WEB Instruments

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***Abstract*—This paper introduces the concept of a Wi-Fi tag that can be used as an extension of the iLab remote laboratory framework. A Wi-Fi tag has been built by Tag4M of Austin, TX, USA, with the purpose of connecting sensors to the Internet where data is displayed using Web Pages that are posted and can be accessed from anywhere in the world. The Tag4M Wi-Fi tag is tiny and low cost works on battery power, and therefore it is very suitable for student experimentation as an extension of the remote laboratory framework. The tag allows remote students logged in the iLab framework to execute local or home based experiments, and by that brings more hands on capability to the framework. The paper introduces the Tag4M tag, the iLab framework, gives an example of using the iLab framework with the NI ELVIS station, and shows how this type of experimentation can be enriched using the tag to introduce local experimentation where remote students can perform hands-on sensor measurements, create their own web page instruments and also post their web page instruments into the general framework for other remote students to use.**

Keywords - Wi-Fi tag; iLab; Web Page Instrument

I. INTRODUCTION

The concept of Computer Based Instrumentation relies on the continuous advancement of PC technology – processor, memory, etc -, improved resolution and speed of ADCs and DACs, and easiness of programming with LabVIEW, the graphical programming environment used by scientists and engineers to build computer based instruments. The entire idea of computer based instrumentation has been built around LabVIEW. Plug-in computer boards, PXI, cRIO, cDAQ and USB devices have been built all with LabVIEW driver support in order to make the idea of computer based instrument viable. Traditional BOX Instrument based setups have been replaced or upgraded, where suitable, with computer based instruments built with LabVIEW.

Figure 1 The Tag4M Wi-Fi Tag

The concept of Virtual Instrumentation is larger than that of computer based instrumentation. A Virtual Instrument is an instrument that leverages **off-the-shelf technologies** to implement its capabilities for measurement, display, storage and communication. Computer based instruments are limited by the strength of one computer and LabVIEW running on this computer.

This paper defines a new class of virtual instrument which we named WEB Page Instrument or WEB Instrument. WEB Instruments move the concept of virtual instrumentation beyond computer based, beyond LabVIEW and into the Internet space where instruments are built, and shared across the world using web pages. WEB Instruments are built on the power of the Internet network (vs that of a single PC). WEB instruments need Wi-Fi tags (Fig.1) that connect sensors to the internet. Wi-Fi tags benefit from the latest advancements in RFID technology, the improved resolution and speed of ADCs and DACs, components miniaturization and low power requirements. WEB instruments also need the network infrastructure, the Internet, web pages, more advanced web page technology that has not been invented yet, Google search engine, etc, mainstream network technologies. Sensors connected to Wi-Fi tags send data to Access Points that push data further into the Internet to web pages, widgets and other web based applications that reside at IP addresses all over the world. WEB Instruments change the way we acquire data, control and share measurements. WEB Instruments will change the way we teach instrumentation.

II. THE SYSTEM

We have created a tag that links the physical world of measurements with the Internet. Tag4M is an active ultra-low power Wi-Fi tag (Fig.2) that has measurement capabilities. Besides a Wi-Fi radio, the tag contains minimal circuitry for signal conditioning front end to its 14-bit ADC, I/O connectors for signal wiring, and a battery holder. The tag is capable of running for years on a 3V battery if it is programmed with sleep times in the range of 100 seconds.

Figure 2 Wi-Fi Tag

The tag, if connected to sensors will perform two functions:

a) **Measurement.** The tag converts signals coming from sensor(s) into digital values. Tag4M tags are capable of measuring analog signals in 0-10V and 0-0.4V with 14-bit precision, 4-20mA current signals, and digital lines.

b) **Communication** (Wi-Fi). The tag is continuously looking for an Access Point(AP) who it can associate with. If at boot-up or wake-up time the tag finds an AP, then it will send data and get commands to/from this AP. The AP will further send data to the Internet. Somewhere on the Internet network there will be one (or several) computer that is hosting a web page which presents tag data for other client computers to access. The WEB Page is the instrument (Fig.3). Users of the web instrument will connect tags to their local sensors and run the web instrument for local data acquisition, processing, storage and communication.

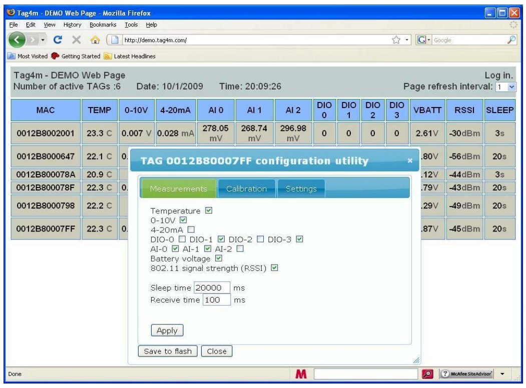


Figure 3 WEB Instrument Page with Configuration Panel

WEB Instruments can be shared in the classroom and school laboratory. In distance learning environments the web infrastructure for class material is located on a server. This infrastructure also includes the lab associated web page instruments. While measurements for this lab are done locally using Wi-Fi tags connected to sensors, the results are posted remotely by web pages inside the lab web infrastructure. This is something new, a new facility of the lab web infrastructure where students can perform local lab related measurements using Wi-Fi tags as hardware extensions of the lab web infrastructure.

III. WEB INSTRUMENTS IN WEB BASED TRAINING WBT

Distance education and traditional face-to-face classroom course delivery are not mutually exclusive. Each has positive aspects that can be maximized and negative aspects that can be minimized by combining them, an approach known as blended learning. Student learning is enhanced when technology is made available that allows for a live learning environment and remote labs are an ideal delivery method for distance education curriculum. The addition of Wi-Fi tags that connect sensors to web pages brings a new and powerful tool to remote labs. Instruments are supplied as web pages hosted by Internet services inside the actual Remote Laboratories (Fig.4).

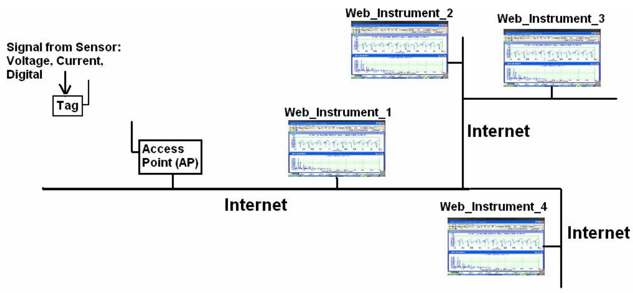


Figure 4 WEB Page Instruments

Academic departments seeking to reach students via distance education course offerings find that some on-line curricula require a traditional hands-on lab model for student evaluation and assessment. The authors solve the problem of providing distance education curriculum and supporting instruction lab components by using a low-cost remote lab based on WEB Instruments.

Web Based Training WBT as an E-learning technology or method is characterized by followings:

- Online computer education
- Education supported by web technologies
- Teaching synchronous and asynchronous online courses
- Studying materials that are mostly available via web browser
- Studying materials that are located anywhere in the world (on the web)
- Opportunities to work inside the virtual classroom

Researchers around the world are thinking about the possibility of enriching the idea of Web Based Training with some elements of local experimentation where students acquire and use small low-cost devices to complete so called “in home” experiments that are part of the weblab topology, described and scheduled inside the Web Based Training labs.

The Internet portal creates an entry gate to the world of information related to a certain subject. The technology of thin-client (“thin-client/server computing“) is a model where applications are accessible, administrated and operated fully on the server’s side. This technology provides advantages of better administration, access, performance and safety, which help reduce requirements imposed on property owners. But you do not want technology, even the one that is very good and very well administered, to eliminate creative thinking and hands on experimentation, the out-of-the-box element.

Remote laboratories can be **real** or **virtual**. The real model is based on getting information from real experiments, with visualization, providing information in the form of numbers and graphs. The virtual model is based on simulations with the help of software applications like Matlab’s server / Simulink, or National Instruments’ LabVIEW. Both models can now benefit for a complementary tool, the very low-cost Wi-Fi tag that can be used by the “educational client” in an “at home” type of environment for doing real experiments.

IV. IV iLAB INTRODUCTION

Our team has been involved in the implementation of MITs iLAB technology in Europe. The idea is to offer a standardized Remote Laboratory technology that is adapted and completed with local expertise in order to increase its efficiency.

There are many approaches to the design of Internet-based remote laboratories for education. Early systems required specialized platform-dependent software running at the client computer. Later approaches moved towards browser-enabled technologies for the client, including Java applets, static and dynamic HTML pages, and CGI scripts. HTML-based solutions often result in thin clients with little processing abilities and rely heavily on server-side technologies such as CGI that tightly couple client and server development.

The iLab architecture provides a framework for lab development and deployment. This approach differs from sockets-based solutions by hiding many of the details involved in network communication from the developer.

This was implemented using web-service technology, which provides an object-oriented interface to client/server communication based on traditional method calls that take place over HTTP. In addition, the iLab architecture decouples laboratory-specific operations related to running experiments from the more generic administrative tasks of user authentication, user authorization, group management, and results-storage functionality. The iLab architecture extends the client/server weblab topology by incorporating an additional third tier: the Service Broker, as shown in Fig.5. The Service Broker handles all administrative tasks, thus freeing the server machine (and its developers) from having to implement custom administrative solutions for each different weblab.

However, today experiments have become more and more complex. As a result, the demand for ever more specialized and expensive equipment has increased. Presently, only some large research institutions and perhaps some universities can afford such equipment, and even these more fortunate institutions can only partially have what they need. Remote Laboratories present a viable solution that permit greater access to resources, following ongoing changes in learner interactions online curriculum facilities.

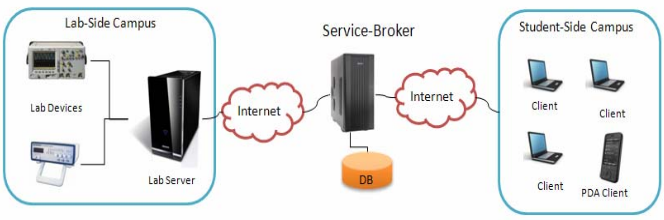


Figure 5 iLAB Shared Arhitecture

Meanwhile, modern learning theories, including constructivism, have emerged and have been employed more and more in Higher Education teaching practices. This trend has significantly modified the traditional learning process model. Students are now expected themselves to build their own interactions with learning experiences as well as materials and different actors that they have to interact with as they complete their curriculum.

In the field of Engineering Education, this suggests a stronger contribution of hands-on approaches in the process of quality of learning. Hands-on approaches are a support of several pedagogical objectives:

- *to compare theory and practice,*
- *to learn how to employ specific tools and devices,*
- *to face real-world situations,*
- *to interact with peers in circumstances that require problem solving skills developed through close*

collaboration, which is characterized by initiative, creativity, etc.

This also emphasizes the need to use experiments within online learning activities, in part, because these online activities permit students to interact multi-culturally across national boundaries, reflecting present and future business, academic and scientific interaction.

V. iLAB AND TAG4M

If we access the web page of the iLAB ServiceBroker and log-in as Guest (http://ilab.mit.edu/ServiceBroker), we will connect to the iLAB labs (Fig.6).

From the list, we choose to connect to the ELVIS laboratory. Using this laboratory as an example, we would like to show how we can add more functionality to the iLab system by having a student behind the iLab client use the Tag4M tag for local experimentation.

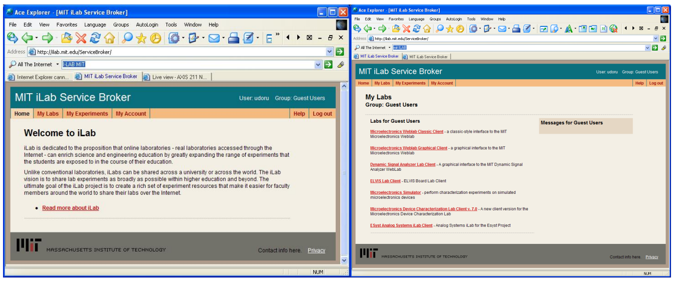


Figure 6 MIT iLab Guest access

Students may be located anywhere and have access to Internet connection so they can log in the ELVIS laboratory (Fig.7) and do some laboratory experimentation as implemented by the iLab platform.

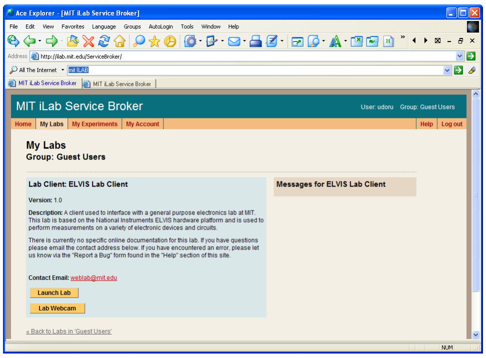


Figure 7 ELVIS Lab Client

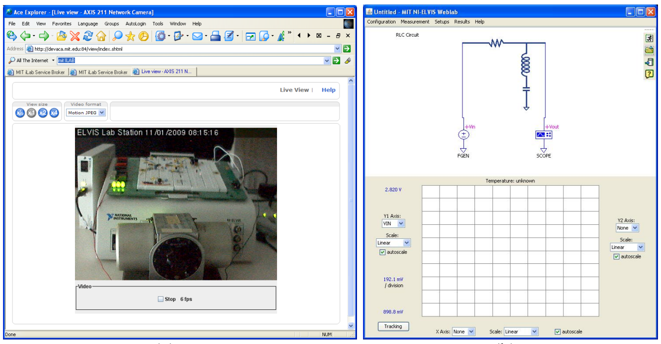
Here, inside the iLab platform we see two types of student user experience:

a) Completely remote experimentation user experience, or

b) Combination between remote and local user experience.

In the first case, the completely remote scenario, the student will simply log into the ELVIS lab and:

- ➢ Read the laboratory instruction
- ➢ Eventually enter the web site of National Instruments and read about NI ELVIS
- ➢ Have a passive look at the experiment using a web-cam (Fig.8a) and launch the experiment (Fig.8b)
- ➢ Configure the lab and remotely perform the LRC experiments (Fig.9)



(a) (b)

Figure 8 ELVIS experiment:
(a) web-cam image (b) RLC experiment

In the second case, there is an element of local experimentation inside the iLab content, a web page that can interact with the student and ask him to do some preliminary LOCAL experimentation using a WEB Page Instrument that has been build around the TAG4M tag and which is posted inside the iLab framework.

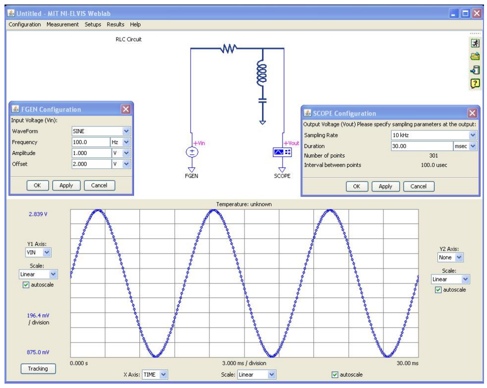


Figure 9 The RLC experiment: configured and executed

This web page instrument allows our student:

- ➢ To better understand the laboratory purpose
- ➢ To perform some "direct hands-on experiment"

The web page instrument has also a testing function where it will verify student's knowledge and ability to perform some related home/local based experiment and if the test is passed, will offer the student permission to execute the next steps inside the iLab laboratory.

Referring to Fig.10 below, we give an example of such direct interaction between iLab's Web Page Instrument and a remote student:

- ➢ Ask the student to implement a potential divider

- Fix the values for the resistors (R1 and R2)
- Select a fixed potential (for example the battery potential is measured using the Wi-Fi tag and the reading is sent via an Access Point into the Internet and to the web page instrument which is part of the iLab framework)
- If the WEB Instrument passes the iLab page a correct value then the student is allowed continue the experiment inside the iLab framework.

Using the Wi-F tag as a local extension of the iLab framework, remote students can:

- perform local qualifying experiments
- develop new WEB Page Instruments that are suitable for their experiments or new experiments that the students want to perform
- implement complex LabVIEW applications
- develop more laboratory material
- post their Web Page Instrument so other students in remote locations can use it with their Wi-Fi tags
- etc.

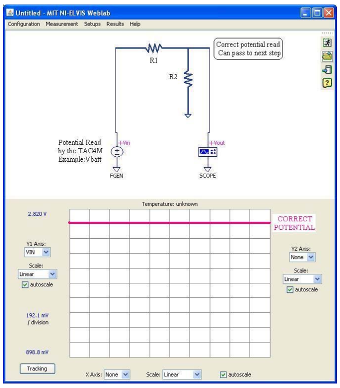


Figure 10 ELVIS + TAG4M experiment

VI. SENSOR BASED ILAB

The iLAB Service Broker may offer a Lab named Tag4M Lab Client. This lab could be structured around types of sensors, so the problem set is sensor based. The iLAB Service Broker for this lab would provide two things:

a) The tag4M Lab Client web page, which is a weblab very similar to the ones currently posted, and

b) One or several Tag4M Wi-Fi tags with sensor extensions to be used in the experiments.

Under this paradigm the tag becomes an extension of the remote lab into student's hands, and this allows for local experimentation with weblab interaction. The following is an example of content for the Tag4M lab.

Tag4M Client: Measurement of Acceleration, Motion, Tilt

1) Description of the type of measurement that is investigated. **Vibration, Motion, Tilt**

2) Description of the sensor used to implement this type of measurement (Fig.11).

ADXL330 3-axis accelerometer with voltage outputs connected to Tag4m Wi-Fi tag.

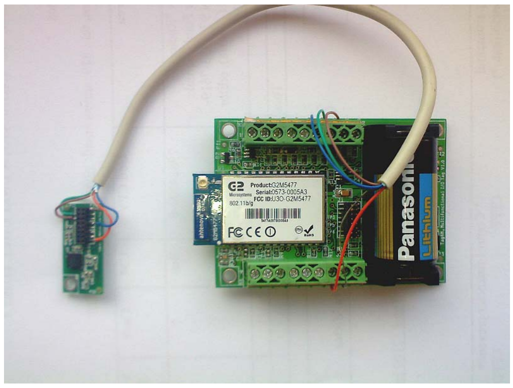


Figure 11 ADXL330 attachment board with TAG4M

3) Schematic or diagram of the circuitry showing how the sensor is connected to a measurement device - Web Page Instrument area that shows Tag MAC and IP address and a graph containing X, Y, and Z voltage levels that correspond to positions of the ADXL330 during the experiment (Fig.12).

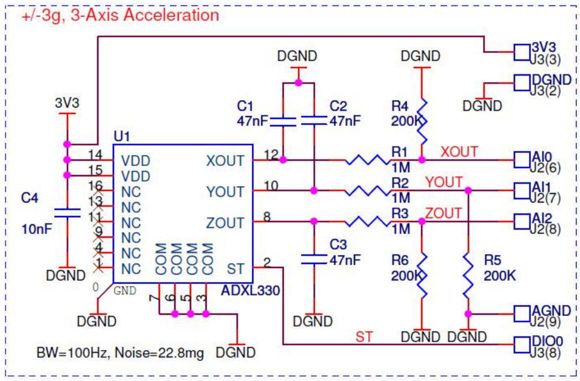


Figure 12 ADXL330 sensor attachment board circuitry

4) The Web Page Instrument is part of the iLab Tag4M Lab Client (Fig.13).

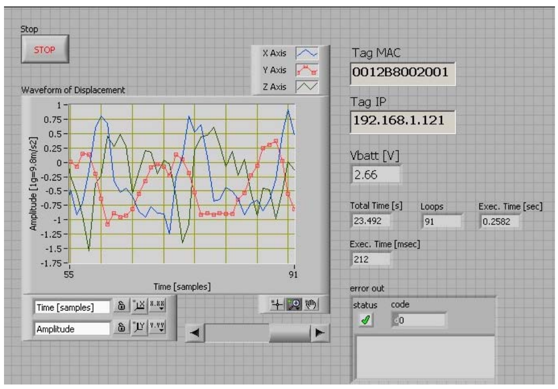


Figure 13 3-Axis Acceleration measurement using the Web Page Instrument provided by the Tag4M Client weblab

The student will physically perform the experiment using a small ADXL330 attachment board connected to the Wi-Fi tag (Fig.11). During the experiment, while the student tilts the attachment board, the tag reads ADXL330 X, Y, and Z axes and sends the data via a local Access Point to the Internet and further to the Web Page Instrument for display.

Similar experiments can be created to measure:

Light intensity (Fig.14)

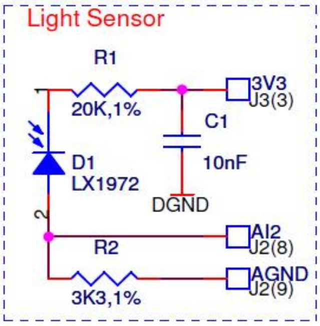


Figure 14 LX1972 sensor attachment board circuitry

Sound (Fig.15)

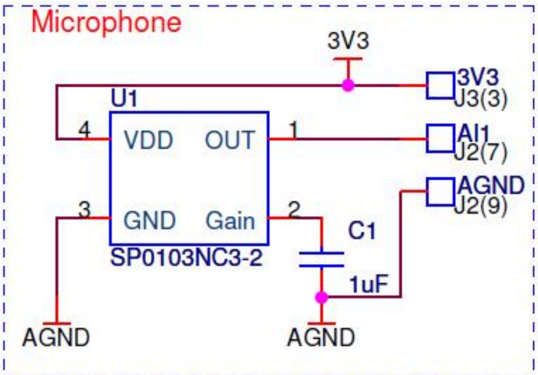


Figure 15 Microphone sensor attachment board circuitry

Temperature and Humidity (16)

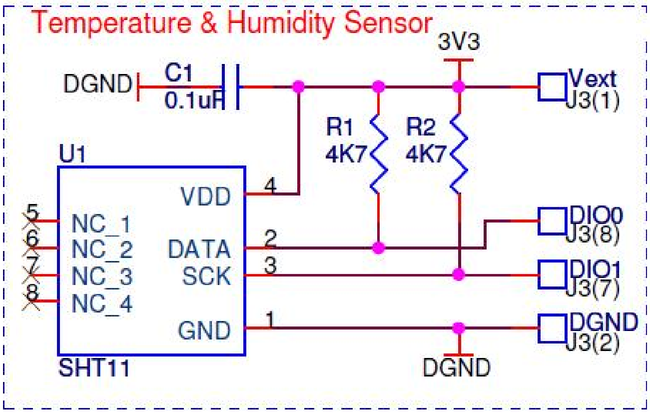


Figure 16 SHT11 sensor attachment board circuitry

LED Pattern (17)

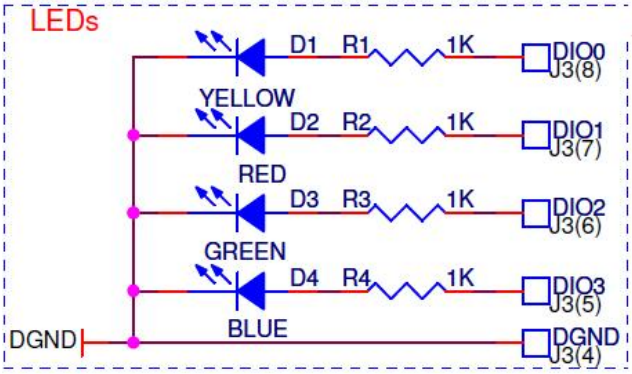


Figure 17 LEDs attachment board circuitry

VII. CONCLUSIONS

A Wi-Fi tag has been built in order to support the concept of a WEB Page Instrument. Tags with Wi-Fi and measurement capabilities are connected to sensors, and measurement data is sent to the Internet network to be posted on web pages. Client computers anywhere on the network can access WEB Instruments to monitor remote experiments or make local measurements using tags connected to local sensors. The concept of WEB instrument moves virtual instrumentation from the computer based space into the Internet networked space. The iLab remote laboratory framework can greatly benefit from using the Wi-Fi tag. Remote students will use the tag as an extension of the remote framework, in order to perform local or "home based" experiments that are part of the general framework but physically executed locally. This is a great combination of virtual experimentation with local flavor. Students can post their web page instruments in the framework for other students in remote locations to use them with their own tags. Work is done currently to create many web page instruments, a community of web page instruments that connect sensors to the Internet.

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