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INTERNET-ENABLED CALIBRATION SERVICES: THE REMOTE CONTROL OF INSTRUMENTS

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Abstract: A growing number of measurements in commercial and industrial sector needs to refer to the traceability to the national (and also international) standards. Since the internet-enabled metrology is rapidly developing in the recent years, it offers new possibilities for calibration services. This paper focuses on the problem of the visualization of the internet-enabled calibration process and instruments. The main goal is to identify the solution for real-time data monitoring and control of measurement equipment.

Keywords: internet-enabled calibration, information security, remote instrument control.

1. INTRODUCTION

Internet-enabled metrology is a term that covers the use of the internet/intranet (and other telecommunication systems) to provide quicker access to a range of measurement and calibration services [1]. These services usually include:

- remote control and monitoring of instruments,
- traceable measurements that are conducted at a customer location but controlled remotely by the calibration facility (this covers the term internet-enabled calibration),
- access to measurement and calibration history and other related data,
- access to libraries of testing and metrology software or algorithms.

All of these tasks have become a topic of increasing interest in recent years. Especially the realization of remote calibration systems using some kind of telecommunication services as a mean of transmission is emerging as a solution to the transportation and cost issues compared with the traditional calibration methods. Remote systems like these offer also new possibilities for the National Measurement System, because calibration procedures can be done more quickly and more safely for the instrument or standard that has to be calibrated, everything leading to increased accuracy of the calibrated device.

This approach implies that the traceability and integrity of the calibration process (that is in this case done over some communication network) directly depends on the collected measurement data. The reliable remote control and monitoring of instruments is a crucial aspect of internet-enabled calibration procedure.

A possible solution is to create a multi-layer network application that would control the calibration process, especially to take care of security and reliability of the measurement process. This approach relies on client and server side core applications developed in *NI LabWindows*^{TM} and platform that ensures reliable measurements and support for a wide range of used calibration instruments.

In particular, this paper focuses on the problem of the real-time control and monitoring of the calibration equipment from a remote side.

2. THE PROPOSED INTERNET-ENABLED CALIBRATION SERVICES SYSTEM

Because of the rapid development of PC-based communication and interface standards, every system that remotely controls measurement instruments and processes should include enough software and hardware features, following possible future technology development. The proposed internet-enabled calibration system [2] has the main goal to enable the control and supervision of the remote standard(s) and instrument(s) that are used in a calibration process. It also needs to control the communication between the remote location (customer side) and Calibration Service Provider (CSP) side.

The basic architecture of the internet-enabled calibration system is shown on Fig. 1. It consists of a PC-based manageable high accuracy traveling calibration device or artifact standard (traveling unit, TU) and a CSP server-side application system that controls and monitors the whole process of calibration.

Traveling calibration device/standard and device (instrument or standard) that is under test and/or calibration (DUTC) must have a communication interface in order to connect them to the client-side PC that controls the calibration event. Application on the CSP side performs calibration procedure without any human assistance on the client side. Operator on the client-side only has to make correct connections between the TCD and the DUTC.

Also, client-side equipment (TCD) has to self-recognize and make automatic configuration of available interfaces, connected instruments and standards.

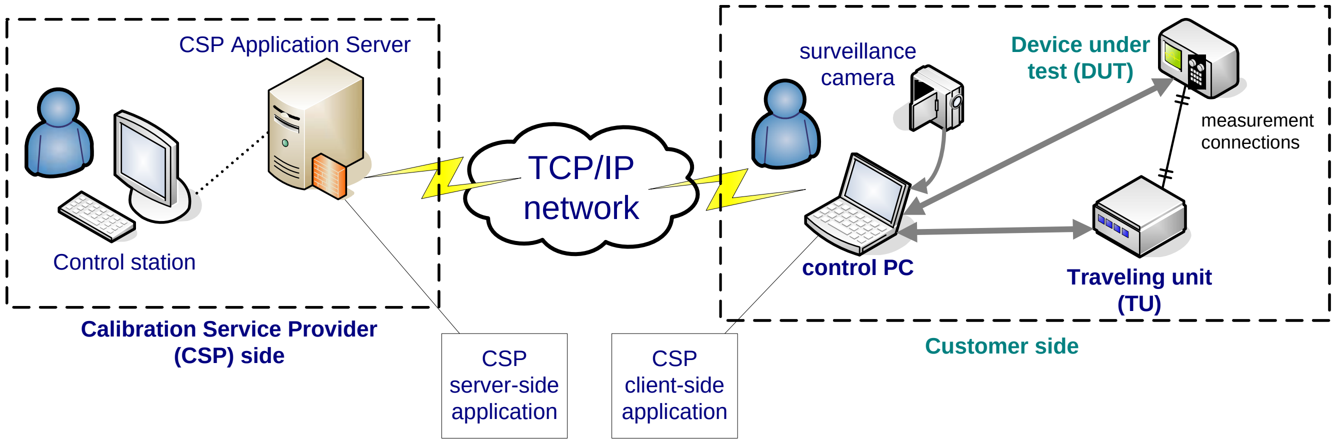

Figure 1. Proposed architecture of the internet-enabled calibration system

This means that there is no need for a specialized engineer or technician in the client side laboratory.

The client-side calibration system (which now consists of both TCD and DUTC) receives all the commands and instructions from the CSP server. It makes continuous scanning of the instrument readings and sends those results to the server on the CSP side. All the relevant operations required to create calibration certificate (data storage, processing and calculation) are executed on the CSP side.

After the calibration procedure is successfully completed, a calibration report is returned to the client. It should contain usual relevant information about the calibration event (date and time of a calibration event, some details of the equipment being used during the session, measurement uncertainty, measurement results and calibration session timings).

The software that runs CSP and client-side calibration and certification procedures is being constantly developed combining several available technologies, but mainly NI *LabWindows*™ platform [3], PHP scripting language [4] and *PostgreSQL* database server [5]. Applications that run under the *Microsoft Internet Explorer*™ have been configured to have access to all the client computer functionality, especially to the IEEE 488 (GPIB for controlling instruments) and USB interface (surveillance camera video streaming). The complete calibration system is under process of constant development in the Croatian Primary Electromagnetic Laboratory (PEL) on the Faculty of Electrical Engineering and Computing, University of Zagreb.

The use of a client-server application is needed in order to monitor the calibration procedure and to perform real-time test of calibration results. In this way the operator on the CSP side is able to warn for every error that could happen while the calibration is in progress.

More detailed description of the travelling calibration device and information transport between CSP and client side is available in [2].

In the following section, a brief description of the proposed remote control of the equipment is discussed.

2.1. Architecture of the calibration system

The calibration system architecture consists of server and client unit. The implementation code is divided in several main parts (as shown on Fig. 2):

- a set of instrument-specific libraries (ILS) that allows to update or add new drivers for additional measurement equipment,
- a device-independent control and monitoring layer (DEICON),
- transport network control (TNC) layer,
- server and client side application management layer (SECM),
- database management system layer (DBMS).

Architecture mentioned above assures several topics:

- simplified management and control of the hardware resources,
- reliable and secure communication between client and CSP side,
- foolproof software upgrade operations.

Most of the system operations that are carried out within a test and calibration procedures are based on the abstract functional layer. This approach helps to simplify software control and monitoring of instruments, because it is independent of the instruments connected to the client-side control computer.

The main part of the calibration system has been coded in PHP (future versions will probably be re-designed on the .Net platform), but every hardware component connected to the remote calibration (client) PC needs low-level control. For this purpose libraries were designed in the *NI LabWindows*™ environment. This C-based language is convenient to drive hardware peripherals and instruments and the driver functions that are located in libraries that are regularly maintained by a number of instrument and other hardware manufacturers.

The PHP part of the application is responsible for managing between multiple clients and a set of remote instruments, video-streams and security infrastructure, leaving hardware low-level control to the corresponding *NI LabWindows*™ driver libraries. In this way it is possible to

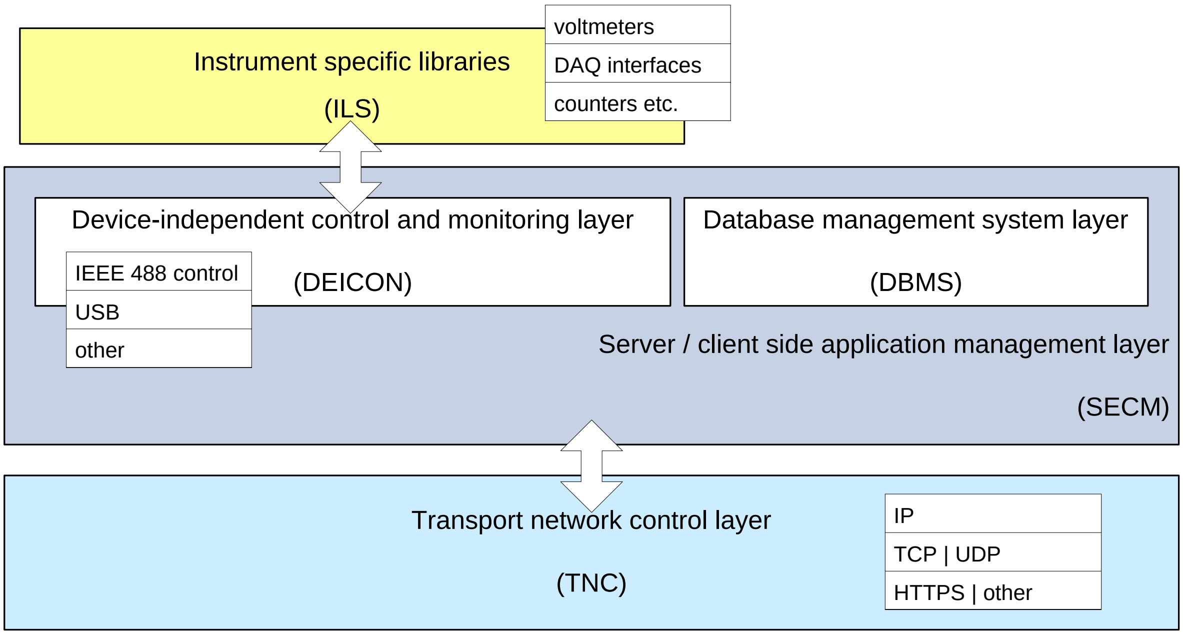

Figure 2. Parts of system implementation

add new equipment without the need for modifying existing application. Whenever a new component is added to the calibration system, it is necessary to add only a new instrument library (which defines functions and commands for communication with related equipment) and a dedicated class that defines user interface and parameters for data acquisition and storage that specific instrument does.

Designing and programming of instrument driver libraries regards the equipment manufacturers. They usually keep drivers for *National Instruments* development platforms up-to-date, but it is always possible to create a new driver based on instrument manuals that usually supply enough information.

Instrument libraries on the client side are loaded dynamically accordingly to the connected equipment and instruments. DEICON assures transport of commands, control messages and data to the connected measurement equipment. All the control information between server an client side is transmitted over TCP/IP communication protocols. The whole core of the software application (client side program component and instrument drivers) resides permanently on the server. As soon as a new client request for connection is accepted, client-side component in a form of an *ActiveX* control downloads to the client-side control PC. In this way, there is no need to install any special software tool on a client PC (except for a standard web-browser), providing thin-client application architecture safe for the whole calibration system.

3. FUNCTIONAL DESCRIPTION OF THE CALIBRATION SYSTEM

In this section, the short description of remote calibration system will be illustrated.

Once a connection between server and client has been established, after the opening server's main page and successful authorization, remote user is presented with a user interface showing a list of available interface cards and instruments connected to them. According to user's rights in the calibration software, user can select specific calibration procedure from a list of available ones, clicking on its name. Before calibration starts, software starts a sequence of tests on IEEE 488 interface and instruments physically connected to it. In the same time, client part of application returns information about hardware status to the server (SECM/DEICON layer). Server returns a set of instrument-specific methods needed to drive all the hardware for specific calibration event to the client side. Then, a dedicated calibration control panel is opened to the client. In this way, user can choose calibration parameters that will be sent to the server. Server initiates calibration sequence by sending commands to the client part of the application that directly controls the instruments and other equipment involved in calibration, and receives data from the remote side. On the completion of the calibration procedure, the results are processed, stored and also returned to the client and displayed.

As additional help, there is a possibility of using video-surveillance for monitoring the calibration process. For this purpose, an ordinary web-camera that is connected to the client PC can be used. This is useful only if the connection bandwidth permits video streaming (xDSL or other type of connection with over 128 kbps upload speed is convenient).

As mentioned earlier, an internet-enabled calibration session takes place between two parties – the CSP, the laboratory with the reference standards, and the customer laboratory with the equipment (standards and instruments) that needs to be calibrated. In this case the measurement data is constantly vulnerable, especially when it is transmitted over the communication media during the calibration process and when it is stored in a database as a part of calibration data.

Auditing subsystem (a part of DBMS layer) is used to store sufficient data about every relevant action in the calibration system. In this way it can be confirmed that calibration took place and can be determined types of measurement, values ad final result of the calibration process.

Data integrity protection over the communication network can be obtained by using some kind of encryption. In our case it is achieved using integrated IPSec security mechanisms that assure no data has been seen or altered during the transmission over the network [6]. Integrity of the whole calibration system is achieved by combining the use of IPSec, authentication control on the client and CSP side and the storage of all (raw and processed) calibration data on the main CSP server. Currently, the PEL CSP information system implements SSL protocol in the *NI LabWindows*^{TM} environment (part that is used for calibration procedure control and network data transfer). A part of the TNC layer is responsible for these tasks [7].

Currently, the PEL CSP information system implements SSL protocol in the *NI LabWindows*^{TM} environment (part that is used for calibration procedure control and network data transfer). In the future, it is planned to use Java Secure Socket Extension (JSSE) set of packages. JSSE implements SSL and TLS protocols and includes software parts for server and client authentication, data encryption and integrity.

It is also possible to use Java applets to run client-side calibration procedure. In that case security issues related to the connection between server and client can be addressed directly to the secure web server (again using the SSL/TLS methods). Also, the portability of Java code is a major advantage over the *Microsoft ActiveX* technology (that is related mostly to *Microsoft* operating systems). These solutions are to be explored in the future.

4. CONCLUSION

This paper has shown a client-server architecture devoted to the Internet-enabled instrument calibration and management in Croatian PEL. The key feature of the proposed distributed calibration system is its usability and extensibility.

A client-server application manages the calibration process and implements all the necessary security solutions that minimize the possibility of fraud. It is important to consider that the data security methodology is relevant to the user of Internet-enabled calibration services.

The system proposed could become the kernel of a future accredited certification service based on remote on-site calibrations.

REFERENCES

[1] R. A. Dudley, N. M. Ridler, "Traceability via the Internet for Microwave Measurements Using Vector Network Analyzers", IEEE Trans. Instrum. Meas., vol. 52, no. 1, pp. 130-134, February 2003

[2] M. Jurčević, M. Boršić, D. Cmuk, "Design of an internet-enabled calibration system", Proc. 19th Metrology Symposium, September 2005, pp 118-121.

[3] National Instruments LabWindows/CVI development platform, http://www.ni.com/labwindows

[4] PHP scripting language, http://www.php.net

[5] PostgreSQL Open Source Database Server, http://www.postgresql.org

[6] Stallings, W., "Cryptography and Network Security", Prentice Hall, 2002

[7] M. Jurčević, M. Boršić, "Internet-enabled calibration services: aspects of laboratory information system security", IMTC 2006 – Instrumentation and Measurement Technology Conference, Sorrento, Italy, 24-27 April 2006