Work in Progress - A New Time-sharing Remote Laboratory e-Learning System for Hardware Design and Experiment of Digital Circuits

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Abstract - **A new remote laboratory system for learning hardware design and experiment of digital circuit has been developed. It employs shared resources and an e-learning system based on the top-down method specializing in the logic circuit design and featuring a quick acquisition of the Hardware-Description-Language-based design skill. Wide use of the Internet motivated us to develop seamless remote and actual hardware laboratories for hardware design laboratory course, and for students to learn the digital circuit design by themselves. The proposed remote laboratory utilizes actual hardware and actual measurement tools in a time-sharing fashion. The combinatorial use of FPGA/PC connected test hardware and PC-based measurement equipments has made it possible to develop a remote multi-user and time-sharing hardware experiment system. As all students are equipped with high-performance Laptop PCs, CPU intensive development tasks can be performed by each student's client PC in a rich-client environment. The prototype the remote-laboratory and self e-learning system are under-construction, and will be used for the third grade CS students from year 2005.**

Index Terms – Distance Learning, Topdown method, Remote laboratory, Hardware Experiment, Shared-Lab, TDeLMS

INTRODUCTION

This paper describes a new Remote Laboratory e-Learning System combined a digital circuit design education support system and a remote multi-user and time-sharing hardware experiment system. At the Faculty of Computer and Information Sciences, Hosei University, a hardware experiment laboratory course has been given for the third grade students from year 2002. All students are required to learn CAD-based hardware design process and to acquire enough skills to design 16bits CPU. As all experiments take place at an actual laboratory, 70 students are grouped into 20 teams and share 20 sets of hardware equipments, measurement tools, and CAD-tools. As the allocated course time is rather short compared with the amount of work required, home works and extra-hour laboratory works are inevitable. So, the laboratory resource became a bottleneck. In order to overcome current situations, and find a new way to open up a virtual university, the remote laboratory project has started.

Authors have already developed the prototype of TDeLMS (TopDown eLearning Management System) [1] as digital circuit design education support system. TDeLMS has been designed for students to perform self-learning effectively. It contains a database system based on the topdown technique [1], for circuit modules described by making use of Hardware Description Languages (HDLs). Furthermore, a new remote laboratory system for digital circuit experiments, namely Shared-Lab [2], has been developed. It employs shared resources, enhanced service management scheme based on the Web Services. Hardware experimental environment is usually treated as an exclusive resource, for single user usage. However, the actual test run time is rather short and most of the time is wasted leaving those precious resources idle. Shared-Lab therefore employs a time-sharing fashion to make students at remote sites perform actual experiments using actual hardware equipments and tools concurrently. We started researches on realizing a Web based experimental environment system, combining the top-down eLearning system and the Shared-Lab with the rich-client web services.

SYSTEM OVERVIEW

The Remote Laboratory e-Learning System performs the following workflow steps as shown in Table 1. These steps are required to complete the digital hardware design cycle and implement on FPGA.

TABLE 1
DESIGN AND IMPLEMENT WORK FLOW

Step	Workflow	Location
1	Learning Logic Circuit	TDeLMS
2	Learning HDL	TDeLMS
3	Learning Design of Circuit	TDeLMS
4	Reuse & Refer Resources of Circuits	TDeLMS
5	Design Entry	Client
6	HDL Code Compiler	Client
7	Logic Synthesis	Client
8	Logic Simulation	Client
9	Placements and Routing	Client
10	Implementation to the actual target unit	Shared-Lab
11	Tests and Validations	Shared-Lab
12	Analysis of obtained data (post-analysis)	Client

The Logic Circuit Design Education and Experiment Support System consist of three major function modules: namely, TDeLMS, Shared-Lab and Rich Client Site, as shown in Figure 1.

I. TDeLMS

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The TDeLMS provides the functions for dynamic and efficient retrieval of suitable learning materials across the network such as the Internet. It dynamically generates appropriate courseware materials according to the learner's needs, and skill levels. It assists the learner to achieve the learning target efficiently. Using the TDeLMS equipped with these functions, learners can keep focusing on their primary interests to achieve their goals successfully [3].

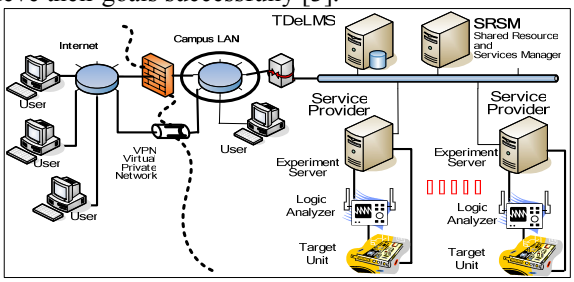

FIGURE 1
SYSTEM OVERVIEW

II. Shared-Lab

Recently, a large number of students own laptops or desktop computers and have access to the Internet using the broadband connectivity from home, on-campus or off-campus. That leads us to organize them as usable remote laboratory environment across the Internet. To realize the remote laboratory features using these networking environments, we should consider the following 3 technologies:

- **Job Managing Technology:** Existing other remote laboratories limit the number of users to the number of actual available resources. Because, these systems are simply client-server systems and the scheduler for processing user requests are not fully functional to support the multi-user time-sharing system. Therefore, we adopted the Job Managing Technology.
- **Shared Resource and Service Management (SRSM):** The multi-user remote laboratory includes SRSM to perform allocations of the restricted shared services. SRSM controls service providers which provide the sharable services. It finds out an available service, which satisfies the user's request and instructs the selected service provider to begin an immediate processing. It then returns the service results to the user.
- **Occupational Services and Sharable Services:** The remote laboratory provides two kinds of services; local services and remote services. The local services can be categorized as computation-intensive services and the remote services as sharable services. The local services take forms of the rich client organization, and are named as occupational services. The remote site takes the form of a Service Provider and implements multiple sharable services as the Web Services.

III. Client Site

As all students are equipped with high-performance Laptop PCs, CPU intensive tasks, from Step5 to Step9, and Step12 in Table 1, can be off-loaded from the server host and can be performed by each student's client PC. Such a rich-client configuration allows the server to concentrate on the service management tasks and hardware resource managements.

Complete integrated design environment (IDE), named FPGA Advantage from Mentor Graphics Corp., targets multi-discipline concurrent FPGA device design. Figure 2 shows a screen shot of FPGA Advantage. The IDEs can run their CAD tasks both on desktop computers at the remote site and local PCs, after getting the floating licenses form the license server. Local PC also displays measurement data using TLAVu from Tektronix Inc.

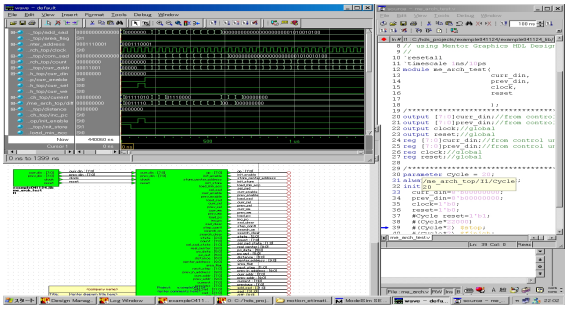

FIGURE 2
FPGA ADVANTAGE

CONCLUSIONS

The expected advantages applying the Shared-Lab are:

- Location-free efficient sharing of actual experiment equipments.
- Quick turn-around-time of hardware design and experiment cycle.
- Cost-effective way of sharing expensive measurement equipments.
- Get the feeling of handling actual measurement equipments and hardware from the remote site.
- Remote acquisition of actual measured data to analyze the designed digital circuits.

The proposed Shared-Lab architecture is developed by making use of the Web services and the distributed resource and services. One of the successful ideas obtained through the development of the system is its generic use of job management organizations. It resulted in effective and practical operations of a remote multi-user time-sharing hardware experiment system. Also, SRSM allows us to implement new services and to integrate them into the target experiment system with minimum efforts.

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