A Cyber Laboratory for Device Dependent Hardware Experiments in a Hybrid Cloud

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Keywords: Remote Laboratory, Hardware Logic Design, Cloud Computing.

Abstract: The paper proposes a cyber laboratory in the form of a hybrid cloud, where the actual laboratory and the remote laboratory are combined. At the existing physical experiment laboratory, the limitation of the number of experimental devices for FPGA hardware design course resulted in platform usage congestions and extended laboratory hours. Migration to the cloud should be the natural solution. However, existing devices such as FPGA evaluation devices and Logic analyzers became obstacles to migrate to public clouds. The proposed system combines an On-Premise private cloud organized by laboratory platforms to perform device dependent services, and a public cloud where remaining design, development and evaluation stages, are carried out in the form of a PaaS (Platform as a Service). The design and experiment tasks should be modified accordingly to accommodate CAD tools in the set of the Web Services. Existing faculty database server and educational support system combine the private cloud, the public cloud and the faculty servers, in a seamless way. Students can migrate to and from laboratories at any design stages. As the device dependent tasks have been implemented in the Web Services, efficient sharing of platforms can be achieved in space and time sharing fashions. The public cloud ensures a scalable increase and decrease in server machines according to the student usages and seasonal load changes. The laboratory managing software takes care of the allocation and migration of student Virtual-Machines between the On-Premise private cloud and the public cloud. It can also accommodate the BYOD (Bring Your Own Device) style student usage, by preparing three different access methods: student side BYOD applications, the Web accesses and remote desktop connections. The hybrid cloud approach achieves a scalable realization of the cyber laboratory suitable for the BYOD style experiments, where efficient sharing of On-Premise laboratory platforms can be realized in the mixed use of actual and remote laboratories.

1 INTRODUCTION

The author has been engaged in remote laboratory projects and combining them to the actual laboratories (Koike, 2012, Fujii and Koike 2008). Hose University accepts around 100 new undergraduate students each year to take the hardware design course, utilizing twenty FPGA-based design platforms including logic analyzers and function generators. Students also share twenty PC-based Logic analyzer/function generators. Allocated time for the class is three hours per week. So, four students share one platform as an average. Schematic entry approach and Verilog-HDL design approach are both employed in the coursework. Each student is expected to design his/her own 32 bit CPU as the final project. The 32bit CPU design by making use of Verilog-HDL/logic synthesis tools, implementation in a FPGA evaluation board and verification of the designed hardware by running test software, are complex tasks and time consuming but it is effective for undergraduate students to acquire enough knowledge and skills in the field. Such a real life experience in the actual laboratory is very important and rewarding for developing student carrier. It is desirable for students to continue their experiments outside the actual laboratory. The author started the remote laboratory project, and tried to combine the remote laboratory with the actual laboratory. The former effort to access remote experiment sites (Hassan, 2012) only achieves the functionality of remote experimental data access via Web browsers. It had no control of remote experiment devices. Also, there are many efforts to migrate campus environments to the cloud computing, e.g. (Kumar, 2012; Hassan, 2012). In such a cloud configuration, the remote desktop services should be employed for remote experiment

Koike N..
A Cyber Laboratory for Device Dependent Hardware Experiments in a Hybrid Cloud.
DOI: 10.5220/0004942504400445
In *Proceedings of the 6th International Conference on Computer Supported Education* (CSEDU-2014), pages 440-445
ISBN: 978-989-758-020-8

device accesses. However, they have their scalability problems due to the exclusive use of On-Premise laboratory devices. The author's former implementation (Koike, 2013) adopted the On-Premise private cloud solution. However, the laboratory platform/servers become a bottleneck, if the number of simultaneous remote laboratory users is increased. It is also difficult to support recent BYOD style student usages, as the former system heavily relied on student side powerful laptops, where time-consuming, latency-sensitive tasks can be executed locally by offloading them from the laboratory platforms. However, BYOD devices could not meet such performance requirements. Addressing these shortcomings, the author started the new cyber laboratory project, which combines the On-Premise private cloud and a public cloud in a seamless way, namely the Hybrid Cloud solution. On-Premise private cloud computers only perform device depending services in the form of the Web Services. The remaining services have been migrated to public cloud computers. If a student is accessing through the university-leased high-end laptop, it can still exploit student's laptop PC powers, by migrating time-consuming services, such as logic entry, simulation and verification to the laptop, in the form of native Windows applications. On the other hand, for the BYOD case, the allocated Virtual Machine in the public cloud acts as a BYOD proxy for the user. The proxy performs most of the works and the communications with the BYOD can be carried out via remote desktop, BYOD applications or http connections. In this way, it can achieve a scalable increase in the number of public cloud computers, according to the students' actual usages, and also it can decrease during off-seasons. It can drastically reduce the TCO (Total Cost of Ownership).

By combining those technologies, highly scalable and flexible cyber laboratory can be realized.

2 SYSTEM CONSIDERATIONS FOR CYBER LABORATORY IN A HYBRID CLOUD

In order to give students real life laboratory experiences, it is important to realize almost the same laboratory environment both in remote and actual laboratory modes. The efficient sharing of the laboratory platforms and their devices becomes important for realizing a scalable Cyber Laboratory. In case of the remote laboratory mode, most experiment tasks can be offloaded on the public cloud, except device related works, such as FPGA setup/run or logic-analyzer setup/get results.

Thanks to the advancement in cloud computing, implementing the laboratory computer environments in a public cloud becomes advantageous to reduce total cost of ownership. However as said, laboratory devices, such as Verilog-HDL synthesis tools, FPGA evaluation platforms, Logic Analyzers and pattern generators have made it difficult to migrate to the public cloud. Instead, the author's previous system, have chosen an On-Premise private cloud solution. On-Premise private cloud allows any connections of propriety devices to the On-Premise laboratory platform computers to organize as a private cloud. Although it achieved an efficient sharing of laboratory platforms/servers, it has its own scalability problem. If the number of remote laboratory users is increased, the server becomes overloaded and resulted in higher latencies and longer elapsed time. The former system also took advantage of students' high-end laptop PC performances, to offload time consuming tasks to the laptops. Thus, effective offload of laboratory platforms was realized. However, this approach becomes difficult to adopt for recent trend of BYOD (Bring Your Own Device) style student usages. Usually, BYODs are rather poor in CPU performance. It is better to offload such laboratory PC loads to computers in a public cloud. So, a hybrid cloud organization, where the On-Premise cloud performs device dependent tasks and the public cloud performs rest of the works, allows the realization of a flexible and scalable Cyber Laboratory.

The Figure 1 shows the Cyber Laboratory System organization, which have been designed based on the followings design considerations:

-Use of Special devices in the On-Premise private cloud: The requirement to connect specialized devices became an obstacle to choose a public cloud solution. Instead, an On-Premise private cloud solution has to be employed. However, the amount of workloads should be as little as possible. Only, device-related tasks such as FPGA Load/RUN, Logic-analyzer setup /measurement /results, should be remained in the laboratory platform (private cloud computer). The rest of the workloads should be offloaded on the public cloud. Only when device related services have been requested, the Web services should be generated and sent to the laboratory platforms. In order that such device dependent tasks can become accessible through the internet, they should be first transformed into Windows applications, and then encapsulated in the form of the Web services. If a student virtual machine is resided in the same laboratory platform, it realises an actual laboratory environment. The virtual network connection provides enough bandwidth to connect them. Nowadays, various system software for building such a private cloud, are available (Hasan 2012). So, the system development efforts and system management works can be remarkably reduced. The system manager only set the policies and the rest of the works can be handled semi-automatically. Students can find out an appropriate platform and log-in through the "dash-board" monitoring page of the Cyber Laboratory Manager in a self-serviced manner. It performs VM allocations/ migrations, server assignments and cloud storage link setup/ synchronization.

-Use of public cloud for handling non-device-related services: Non-device-related tasks can easily be offloaded to the public cloud, once they have been transformed into Windows applications and again encapsulated in the Web services. For each student one virtual machine is allocated in the public cloud, thus the remote laboratory environment is realized. In case when device-related services have been requested, these services should be forwarded to one of the private cloud computers in the remote laboratory service mode.

The use of the public cloud allows an efficient computer usage, as the number of actual computers can be flexible, according to the student usages and seasonal load variations. Each student is allocated an individual virtual machine, which can be migrated between private and public clouds, according to the actual /remote laboratories or mixture configurations of them.

-Adoption of the BYD style student use: The cyber laboratory managing software should detect the student BYOD devices and set up an appropriate service either in the private or public clouds. If the student is using the University-leased laptop, most design tasks, except the license logic synthesis tool and actual FPGA device use, can be offloaded on the laptop, and the student can enjoy a comfortable experiment. In case when Logic synthesis and FPGA run services have been requested, the resident software issues the corresponding Web services to

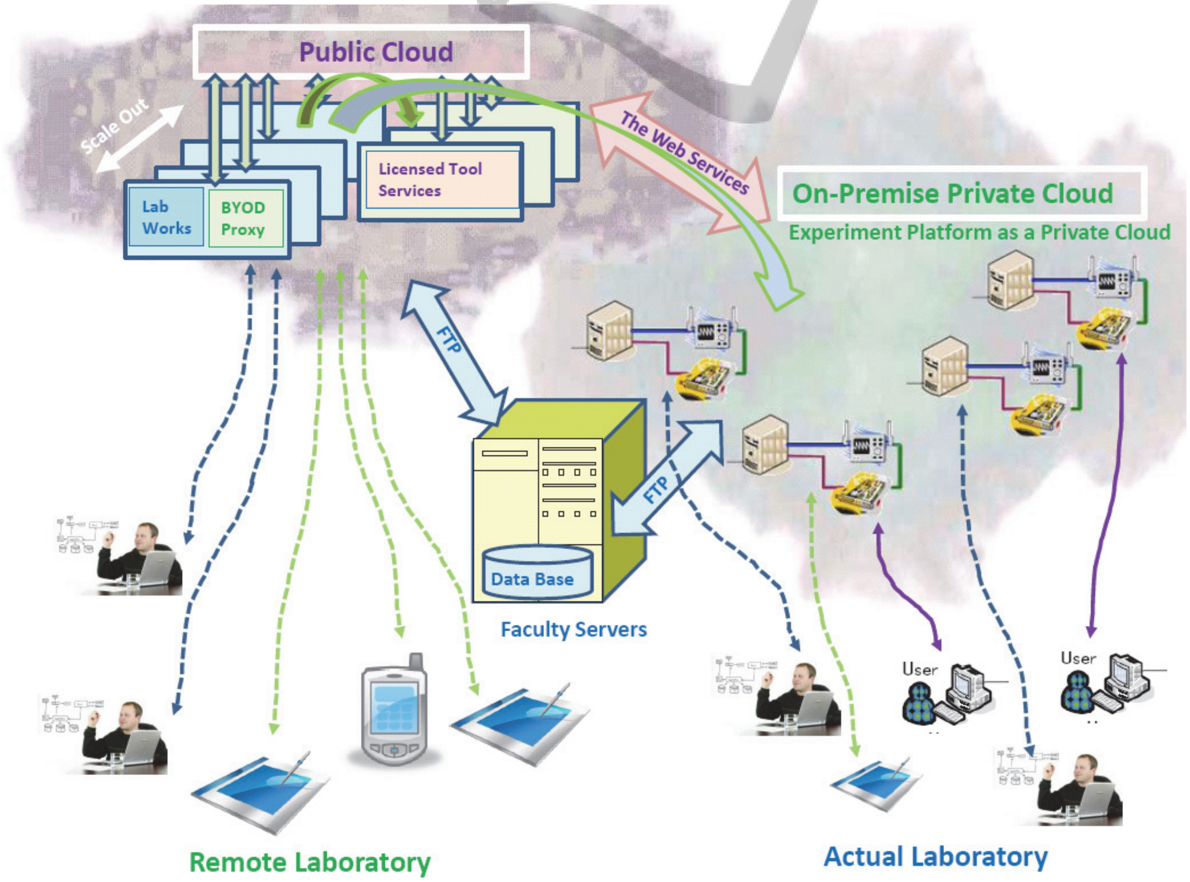

Figure 1: Cyber Laboratory in a Hybrid Cloud Organization.

the On-Premise private cloud. In case when the use of non-laptop BYOD is specified, one virtual machine is allocated as a proxy in the public cloud. The proxy performs most laboratory works. Only when the device related services have requested, the request is forwarded to one of the platform servers in the private cloud, via the Web services.

-Cyber Laboratory managing software handles allocations of the actual and remote laboratory Virtual Machines (VMs): It manages all setups of laboratory machines (private cloud), and the remote laboratory machines in the public cloud. The Cyber Laboratory manager serves as the portal of the Cyber Laboratory. After usual login, and VPN setups, it handles each student's VM allocation, which can be done through "dashboard". As it shows current actual and remote laboratory work-load status, students can easily select either actual or remote laboratories. Also, the user can ask the manager for the VM migration to/from actual/remote laboratories. Once the VM setup completed, the manager redirects the request to the designated VM/server. If the student's BYD is specified, the allocated VM performs not only usual experiment works but also performs the proxy services for the BYOD. The customized remote desktop/application or Web browser in the BYD will communicate with the proxy server in the VM. The course manager just set laboratory platform usage polices, according to the office-hours/ off-hours. The laboratory platform allocations can easily be realized by making use of available VM allocation software. The ratio of the actual/remote laboratory platforms can be adjusted according to the platform usage.

-CAD design file sharing among Private/Public cloud, faculty database and faculty educational system: In order to realize efficient sharing and transferring huge CAD data, the faculty database (file server) serves as a kind of cloud storage. As all the Web services send/receive only file IDs, an efficient data transferring can be achieved.

3 CYBER LABORATORY IN A HYBRID CLOUD ORGANIZATION

The proposed Cyber laboratory consists of On-Premise Private Cloud and the public cloud. Between two clouds, the Web services are employed as the communication means. It can combine the actual laboratory and the remote laboratory, with newly designed CAD services and FPGA-run services realized in the form of the Web Services. The faculty database plays an important role in Data sharing and synchronizations. It enables to share large experiment data among laboratory platforms, student/Teacher/TA PCs. As large CAD design files can become accessible from any PCs, the web services only need to transfer a few CAD parameters and the design file location IDs. Thus the file transfer overhead can be minimized. It is also useful for students, TAs and Teachers for further consultations and evaluations. Students can easily migrate from actual laboratory to remote laboratory and vice versa. And students can continue their projects at home, using their own PCs in almost the same environment as in the actual laboratory environment. Figure 2 show the private cloud system organization. For each laboratory experiment platform, which is one of the On-Premise private cloud components, a Web service virtual machine is allocated. It contains integrated FPGA tools, license Verilog-HDL synthesizer and the Web service server. The integrated FPGA tools accept the FPGA related Web services and perform device related tasks, such as FPGA Set-up/Run, logic-analyzer setup/run/get results. The Verilog-HDL logic synthesizer is the license software, encapsulated in the Web services. It accepts high-level descriptions and returns synthesized Verilog-HDL descriptions.

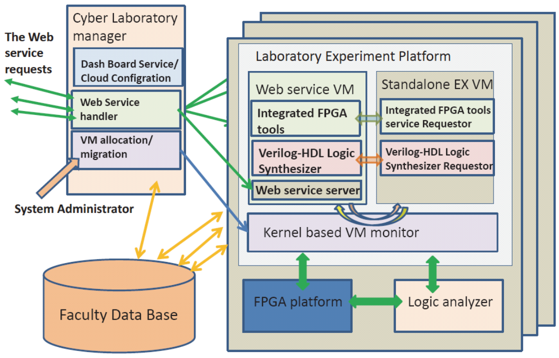

Figure 2: On-Premise Private Cloud System Organization.

The synthesizer is not a "must". Although students can do experiments without them, it can reduce significant amount of design works by combining high-level design and use of such logic synthesis tools. The synthesizer is not affordable to install all students' laptop or public cloud computers. So, the license software are only installed in the On-Premise private cloud laboratory platforms and the limited number of the public cloud computers. By preparing the Web services for the logic synthesis, students who want to use this functionality, can use them from remote site.

In the case of actual laboratory mode, student virtual machines are also set up on the corresponding laboratory platforms. The virtual network switch allows rapid inter virtual machine connections, as they reside on the same computer and messages do not go out of the computer. In this way, plural students' experiments can be carried out concurrently, by sharing FPGA and logic analyzer devices, even in the actual laboratory.

The cyber laboratory manager performs the system management tasks, such as student login/logout, VM allocations/migration, experiment platform allocations in On-Premise private cloud and the public cloud setups. The course manager set the policy to the cyber laboratory manager, and the rest of works can be done in self serviced fashions. The dash board service lets students to know current workload status and to select available platforms.

Figure 3 shows the public cloud side virtual machine organization. After the public cloud setup is completed, physical servers become available. The limited number of them should be assigned to run the logic synthesis virtual machines. Remaining servers are pooled for the use of student virtual machines. The purpose of the logic synthesis VMs is to offload the logic synthesis works from the laboratory platforms and to run the services in the public cloud. As the license limits the number of VMs, student VMs have to be installed the integrated FPGA tools without license Verilog-HDL synthesis tool and FPGA setup/RUN tools. Those removed tools are replaced with the corresponding Web services.

The logic synthesis VM organization is rather simple. It accepts the logic synthesis Web service requests, these are generated from other student VMs. In order to get/set the Verilog-HDL descriptions, the FTP is setup with the faculty data base (Experiment Data server).

Each Student VM handles the remaining laboratory works, except the device related services and the license Verilog-HDL synthesis. The student VMs generate corresponding Web services and send them to the designated VMs: Logic synthesis VMs in the same public cloud or the Web service VMs in the On-Premise Cloud via the internet. Another student VM's role is to act as the proxy for the student. If the student specifies the use of BYOD, then BYOD Proxy establishes the connection with the BYOD, via the remote desktop, BYOD application or Http.

The Figure 4 shows the experiment flows in actual and remote laboratories. For each student, a student virtual machine is allocated. By allocating

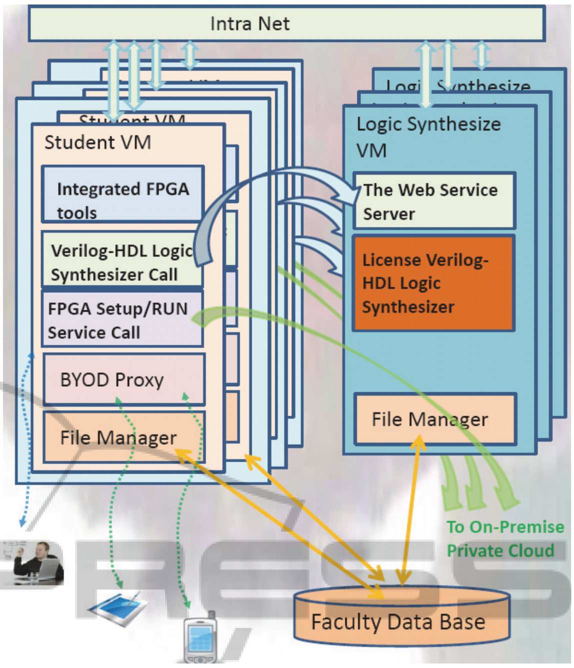

Figure 3: Public Cloud Side Virtual Machine Organization.

the student VM in the same laboratory platform as the Web Service VM, the actual laboratory environment is realized. All design stage works are carried out within the same platform.

In case of the remote laboratory mode, the student VM is allocated in one of servers in the public cloud. If the FPGA run is requested, the student VM setups the connection with one of the FPGA Web service VM in the On-Premise private cloud to do the FPGA run.

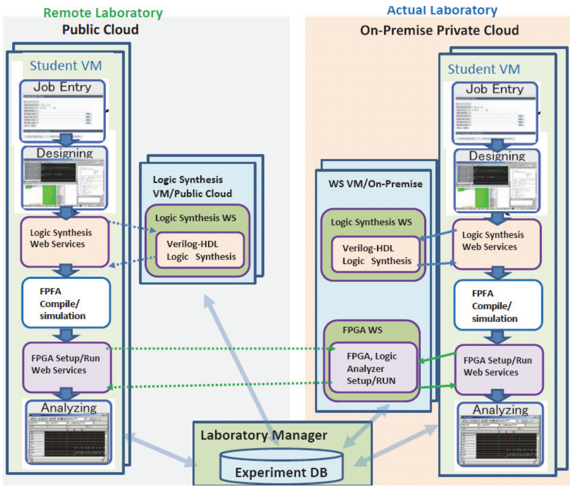

Figure 4: Experiment Flows in remote and actual laboratories.

In case of the logic synthesis request is issued, the student VM setups with one of the logic synthesis VMs in the public cloud. The corresponding logic synthesis Web services connect VMs via the public cloud intra-net. In this way, almost the same experiment environment can be realized both in actual and remote laboratory modes.

4 CONCLUSIONS

The Cyber laboratory in a hybrid cloud project combines the actual laboratory and the remote laboratory in a seamless way. It gives remote users real life experiences in hardware logic design and implementations. The device related services are handled by one of laboratory platforms as a private cloud.

The remaining non-device-related tasks are handled by student virtual machines in the public cloud. It can still exploit student side PC powers to offload platform workloads, if high-end PCs are available. In case when a student should login through a BOYD, a virtual machine in the public cloud is allocated and it serves as a proxy. The use of available cloud computing system tools contributed to reduce system developments works as well as system management/operation works.

The use of the experiment server as a Web storage contributed to realize a seamless migration between remote and actual laboratories. It also made it possible to share experiment data among students, TAs and teachers for further consultations. So, a flexible and scalable Cyber Laboratory, which can reduce the TCO, can be realized.

The project is just started and it is rather early to evaluate the effectiveness of the proposed system, but the author believes its success. The remaining problem is how to decouple the hardware integrated software, and to combine public cloud computing environments.

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