions. This reflects into a cost that includes the specialist staff time dedicated to the maintenance operations, taken away from other more relevant activities.

In this architecture too, the Remote Client starts set-up and manages all the modules that are part of the measuring environment by a common web-browser. The RABBIT microprocessor receives commands from the client and delivers these inputs to the software driver that communicates with the instruments by standard protocol (IEEE 488, RS232 or otherwise). The results of the operation are shown on the client page by acquiring the image via web cam. Images synchronization is linked to client's commands in order to avoid incomprehension about the results obtained from the measurement.

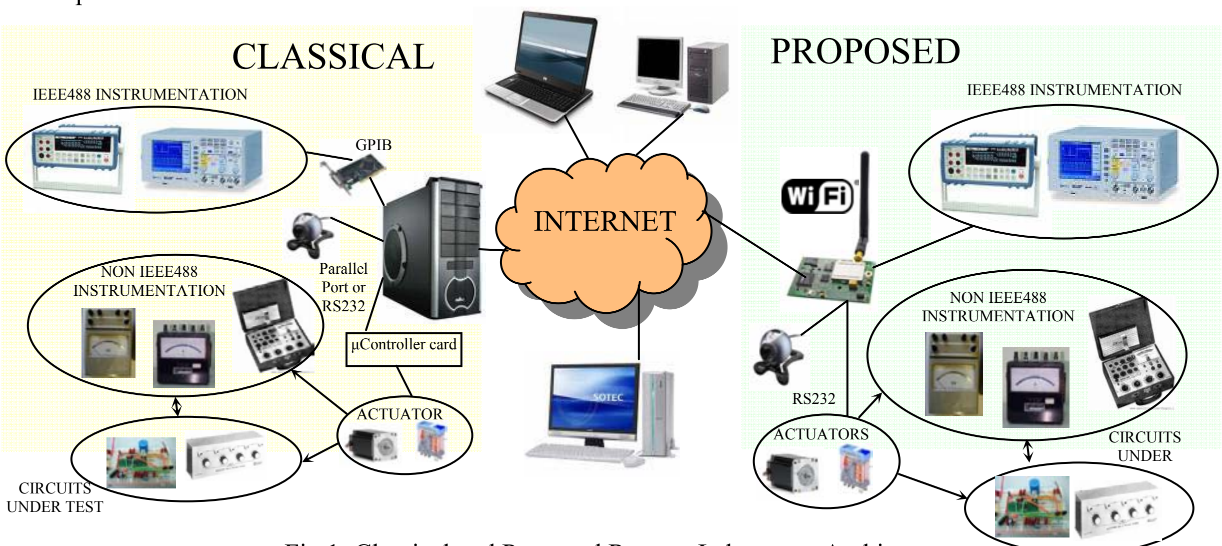
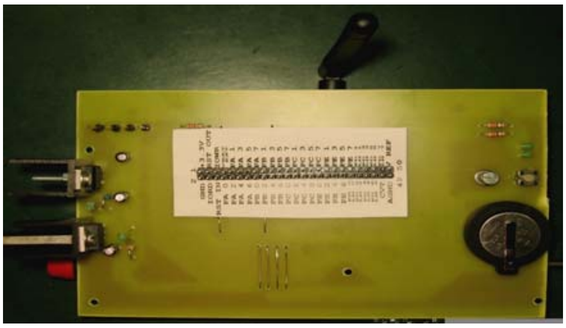



Fig.1: Classical and Proposed Remote Laboratory Architecture

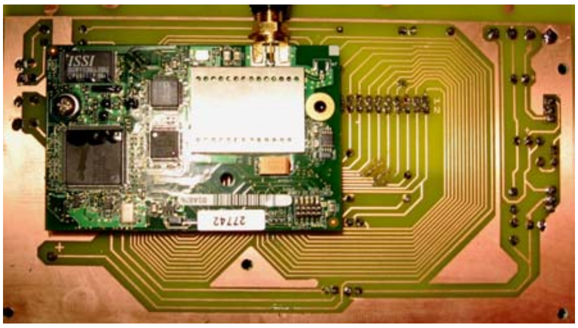
The user appreciates the interaction capabilities and immediate utilization of the laboratory. Error corrections can be available at every level foreseen by the architecture. They have to be both clear and exhaustive to allow a self-learning of the client, eventually providing a test to evaluate progress made by the students. The manager of the remote laboratory is interested in having low cost implementation while still being able to provide system flexibility and dynamicity.

## *A. Hardware*

As stated before, the core of the new architecture is the "RCM440W RabbitCore " card with WiFi functionality. It allows to create low-cost, low-power Wi-Fi based control and communications for embedded systems. The WiFi RCM440W RabbitCore modules are equipped with on-board WiFi 802.11a wireless connectivity. Features include 512K Flash memory, fast program execution SRAM, 35 general-purpose IO pins (GPIO), 3.3V I/O, and low power modes. At the heart of the RCM4400W WiFi module is the Rabbit 4400 microprocessor, featuring a clock speed of up to 58.98MHz. Other features include a true hardware DMA, auxiliary I/O, a quadrature decoder, input capture, GPIO lines shared with up to six serial ports, and four levels of alternate pin functions including a variable phase PWM (pulse width modulation). With a small footprint of 47 mm x 72 mm 1.84"x2.85"), the RCM4400 is compact and can easily be mounted directly onto a user-designed motherboard, along with CMOS-compatible digital devices [15]. The card is inserted in a circuit that provides the power supply and the external connections to drive the GPIB instruments and drive the actuators (figure 2). The rest of the hardware is similar to the general architecture.



a)



b)

Fig.2: Management Circuit for RCM4400W module: top (a) and bottom (b) views.

## *B. Software Server Side*

A RABBIT web application is made up of six main blocks that integrate all the functionalities that the program needs in order to operate correctly [15]:

- APPLICATION: represents the code that must be created. The Application block includes all the activities related to: the initialization of the card that sets the I/O pins, the initialization of the variables of the program, the initialization of the TCP/IP networking system and the HTTP server; the server main functional part that manages the connection with the client; the application specifics and I/O that represents the "back end" of the HTTP server, allowing the driving of the devices; the possibility to use CGI functions, because in many cases their power and flexibility is required;
- HTTP: this section is responsible for collecting requests from the outside world. Each request is analyzed to determine the resource that is being requested, the user who is making the request, and whether the user is authorized to obtain the resource. If the resource is available and the user is authorized, the resource is transmitted back to the browser;
- ZSERVER is the central control unit for all the resources and receives and sends the information to the others diagram blocks. Zserver is designed as a Virtual File System that is a notational convenience for accessing all resources, using a uniform naming scheme. It is responsible for the mapping of the various file system and resource types into a single unified API. In addition, to resource storage and file system, the resource manager needs to be able to associate other data (Metadata and Authorization) with each resource.
- METADATA consists of two tables: the MIME and the Rule table. The MIME indicates to the browser how the content has to be presented to the user, while the Rule table is used by the ZSERVER to apply access permissions to the resources contained in a file system.
- AUTHORIZATION is a mapping from external entities ("users") to the central unit in which authorization is performed, namely user groups;
- TCP/IP block contains the network configuration for the TCP/IP protocol.

Based on the structure previously described, the RCM4400W is programmable by means of Dynamic C that allows the implementation of the TCP/IP, moreover thanks to several libraries, it is possible to implement DNS (Domain Name Server), IP and UDP (User Datagram Protocol). The libraries allow setting up File Transfer Protocol (FTP) both for the client and the server side, Hyper Text Transfer Protocol (HTTP), Trivial File Transfer Protocol (TFTP), Simple Mail Transfer Protocol (SMTP), Post Office Protocol version 3 (POP3) and Telnet.

### *C. Software Client Side*

The software client side is fundamentally constituted by a HTML page accessible via a web browser. In order to obtain the better performance from the software and a more friendly visual interface, it is possible to implement applets by means of other programming languages as VB6, .NET platform, Flash MX etc.

### *D. Costs*

The next table points out the costs of the two different architectures; obviously the costs of the common components have been neglected. The prices can be found on the internet.

Table 1. Costs Comparison between standard and proposed architecture

| | Hardware | | | Software | | Total costs |
|---|---|---|---|---|---|---|
| Standard Architecture | PC ≈ 500 € | PCI card for IEEE 488 ≈ 550 € | µController Card ≈ 100 € | LabView (or similar) ≈ 2400 € | Operating System i.e. Windows ≈ 100 € | ≈ 3650 € |
| Proposed Architecture | RABBIT4400W + support electronic card ≈ 120 € | | | Not needed | | ≈ 120 € |

## IV. THE FIRST EXPERIENCE

In the first application of the proposed architecture we consider one measurement bench that allows measuring the behaviour of first and second order passive filters that can be settled in kind and values of components.

The elements included in this experience are divided into two categories: the local structure, corresponding to the remote laboratory hardware, and the wideband network, corresponding to the access network and the remote client.

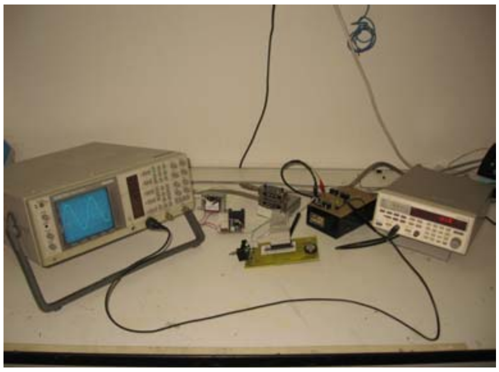


Fig.3: Remote Control Measurement Bench.

The first is composed of:

- the RABBIT card that operates as server and which drives the local hardware;
- the Yokogawa function generator FG 120, that offers two fully independent channels output that can provide five standard output waveforms with frequency range between 1 µHz and 2 MHz, and GPIB interface;
- the Philips PM 3350A oscilloscope with two 60 MHz bandwidth channels and add-on modules to interface for remote control output to RS-232 and GPIB [16].
- the devices under test, constituted by a set of three configurable filters: the implemented filters are low-pass, band-pass, and high-pass in which is possible to change components values.
- the actuators (relays) to drive the re-configurability of the filters.
- the webcam needed to capture what happens in the oscilloscope monitor.

The wideband network is composed of:

- the access point which allows to connect to the World Wide Web and the control of the remote laboratory.

The interaction between the two previous categories is obtained by the RCM4400W that takes the data stream coming from the client and uses it to drive instruments and actuators.

The incoming data streaming feeding the RABBIT is in the form of ASCII strings through sockets. The data is interpreted by the software inside the RABBIT which distributes the information to instrumentations, actuators or webcam.

If the ASCII string is a command to drive the instrumentations, the software translates it in the IEEE 488.1 standard, otherwise outputs it to the I/O Pins to drive the relays or uses it to capture the webcam images. These images are snapshots taken at a time frame interval of seven seconds. As the figure 4 shows, on top there is the configuration set for the YOKOGAWA function generator. The data setting is inserted in a string code and, after the execution command sent to the RABBIT, it is then translated into IEEE 488 standard to drive the instrument. With the same procedure we obtain the oscilloscope control that is enabled by the acquisition (acquisisci) button. Seven seconds after the push of this button, the RABBIT will prompt the webcam to collect the image that is in turn sent to the client. This operation is however repeated every seven seconds. We engineered this refresh time not to consume too many resources but, at the same time, to allow a realistic oscilloscope operation status view without significant loss of information. The program running inside the RABBIT rejects multiple access avoiding overlapping between students requesting the same experience at the same time, without using a database to control the access.

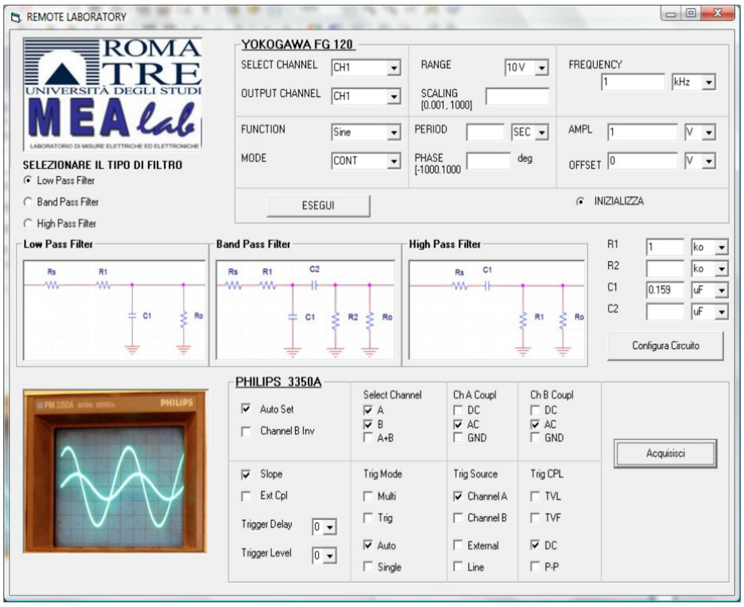



Fig.4: Panel of remote control for the Measurement Bench

## V. Conclusion

A Wifi measurement remote laboratory has been realized. The proposed approach takes advantage of the cheapness and the flexibility offered by RABBIT 4400 card both in assembly easiness and in the easiness of realization of software handling the internet interface and the local instrumentation implementing IEEE 488 or different standards. A first practical realization of the system, with the aim to implement a typical measurements laboratory experience, was set up to try out the capabilities of the proposed architecture. The single measurement bench is extremely cheaper than the one realized with a PC architecture.

Offering the same performance, it allows saving money both on the hardware and on the software, making the cost of the apparata accessible to everyone.

A more articulated instrumentation structure could require a more elaborated or powerful hardware, but this issue has to be better focused and investigated.

## References

[1] H-P Huang, Z-Y Hsiao, “Development of Remote Control System of a Semiconductor Cluster Tool,” in *Proc. of IEEE International Conference on Systems, Man and Cybernetics,* October 6-9, 2002, vol. 4, 6 pp..

[2] H. C. Lin, “A Precise Multi-Location Riveting System using Remote Monitoring and Control,” in *Proc. of 2004 IEEE Conference on Robotics, Automation and Mechatronic,* December 1-3, 2004, Singapore, pp. 578-582.

[3] F. Mighela, C. Perra, “Remote Control for Microscopy Applications,” in *Proc. of IMTC 2006 “Instrumentation and Measurement Technology Conference,”* April 24-27, 2006, Sorrento, Italy.

[4] R. B Sepe, N. Short, “Web-Based Virtual Engineering Laboratory (VE-LAB) for Collaborative Experimentation on a Hybrid Electric Vehicle Starter/Alternator,” *IEEE Transaction on Industry Application*, Vol. 36, no. 4, July/August 2000.

[5] Y-C Chang, C-F Chen, H-S Lin, J-J Luh, J-S Lai, F-C Chong, “Monitoring and Transmission via Wireless Network for an Assistive Device,” in *Proc. of 2005 IEEE Engineering in Medicine and Biology 27th Annual Conference,”* September 1-4, 2005, Shanghai, China, pp. 581-584.

[6] G. Xiang, Y-H Liu, D. Ding, Y-T Shen, “An Internet Based Pulse Palpation System For Chinese Medicine,” in *Proc. of 2002 IEEE/RSJ International Conference on Intelligent Robots and Systems EPFL,* October 2002, Lausanne, Switzerland, pp.1481-1486.

[7] M. Caciotta, F. Germoni, A. Trifirò, “Remote Laboratory: “How to Render Less Virtual as Possible The Meet with the Instrumentation,” in *Proc. of XVII IMEKO World Congress “Metrology in the 3rd Millenium“*, June 22-27, 2003, Dubrovnik, Croatia.

[8] N. Ranaldo, S. Rapuano, M. Riccio, F. Zoino, “Remote Control and Video Capturing of Electronic Instrumentation for Distance Learning,” *IEEE Trans. on Instr. Meas.,*vol. 56, no. 4, pp. 1419-1428.

[9] D. Bonatti, G. Pasini, L. Peretto, R. Tinarelli, “An Interactive Measurement System for Remote Laboratory Activities,” in *Proc. of IMTC 2005 “ Instrumentation and Measurement Technology Conference,”* May 17-19, 2005 Ottawa, Canada, pp. 2108-2112.

[10] S. Gallardo, F. Barrero, S.L. Toral, M.J. Durán, “eDSP*lab*: A Remote-Accessed Instrumentation Laboratory for Digital Signal Processors Training Based on the Internet,” in *Proc. of IECON 2006 “32nd Annual Conference of IEEE Industrial Electronics Society”*, November 7-10, 2006, Paris, France, pp. 4656-4661.

[11] F. Barrero, S.L. Toral, S. Gallardo, “eDSPlab: Remote Laboratory for Experiments on DSP Applications", *Internet Research-Electronic Networking Applications and Policy*, Vol. 18, Núm. 1, 2008, pages 79-92.

[12] S. Gallardo, F. Barrero, M. Rocío Martínez-Torres, S.L. Toral, M. J. Durán, “Addressing Learner Satisfaction Outcomes In electronic Instrumentation and Measurement laboratory Course Organization”, *IEEE Transactions on Education*, Vol. 50, Núm. 2, 2007, Pages 129-136.

[13] D. Kolarić, K. Skala, A. Dubravić, ”Remote Control and Measurement of Temperature over the Web”, in *Proc. of the 47th International Symposium ELMAR-2005,”* June 8-10, 2005, Zadar, Croatia, pp.117-119.

[14] Y. Kim, R. G. Evans, W. M. Iversen, “ Remote Sensing and Control of an Irrigation System Using a Distributed Wireless Sensor Network,” *IEEE Trans. on Instrumentation and Measurement*, Vol. 57, no. 7, July 2008.

[15] RCM4400W RabbitCore Users Manuals.

[16] IEC 60488-1 (or IEEE 488.1™) International Standard, “Higher Performance Protocol for The Standard Digital Interface for Programmable Instrumentation”, first edition 2004-07.