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A proposal of virtual laboratory structure

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Abstract – *The nearly avalanche expansion of the information and communication technology (ICT) strongly influenced many domains of our lives. From the viewpoint of an academic teacher specialized in the area of instrumentation and measurement (I&M) these influences alter both measurement techniques and didactic process. Distance learning based on the Internet technology is becoming more and more popular. In this context remote virtual laboratories are very useful tools. Students can access virtual instruments via a computer network and carry out real experiments directly by using a standard Web browser. In the paper there is presented a proposal of a virtual laboratory structure. To the key elements of the proposed system architecture belong: the main server, the so called system manager and measurement server. The software is created for Microsoft Windows 2003 Server and Windows XP Professional. The system has a modular structure which can be scalable in a simple way.*

Keywords – *virtual laboratory, virtual instrument, distance learning, distributed systems.*

I. INTRODUCTION

Recent developments in the area of information and communication technology have a great influence on various techniques of education. Distance learning, based on modern Internet techniques, has become of great importance. As a result, there is a need to create platforms delivering on-line courses and to work out systems, such as measurement systems, that would enable to conduct experiments in distance learning. The recently coined concept of virtual instrument has led to the application of new techniques in the field of measurement systems design. Virtual instruments replaced expensive and complicated real instruments, the main part of didactic laboratories. This has simplified the process of designing, setting and modernizing these laboratories. The graphic user interface, which resembles real measurement instrument front panel, enables the users of conventional instruments to understand and operate new

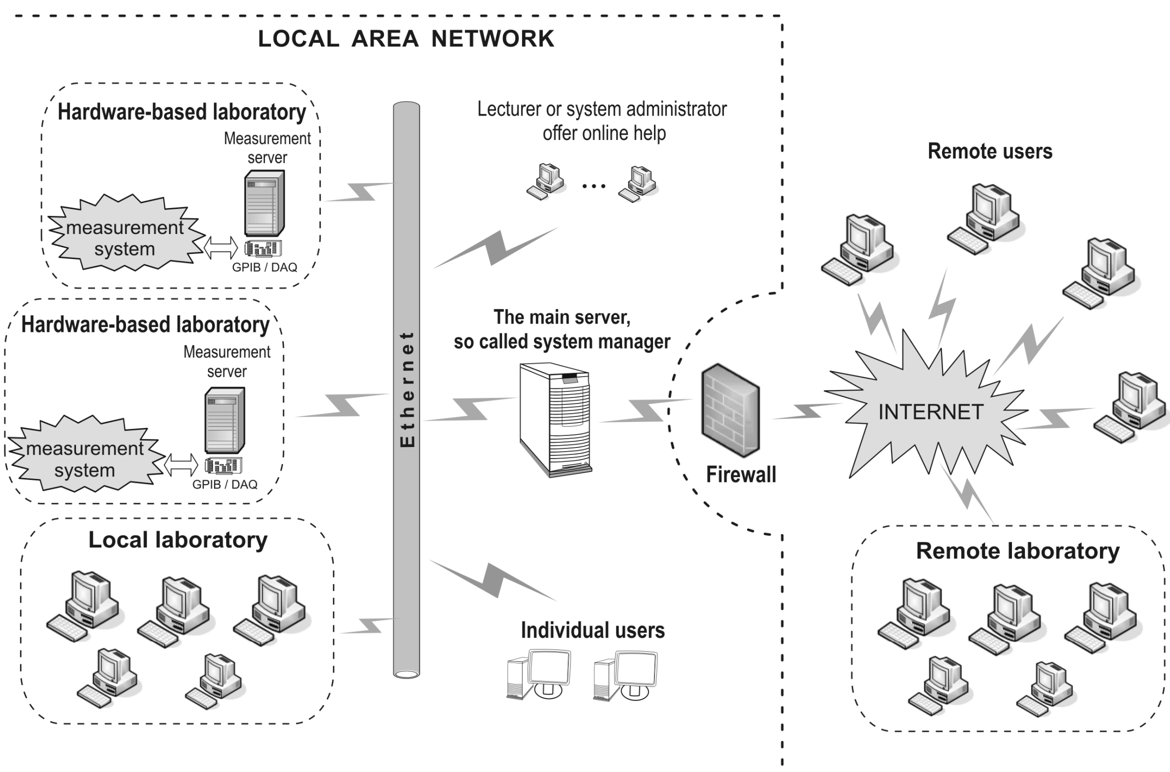

Fig. 1. Virtual laboratory architecture

instruments intuitively. The possibility to modify measurement procedures only by changing software, and without changing hardware elements, enables flexible, modern and simple research and experiments.

Interfacing the virtual instrument with local area network is a simple task. The only requirement is to install a network card in a computer and to assign an IP number to it. The network protocol, being a part of the most tool software libraries, enables to build simple client-server applications. The development of the Internet technology has also led to the introduction of measurement system model [2] that is distributed in a computer network and constitutes a basis for virtual laboratory [1]. Such a laboratory enables so called remote access to its resources from any place and in any time. Remote access should bring a number of benefits, the most important of which is an effective use of laboratory equipment. As a result the students can conduct experiments during lectures, in spite of the fact that measurement instruments will be placed in remote laboratories distributed in different universities or all over the country.

Computer intranet and Internet networks let us to build systems that facilitate monitoring, control and coordination of territorially distributed production, research processes or didactic laboratories. Figure 1 shows a virtual laboratory structure, which constitutes a basis of the presented project.

The proposed architecture of virtual laboratory that implements both local area network and the Internet is characterized by features that are, in general, assigned to territorially distributed systems [2]. These features involve:

- use of mass storage to archive/back up data, which is delivered from different hosts;
- sharing of software resources that are installed in a network;
- functional integration of distributed measurement resources;
- open access, concurrency and calibration;
- fault tolerance.

It is important that students can understand the essence of events that take place in a measurement object, and familiarize with measurement systems and techniques. This should be done without limiting the number of accessible instruments of a given measurement unit. Moreover, it is vital that students can freely configure a measurement system, and even build a faulty circuit. This should enable a student to better understand the problem on the basis of 'trial and error' method. Although virtual laboratory software should block any operations which may destroy some hardware parts of the measurement system. More experienced and skilled students will be given more freedom in conducting their experiments.

Another important function of the virtual laboratory is an access to the experiment in the 'off-line' mode. This could allow the user to learn, understand and partially solve problems that he might encounter in practice. Such a system should enable to design and then store the measurement unit architecture. This would minimize the time needed for remote access to real instruments that are essential to conduct experiments. Yet another useful function of a virtual laboratory is a possibility of simulating simple experiments that can be used to present a problem discussed during a lecture. This function may be very beneficial for users that are just about to learn how to use a virtual laboratory.

II. SYSTEM ARCHITECTURE

To the key elements of the proposed system architecture belong: the main server, the so called system manager and measurement server. The software is created for Microsoft Windows 2003 Server and Windows XP Professional. The system has a modular structure which can be scalable in a simple way. The basic task of the software is to enable communication between virtual laboratory and its users and to ensure access to resources (measurement systems and instruments). In other words, the software manages resources, and organizes and controls its users. Proposed virtual laboratory structure defines two types of users. The first type of users is grouped in a local or remote laboratory (traditional computer laboratory). In this case students usually work in one of the university laboratory rooms and conduct tasks together with their tutor. Individual users with an access to a given virtual laboratory belong to the second group. When faced with problems, questions or in need of consulting someone, students are automatically connected with a tutor or system administrator by specially designed communicator-messenger built in the system or by external applications that enable transfer of sound and picture.

The proposed structure of a virtual laboratory requires presence of one managing server equipped with WWW server and database server that is compatible with SQL. To make the structure more versatile we have used an Internet information server equipped with PHP language units. To ensure a better fault tolerance it is necessary to create a 'mirror' server that could take over the tasks of the main server in case of any breakdown.

The system managing server should:

- synchronize and control all system operations;
- direct system users to proper measurement servers;
- assign access to particular measurement instruments and studied objects;
- enable a simulation mode of a given measurement systems;
- enable 'off-line' operations;
- synchronize data with 'mirror' server;
- have open and scalable architecture;
- have tools for automatic creation of electronic handbook on the basis of didactic materials repository;
- deliver courses with instructions and documentation about conducted experiments and simulations;
- implement SCORM standard for exporting and importing learning content;
- implement functions to audit the learning process and get feedback on students work.

A user of a virtual laboratory is only expected to have an access to a computer and the Internet. Using a Web browser the user can open the Internet website containing the system control panel and then observe results of measurements that are presented on the monitor screen. This way of accessing measurement instruments by a remote user is shown in fig.2.

An uninterrupted line shows how the user can access the laboratory with the help of Web browser. The virtual laboratory software enables also access to remote measurement systems with the use of such elements as, DataSocket, NetRemoting or WebServices (a dotted line). Advanced users are given an opportunity to build or use extended Windows applications that are created in such environments like, fore instance: LabWindows/CVI, LabVIEW, Measurement Studio or Soft Wire.

Measurement server (fig. 1) is an another important element of the system. It can be equipped with GPIB interface, DAQ card or PXI modules. Server software should enable the user to conduct on-demand measurements and measurements that take place in the so called ‘gentle’ time. The on-demand measurement is based on question-answer principle. The user defines parameters of the measurement and then sends a ‘demand’ request to execute the measurement. While measurements are conducted the user interacts with virtual instrument, as if he was interacting with the real instrument. During measurements the user can freely change parameters and functions of the instrument and observe results.

A remote user can change configuration of a measurement unit with the help of programmable cross switch [3]. The switch makes possible to build even several different measurement systems based on the same hardware. Another useful feature of the measurement server is the use of multiplexer so that one measurement instrument can be accessed by several users. This enables sharing the access time to a particular measurement instrument between many users. The instrument configuration can be different for each user and is read in the moment the user is assigned to an instrument.

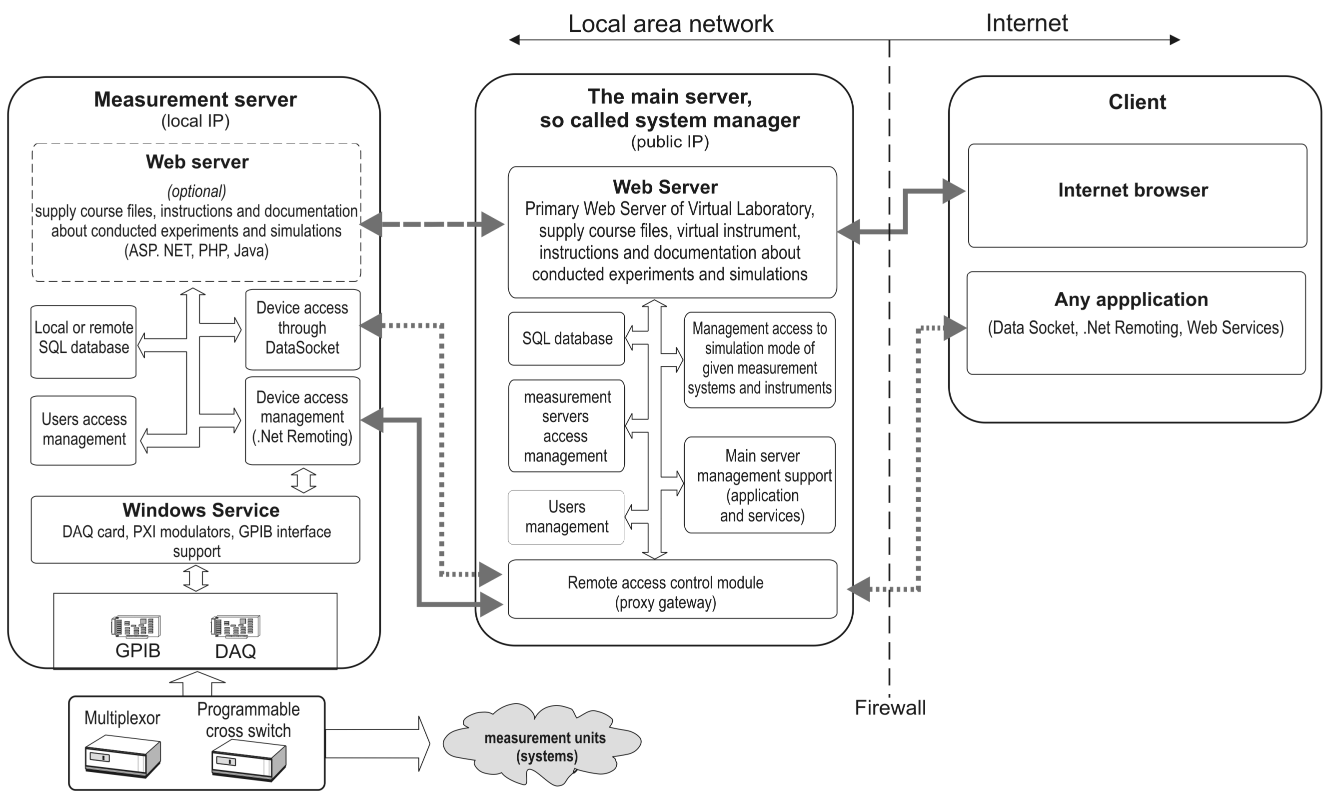

Fig.2. Data flow diagram for virtual laboratory

The measurements server can be equipped with WWW server that facilitates functionality and relieves the main server of such functions as measurement unit simulations or storing laboratory documentation. Advanced users are given an opportunity to build their own virtual instruments and install them on the measurement server and then test it.

As an example of implementation of a measurement server a simple system for a multipoint temperature measurements is described. The system is localized in a local area network and/or in the Internet. It includes a virtual instrument for multipoint temperature measurements build on the measurement server, mentioned above. Main tasks of the measurement server are data acquisition, processing of a measurement and data controlling. The client software has been prepared in two versions. The first one, prepared in the LabWindows/CVI environment, realizes a typical access to the measurement server throughout the DataSockets. The second client has a form on an Java applet and is destined for the Internet web browser. The hardware part of the virtual instrument includes a multichannel data acquisition board, placed in the measurement server, and so called measurement & control unit, placed outside the computer. The main task of the measurement & control unit is the acquisition and conditioning of measuring signals coming from temperature sensors of different kind. Then the processed signals are send to the DAQ board inputs. The measurement & control unit realizes also the control of the heating system which is the additional task of described system. The simplified data flow diagram of the system is presented in fig. 3.

Thus, virtual laboratory should be treated as a very attractive tool supporting education. Remote access to laboratories assures rational managing of an expensive and unique measurement equipment. In other words, it facilitates integration of measurement resources.

It is predicted that in the future the virtual reality techniques will develop so far that the Internet browser will be replaced by 3D interface. The user will have an impression that he is walking inside a laboratory where all the instruments and units will look like real ones. The user may be even tempted to touch these instruments.

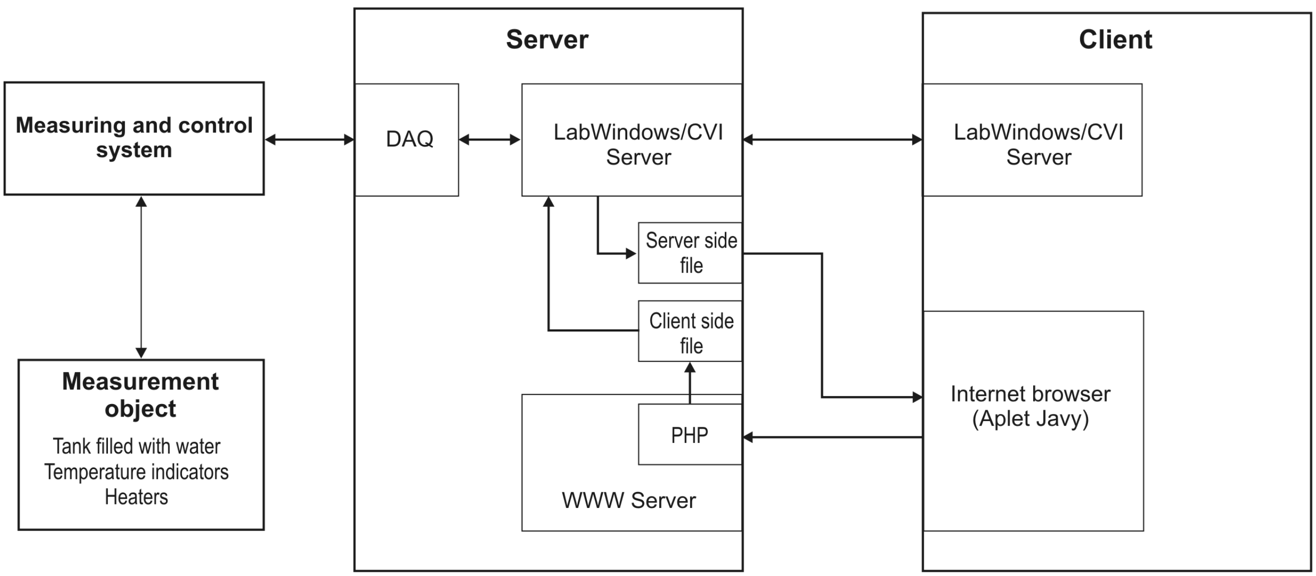

Fig. 3. Data flow diagram for multipoint temperature measurement system

III. CONCLUSIONS

Introduction of measurement instrument in a distributed system in the Internet enables creating advanced and flexible systems that make possible to conduct remote experiments and support learning processes. Nevertheless, one has to bear in mind that neither modern simulation techniques nor remote access to virtual laboratories eliminate necessity of conducting experiments in real laboratories with the use of real instruments. Practical experiments play an important role in the process of gaining knowledge in the field of modern, complex technologies that are conducted on the basis of 'trial and error' methods. This is of great importance whenever complex events cannot be described with the use of mathematical calculations.

Experimental studies of physical events or objects with the use of measurements instruments help students to understand measurement procedures and measurement system structures.

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