

Remote Control and Reconfiguration of Laboratories for Education and Training

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Abstract. Organizing practical courses and training clearly indicates a demand for remote training. This article describes the concepts of the BACnet (Building Automation Control Network) laboratory being set up by the authors. To allow effective learning the control network (fieldbus) as well as the inputs and outputs of the nodes attached to the laboratory environment must be accessible by the trainee. To achieve this goal a web based application which uses a VNC (Virtual Network Computing) server and a special I/O interfacing unit have been designed. Hence, trainees will be able not only to monitor and control the activities on the control network (the primary goal of the offered courses) but also will be able to see the effects of their activities on the laboratory environment.

1 Introduction

The authors' experience with organizing practical courses, training courses and laboratories at university clearly indicates the demand of training equipment that can be used within a flexible and non-rigid time schedule. Aside the positive effect that students can freely plan their timetables within the general schedule of the course (commencement, deliverables and examination), the relief for instructors is almost more important, since the laboratory can be operated, reconfigured and controlled remotely. There is no need for fixed attendance times and special course rooms.

Based on the experience of previous projects described in section 0 this article will describe on-going work to install a remote BACnet control network laboratory. Section 0 will introduce the concepts for (long-distance) remote control of the BACnet laboratory.

2 Remote Control and Education for Control Networks

The Institute of Computer Technology and the Department of Information Technology and Automation Systems have a common research focus on automation control networks and ASIC (Application Specific Integrated Circuits) and FPGA (Field-Programmable Gate Arrays) design and projects co-operating with the industry. In the past these control networks also known as fieldbusses were installed in isolated environments, but driven by the spread of the Internet remote control and maintenance also become important for these systems. This section highlights two of the various research projects, which not only focus on remote control but also have a strong impact on teaching.

2.1 The asix4web Remote FPGA Prototype Board

In the ASIC design course at the beginners level students are implementing a micro-controller, which runs a simple application program like a pocket calculator or a stopwatch. The final test of the design is done by using a UP1 prototype board from the major FPGA provider Altera. The board contains a FPGA, which can be "programmed" with a user's FPGA design, some switches, push buttons and 7-segment displays as general-purpose input/output peripheral elements.

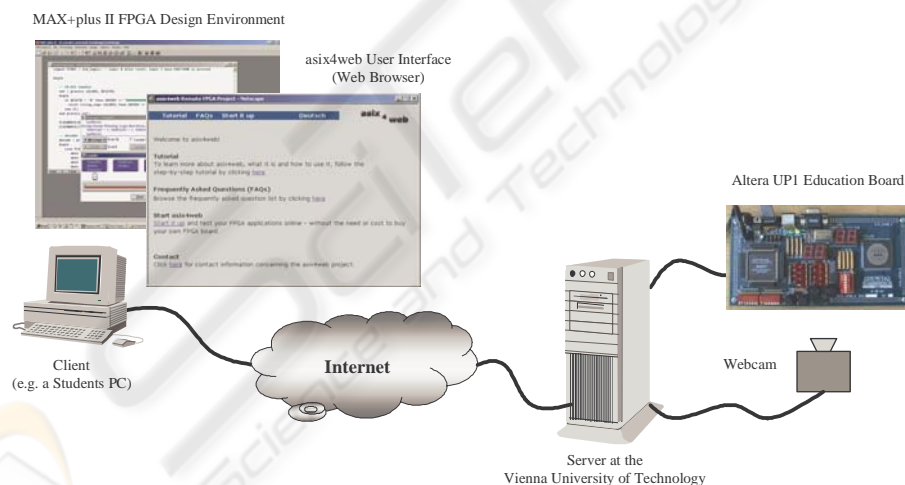


Fig. 1. The asix4web project.

Students are able to develop their FPGA design at home by downloading electronic versions of the lecture notes, a free student edition of Altera's FPGA design software Max+plus II [1], as well as templates and design examples from the course website. However, testing on the real hardware (Altera UP1 prototype board) was only possible at the university lab so far. To overcome this drawback, the project asix4web (an

acronym for "Application Specific Integrated Circuits for the web"), which aims to connect a UP1 prototype board to the Internet, was started some time ago.

A web server and several dedicated application programs make it possible to upload a FPGA design (see Fig. 1). This is done by following a link to the asix4web upload dialog on the asix4web website. Here, a JBC (Jam Byte Code) file is requested which contains configuration data (a user's FPGA design) for the FPGA which is contained on the UP1 prototype in the Altera STAPL (Jam Standard Test and Programming Language) data format. The user has to generate the JBC file by using Max+plus II prior to the upload. Once the user activates the upload, the requested JBC file will be transferred from the client to the server. Next, the FPGA contained on the prototype board which is connected to the asix4web server over the PC's parallel port will be automatically configured with this file.

Finally, the state of the peripherals contained on the prototype board can be controlled and observed via the internet. This is done over a digital I/O card which resides in the server PC. The current on/off state of the 7-segment displays is read out over the I/O card, transferred from the server to the client and displayed on the asix4web user interface. Moreover, the current state of some checkboxes mimicking the switches and push buttons contained on the education board is transferred from the client to the server which stimulates the FPGA pins over the digital I/O card.

The asix4web project was implemented by using pure HTML, a few lines of JavaScript and some CGI scripts. Only a standard web browser is required on the client's side to test a FPGA design on the remote prototype board. Hence, students have access to the board for 24 hours a day, 365 days per year and are able to test their designs whenever they want.

The first version of asix4web is on-line since May 2002. It was successfully tested on a number of common used web browsers (IE, Netscape, Opera) and works also on slower Internet connections, e.g. 56K modems. Since the release of the first version about 60 students per year are using the asix4web prototype board for the ASIC design course. The asix4web project can be visited on the web under [2] or directly at the Institute of Computer Technology.

2.2 Web Interface to Control Networks in Smart Kitchen

One of the ICT's research projects called "Smart Kitchen" is devoted to situation-dependent behavior in building automation but also serves as a laboratory for remote control. The Smart Kitchen is a laboratory at the ICT equipped with various modified kitchen furniture like a control network enabled fridge and coffee machine as well as with various sensors and actuators for cabinet doors, water pipes, etc. All these devices are connected in order to exchange messages and to form a complex entity. The sensors collect information within the kitchen, whereas the actuators try to react appropriate depending on the actual situations (e.g. turn off the light after the last person has left the kitchen).

Besides the interaction with the devices in the kitchen on site, it is also possible to access the Smart Kitchen over the Internet. To interface the local hardware gateways also called residential gateways are needed to translate between different network

protocols. Whereas control networks in general have rather simple communication objects and are limited to a certain protocol, the Internet offers a variety of protocols such as Simple Network Management Protocol (SNMP), the Common Object Request Broker Architecture (CORBA), the Java Remote Method Invocation (RMI) interface, and the Distributed Component Object Model (DCOM). Gateways for the above mentioned protocols were implemented in several projects.

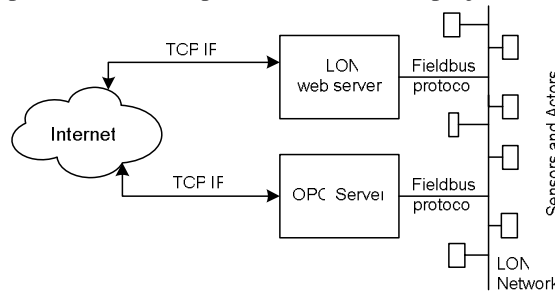


Fig. 2. Gateways between Internet and control network.

In the Smart Kitchen project (Fig. 2), OLE (Object Linking and Embedding) for Process control (OPC) based on DCOM is used for visualization. The i.LON gateway interconnects Internet and the LON network and can be used to access, manipulate and monitor the fieldbus. Both technologies allow users using a standard web browser, to get access to the physical network. The webpage of the Smart Kitchen includes a graphical interface to the control network can be found at <http://smarkitchen.ict.tuwien.ac.at> [3].

3 Remote Laboratory Models for Control Networks

Aside the research done for remote control the newly founded laboratory for BACnet (Building Automation Control Network) should be organized in such a way that all courses can be done remotely. This section will introduce the idea behind the BACnet laboratory and introduce the technologies used.

3.1 The BACnet Laboratory of the ICT

Over the last decade the ICT has acquired substantial knowledge on all aspects of control networks (fieldbus systems). Both scientific and industrial research projects and activities as well as training courses for students and interested experts have been organized and finished successfully.

Besides industrial automation, building automation has always been a main area for ongoing research activities and therefore the construction of a BACnet (a well known building automation network standard [6]) laboratory was initiated. Based on experiences gained by other remote education projects like [5] a flexible and com-

prehensive environment for students as well as for industrial partners should be created.

In the beginning of the course students should get familiar with BACnet as building automation protocol. Later stages present methods of commissioning and configuration of the network. As a remote education lab, the course does not cover electrical cabling but deals with principles of system engineering.

The planned distant education system provides a consistent representation of all components within the lab which is presented via a web interface to distant trainees in a unitary and useable way.

The BACnet laboratory will be composed by diverse hardware from multiple vendors such as Siemens or Sauter. It includes BACnet equipment from simple sensors and actuators to complex building controllers. For the networking topology, all conceivable media types, which are used in the standard, will be provided, to gain maximum flexibility for the interconnected nodes. Up to now BACnet/IP, BACnet/Ethernet and BACnet/Lon are already used. Fig. 3

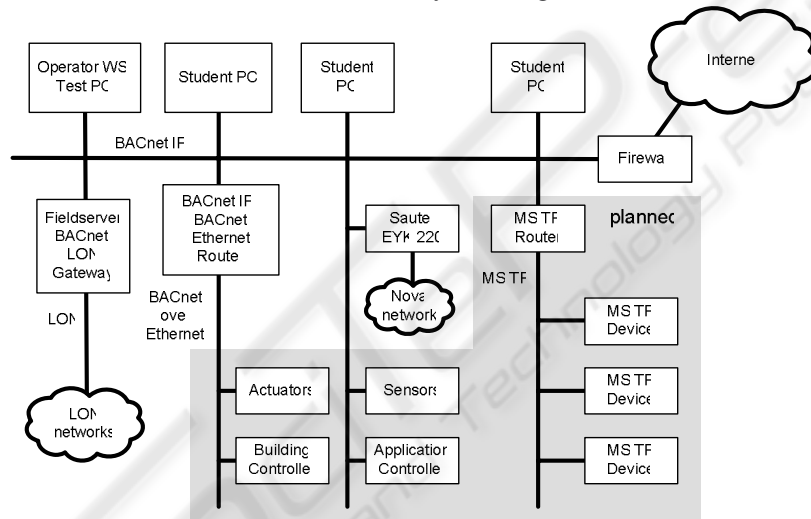


Fig. 3. The BACnet laboratory.

On the software side several applications, like OPC (Open Process Control) software or the Hethereal protocol analyzer are available for the students. These tools permit a modern way of training which is closely related to real life systems. Especially Hethereal [7] a web-enabled version of the popular packet sniffer Ethereal [8] is an important component since it permits the user to capture protocol messages within the lab and to survey the results over the web interface. Hence, Hethereal will be used to visualize the behavior of the protocol stack, the content of the protocol messages and the sequence of packets.

The creation of the BACnet laboratory is currently ongoing. All components, independent of their vendor and their preferable application, are integrated into the lab, in order to provide the same functionality to remote trainees as well as to students on site.

3.2 Remote Control Model for Control Networks

Fig. 4 shows the general structure of the *remote education system for training on distributed control networks*. Users enter the system via web portal. At the second level aside the server for the virtual laboratory there are an authentication server and a server to offer resources for teaching such as e-books, articles, and tutorials. The virtual lab is organized around the stands, where the actual hardware (I/O nodes, controllers, switchers and so on) is located.

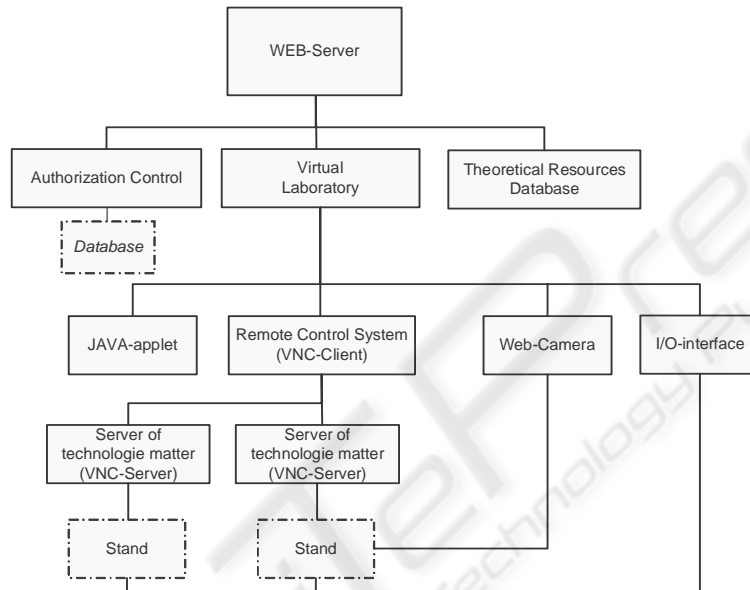


Fig. 4. General structure of the “Remote education system for training on distributed automation networks”.

To access the control network on the stand the VNC (Virtual Network Computing) server (left side of Fig. 4), which permits the configuration of the network, code uploads to the stand and enables the debugging of the system, is used. VNC-server offers the functionality of local software tools and drivers such as LonMaker configuration tool and LNS interface for LonWorks or VIGO for P-NET.

The student or trainee uses a standard web browser to access the VNC-server. To offer a similar look-and-feel to the local control software JAVA applets are used for setting up the VNC client. Fig. 5 illustrates the message flow during a remote session. Special attention is drawn to the capability of multi-user access. Therefore the VNC-Client always encloses additional information identifying the user and the used control network and stand.

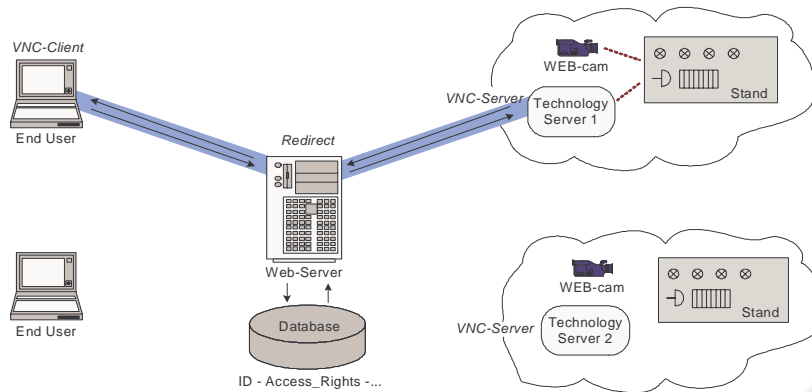


Fig. 5. Communication channel between a user and a stand.

3.3 Interfacing with I/O

Aside from being able to control the network it is also important to see the responses of the system (stand) to its environment. In many cases it is sufficient for a trainee to get feedback from the stand via a web cam (right side of Fig. 4), but for more advanced tasks it is necessary to stimulate the hardware inputs of a device and/or measure its outputs (e.g. reading analog outputs of stand modules or simulating a keystroke on an evaluation board). For such cases the trainees should have the possibility to interact with the inputs and outputs of the device on the stand.

To support such operation a special I/O device is designed at ICT. In order to have a versatile and reusable device for a wide area of applications the following boundary conditions should be met:

- The device should be controlled by plain HTTP for communication
- The implementation should be versatile for other laboratory setups
- The configuration should be simple to allow easy integration in a variety of common software

To meet these constraints a modular concept as shown in Fig. 6 was introduced by the authors. A web server running on an embedded system interfaces different I/O modules connected via an I²C (Inter-Integrated Circuit) bus [8]. The I/O modules are designed as stackable modules and therefore can be individually put together according to the needs of the actual laboratory setups.

In several projects the authors already gained experience on the embedded system IPC@CHIP SC12 [9] from Beck. This chip already includes an Ethernet controller, 512 KB RAM and ROM (Flash) and an I²C bus interface. The software design must also meet the modular hardware approach. To make the configuration as simple as possible a configuration file is supplied with each module that defines the HTTP post commands as well as I²C address and messages to the stackable module.

A CGI (Common Gateway Interface)-Procedure uses the APIs of the IPC@CHIP to convert the commands from the web browser into commands on the I²C bus ac-

ording to the description in the configuration file. This allows for adoption without reprogramming the IPC@CHIP.

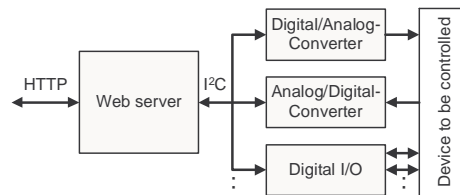


Fig. 6. Embedded device for remote control of laboratory stands.

4 Conclusion

Based on the experience of past projects the authors set up a BACnet control network laboratory for distance courses for students and professional training of companies at the ICT. The access to this laboratory should be totally web based and is based on two components: A remote control model developed by the Perm State Technical University (already running for LonWorks control network) and a gateway to control the I/Os of the used control network devices. The work described here is still work in progress, but finished tasks and past experience clearly indicates that web based approach offers the best flexibility for students and laboratory staff.

5 References

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