

# Laboratory Experiments through Low Bit Rate Internet Link

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**Abstract**—In order to realize an Internet based on-line laboratory, where actual experiments are performed remotely, the bandwidth of the network plays a very crucial role. In a low bit rate link streaming video is not possible. This work focuses a practical remote laboratory module for low bit rate link. The work has been tested from quite a few CIC (Community Information Center) sites and found to work satisfactorily.

**Index Terms**—Remote Laboratory, Remote Experiment

## I. INTRODUCTION

The widespread use of the Internet is leading people to think of many technological endeavors in every aspect of life. This technical thirst may be for better design of business protocol, for transparent and speedy administration or to get a better education system. The remote classroom teaching has already been in practice and there has been a continuous effort for incorporating more and more laboratory components in it. Such laboratory can help to demonstrate pre-lab session of an academic curriculum or doing lab classes from home.

Distance learning may include the laboratory component of an academic curriculum and hence hands-on laboratory teaching is essential to complete the learning process. Advancements in Instrumentation technology and growing internet access from every corner of the globe have made it possible to perform remote laboratory experiments by enabling remote access to various laboratory experiment and instruments over the Internet. With the ability to configure instruments remotely, it has become possible to conduct real-time experiments remotely. Thus remote laboratory experiments and remote laboratory instrument control through Internet is enhancing the remote learning into reality. Setting up a remote laboratory reduces maintenance and laboratory supervision costs of a university [12]. It also reduces space requirements since only one experimental setup is used to facilitate an entire class. Students could be familiarized about the experiment setups before the remote laboratory class (pre-lab session or laboratory tutorial class) during the lecture session. However, in reality, there are certain constraints such as bandwidth requirement, Internet time lag during data transfer, Internet traffic management and technical architectural needs, which need to be addressed. There are various approaches found in literature that have been followed by different universities and researches for setting up remote laboratory in many application areas. The works in [1, 2] describe web-based virtual electronics

laboratories, one on frequency modulation experiment and the other on coupled tank apparatus, a multi-input-multi-output (MIMO) system, developed at National University of Singapore using LabView and Java applet programming. An online laboratory for Microelectronics test circuit utilizing Java applet has also been developed [3]. The work in [4] describes a web-based laboratory for remote control of an inverted pendulum using Matlab and Java programming. A remote laboratory based on experiments for control engineering course has been developed at University of Texas, Arlington using Microsoft Net meeting and Matlab's Simulink environment [5]. An ongoing work for the development of remote lecture demonstration and experiments for communication engineering using LabView through web browser has been described in [6]. It has been found that most of the real-time remote laboratory systems use either LabView software from National Instruments or Matlab software from Mathwork Corporation or Agilent Technologies' VEE pro for instrument control along with Java Applet programming for client and server side web interfaces. In order to use this software, the demand for bandwidth is very high and it takes a considerable amount of time to load the Java applet at the client side over a low bandwidth network link.

This work reports a laboratory module developed for remote experimentation particularly suitable for CIC type of networks, with low bit rate link. It does not require costly GPIB interface in the instrument and server.

## II. CLIENT - SERVER ARCHITECTURE

The client-server architecture used for this module is shown in Fig -1:

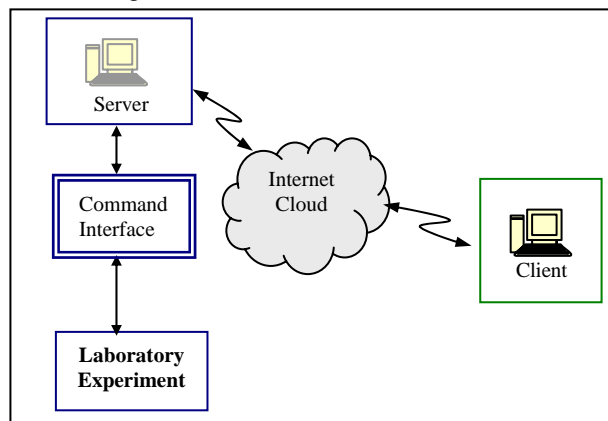


Figure 1. Client-Server Architecture

The architecture is very simple and much more cost effective and can be built around using existing laboratory components and equipment in a general university/ engineering college without much difficulty. It is required to design an experiment set-up and to write software control code for interfacing it with Server PC and Interface with Internet. The web interface browser was written using Visual Basic 6.0 and few controls were design using Visual C++ to interface experiment with Server PC. Both Server and Client do have the Graphical User Interface. The laboratory experiment set-up is attached to a server, which provides the web interface to the remote clients. Single client or multiple clients may be able to get connected through remote login into the system. In case of multiple clients system, only one station or client can conduct the experiment whereas other clients can see the experiment, which is going on. The serial port of the server PC is used for remote command interface to the experiment and serial port is used for the graphical data acquisition from the instrument.

### III. HARDWARE SET-UP

The system set-up is shown in Fig -2, where we have tried to conduct a small experiment on electronic rectifier circuit to see its output performance with the change of input voltage to the input transformer. A digital oscilloscope and a digital multimeter are kept connected. The working of the rectifier can be seen through the use of a user-controlled web camera.

Followings are the requirements for a basic experiment:

- ⇒ Laboratory equipment
- ⇒ Control module interfacing hardware circuit to the server
- ⇒ Web cameras for real laboratory video capture
- ⇒ Embedded chat window to interact with the users
- ⇒ Control software to interface users to the server and experiment set-up.

In the present experiment, an auto-transformer is used to increase or decrease the AC voltage applied to a rectifier circuit (Figure-3). The auto-transformer or the variac is controlled with the help of a stepper motor. An oscilloscope displays the rectifier input/output waveforms and a multimeter measures the input voltage. A web camera takes the photograph of the instruments and sends it through the Internet. To enable the interactive session with the tutor, a chat window has been embedded with the browser. Since voice interface requires sufficient internet link speed, though it is tested, is not included in the system to avoid the congestion in low speed CIC type Internet link.

The web cam gives the visual feedback of the state of a remote experiment at the switching interval as it changes the parameters of the experiment under trial. It is made bidirectional so that the instructor can also get the visual overview of the participating clients.

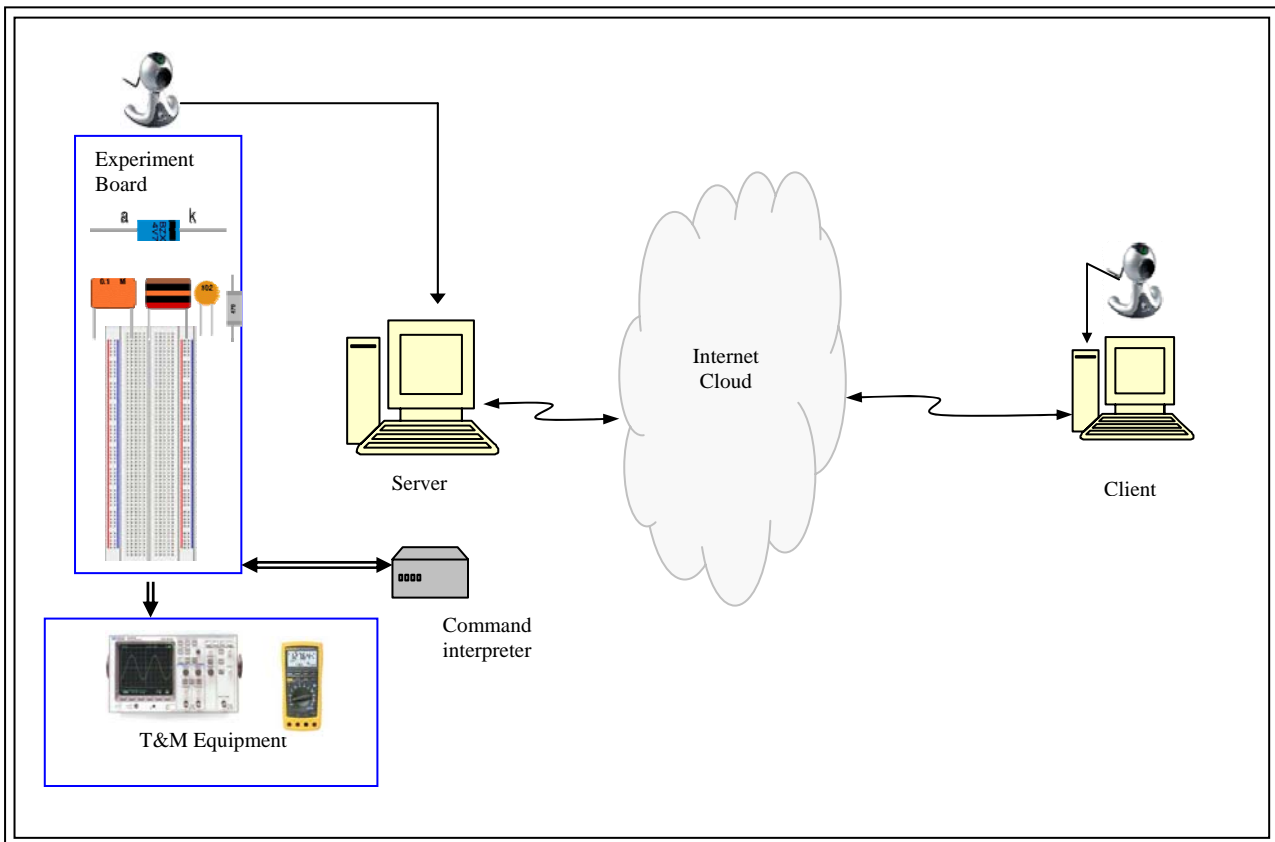


Figure 2. System Set-up

IV. INTERACTION THROUGH INTERNET

The client and server communicates each other as it is design in following fashion-

- The client sends control command to the servers, which are very small TCP/IP packets.
- When the server executes the command it also takes a frame using the web camera. The frames to be transmitted from the server as well as from the client are JPEG compressed. It is a bit lossy compression but found to be satisfactory.
- The picture is now sent to the client terminal where it is uncompressed and displayed in the browser.
- The server-client activities are depicted in figure-4

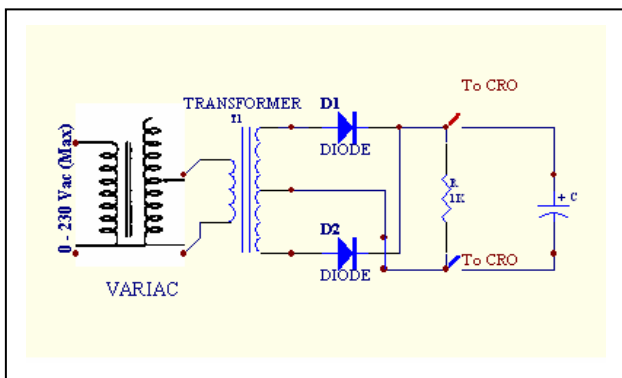


Figure 3. Full wave rectifier circuit

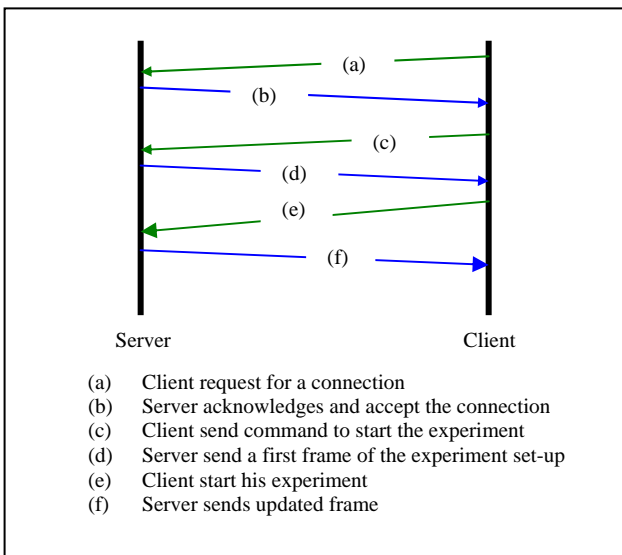


Figure 4. Server-client functioning

It may be noted that for many experiments the change of state of the parameters can provide enough information about the experiment under execution. If we continuously monitor output it will be continuous streaming video and it would require lot of bandwidth. When user clicks a control to change a parameter, he gets a frame instantly and it optimizes the data transmission for video. The

embedded chat window takes only few bits for small text written to communicate with instructor and vice versa.

Frame	Resolution	Compression	Bits required
Video Frame (From server)	320x240	JPEG	8 Kb
Video Frame (From Client)	160x120	JPEG	4 Kb
Text	-	-	400 bits
Command	-	-	8 bits

TABLE I. BIT REQUIREMENT

V. EXPERIMENT AND RESULTS

In trial phase, this remote laboratory experiment for low bit rate network, is conducted from many Community Information Centers (CIC) situated at remote places of Assam. CICs are set up by Government of India and each CIC network is equipped with a Very Small Aperture Terminal (VSAT) with 8-Kbps and 32-Kbps bandwidth for uploading and downloading data respectively. The main experiment set-up is kept at R&D Laboratory of Department of Electronics and Communication Engineering, IIT Guwahati and the following CICs are made clients to perform the experiment:

1. CIC Rani
2. CIC Barbarua
3. CIC Sivsagar
4. CIC Moran

Figure-5 and 6 shows the screen captures of Server and Client browsers. The instructor and client can communicate during the experiment using an embedded chat window in the browser. In the testing phase, it is found to work satisfactorily and client could do the experiments on-line without interruption to the main experiment on rectifier circuit.

The quality of frame received at the client end and time taken to receive the frame depends on the resolution of video frame and Internet link speed. The resolution of the video frame has been made variable and can be set accordingly at server end depending upon the link speed at that instant. It has been noticed that about 3 to 5 seconds are required for a frame shown in Figure-7.

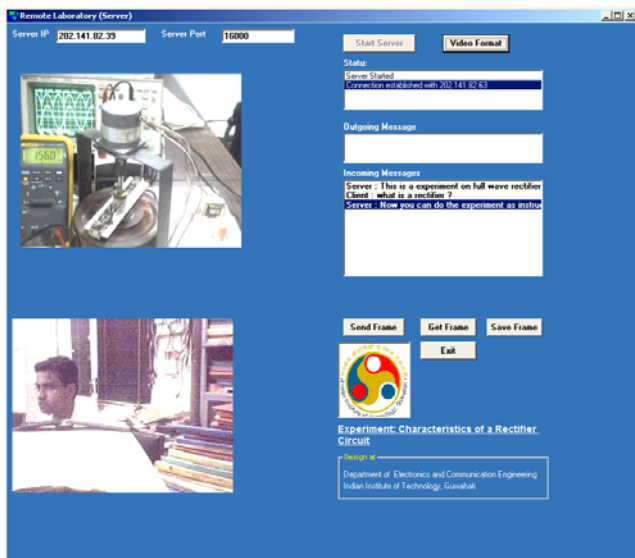


Figure 5. Server browser showing local experiment set-up at the top and client at the bottom

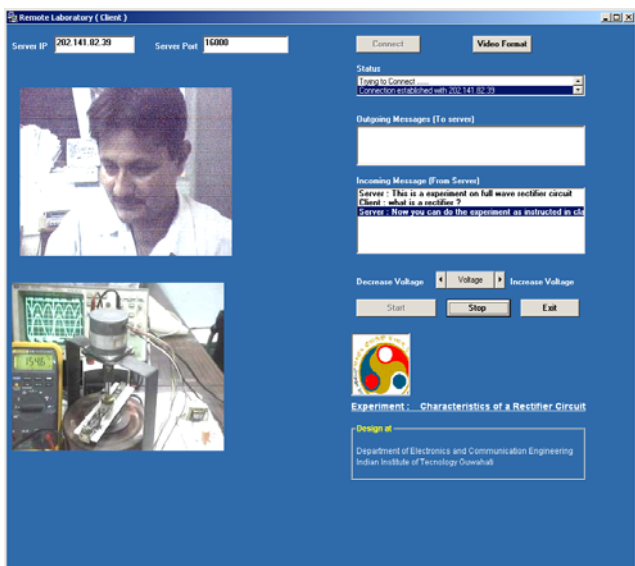


Figure 6. Client browser showing received experiment set-up at the bottom and client at the top



Figure 7. Received video frame (Resolution: 320x240)

## VI. CONCLUDING REMARKS

The model and low cost architecture shown above requires very less inventory and suitable for low bit rate network to cater the primary education and feeling of a laboratory class. The system developed has already been tested from four CIC centers where Internet data rate/link speed is very low. The use of such system in pedagogy for the developing countries where Internet facility remains with bottleneck of low bit rate connectivity can help students in laboratory learning process. The system has to be integrated with more experiments to cover a curriculum. In order to achieve it an additional switching matrix for the various experiment selections has to be designed along with the hardware set-up. Before commencing the session, laboratory hand-out download feature can be easily added in GUI.

The prototype developed showed the feasibility of such system for above cited network condition. If network link speed is higher, more features can be added to the system. Audio codec can be integrated for instructor and students to communicate during on-line experiment. Instead of video frame, continuous streaming video can be transmitted.

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