DEVELOPMENT OF LABORATORY EXPERIMENTS USING LABVIEW FOR A BROADBAND NETWORK COURSE

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Abstract *– This paper introduces two laboratory experiments using LabVIEW for a broadband network course. The goal is to develop and implement laboratory experiments that will help students to understand the concepts of attenuation and queuing delays in order to improve learning outcomes. An introduction to LabVIEW is integrated into the broadband network course. We believe that the experiments provide a valuable opportunity for students and make the course easier to understand. Furthermore, students can master a powerful analysis and visualization tool that can be used later in their career.*

Index Terms – LabVIEW programming, optical fiber attenuation, queuing delays, student-oriented laboratories.

INTRODUCTION

The need for more capacity in the Internet has caused broadband optical networks to evolve rapidly and to play an important role in modern business infrastructure. The expansion demand is driven by many factors such as the tremendous growth in the number of users as well as the amount of time (i.e., the bandwidth) consumed by each user due to the growth in the services on the World Wide Web. As a result Internet traffic has doubled every six months for the past few years. There has also been an increased deployment of broadband access technologies such as DSL (digital subscriber line) and cable modems. At the same time, businesses today use these networks to interconnect multiple locations within a company as well as between companies for business-to-business transactions [1].

National Instruments' LabVIEW (**Lab**oratory **V**irtual **I**nstrument **E**ngineering **W**orkbench) has become a popular programming environment for instrumentation, data acquisition and control systems in academia and industry. It is a graphical programming language which was developed in 1986 [2]. It uses dataflow programming to provide flexibility for building different solutions and it is good for visualization and analysis of complex systems.

In the department of computer sciences, we want to provide an introduction to LabVIEW without adding additional classes or laboratories to the curriculum. Higa et. al. [4] have developed an electronic class exercise for their electrical engineering majors using LabVIEW, and have found that students could easily learn programming techniques and have a great appreciation for its utility.

At Georgia Southern University, we have developed an optical network course, so our students can be better prepared for challenges of their career. The course has been offered for the last two years to computer science students and will continue to be offered on a regular basis every year. The course prerequisites are the basics of data communication and networking, which is based on the 7–layer OSI model with TCP/IP, and the math course statistical methods.

Since it is impossible to cover everything, we have decided to cover topics such as the technology and components of optical networking, WDM networks, photonic packet switching, wavelength routing, and wavelength assignment. We have found that students have many difficulties in understanding principles associated with information transmission in the fiber, components needed in optical networking, message queuing, etc.

The problems occur for two main reasons. First, our students are in the computer science major so they lack an engineering background. And the second reason is for the simplest fact that it is a new area, which is still under development. Thus, in order to improve the quality of the class and to help students to better understand these concepts, we have developed two laboratory experiments using LabVIEW.

The laboratories developed measure the attenuation in the fiber and queuing delays. We have chosen LabVIEW as the programming environment because it has many advantages compared with other programming languages. First, LabVIEW is a graphical programming language so it is easy to express a solution. Furthermore, it helps students understand the problem better since they are required to visualize and maintain the correct flow of data for the given solution. This will result in an improvement of learning. Finally, by the end of the course, students will possess a powerful tool and the skill to use it so they will be better prepared for the challenges of industry. Next, we introduce and explain in detail the two laboratory experiments developed.

LABORATORY EXPERIMENTS

The experiments developed for the optical network course are: the measurement of the attenuation in fiber and queuing delays.

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Attenuation in Fiber

Before analyzing the attenuation problem, let us first explain how the optical transmission is carried out in fiber. Fiber is essentially a thin filament of glass, which acts as a waveguide. A waveguide is a physical medium or a path, which allows the propagation of electromagnetic waves, such as light. Due to the physical phenomenon of total internal reflection, light can propagate the length of the fiber.

There is a difference in the light propagation speed for vacuum and any transparent material. The ratio of the speed of light in vacuum to that in a material is known as the material's refractive index (n). When light travels from material of a given refractive index to material of a different refractive index, the angle at which the light is transmitted in the second material depends on the refractive indices of the two materials as well as the angle at which light strikes the interface between the two materials. Thus, the light can propagate in different ways through the fiber. Each one of these possible ways is called a mode.

There are two types of modes, single mode and multimode. Multimode fiber supports different wavelengths but it introduces the phenomenon of intermodal dispersion. While with the single mode fiber, which supports only one wavelength, this phenomenon is eliminated. Single-mode fiber supports transmission over much longer distances.

There are many effects in optical fibers, such as dispersion in fiber, attenuation in fiber, nonlinearities in fiber (nonlinear refraction, stimulated Raman scattering, stimulated Brillouin scattering and four-wave mixing [5]), that potentially limit the performance of the optical network. Such effects may limit the optical power on each channel, limit the maximum number of channels, limit the maximum transmission rate, and constrain the spacing between different channels. Thus, we have to make sure that students understand these effects very well.

Let us now explain the attenuation in fiber effect and the experiment related to it. Attenuation in optical fiber is the reduction of the signal power as the signal propagates over some distance. This is an important effect that one should consider when determining the maximum distance that a signal can propagate for a given transmitter power and receiver sensitivity. Let P_{out} be the power of the optical pulse at the receiving end of the fiber of length L (km) and A be the attenuation constant of the fiber (in dB/km). Attenuation is characterized by:

$$P_{out} = P_{in} e^{-AL}$$

where P_{in} is the input power. The parameter A represents the fiber attenuation and it is customary to express the loss in units of dB/km; thus a loss of A_{dB} dB/km means that the ratio P_{out} / P_{in} for L=1 km satisfies

$$10 \log_{10} \frac{P_{out}}{P_{in}} = -A_{dB}$$

The two main loss mechanisms in an optical fiber are material absorption and Rayleigh scattering. Material absorption includes absorption by silica as well as the impurities in the fiber. Both of these have now been reduced to negligible levels by the technology, thus the loss due to Rayleigh scattering is the dominant component in today's fibers.

For our experiment we ask the students to program the attenuation in fiber using the above formula. Then they are asked to change the length of fiber keeping the attenuation factor and input power constant, and report on the results they observe. Then they are asked to keep the fiber length and input power constant and change the attenuation factor and, again, report the results they observe. Finally they are asked to change the input power keeping the fiber length and attenuation factor constant. The LabVIEW program that our students wrote and one of the graphs they obtained are shown in Fig. 1.

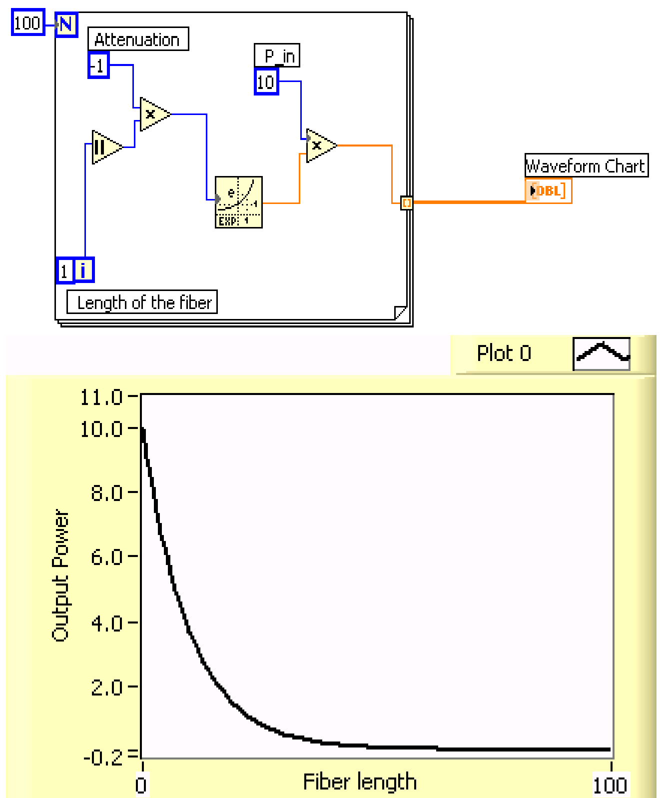

Fig. 1. Simulation of attenuation in optical fiber.

After completing this experiment, students have a better understanding of the concept of attenuation and its effect on optical fibers. From the experiment, students observed that output power falls rapidly even for small changes in the attenuation factor. Also they observed that changing the input power over a wide range will have a small impact on the reduction of the output power. Thus, they learned that the maximum distance between the transmitter and the receiver depends more heavily on the attenuation constant A than on the optical power used by the transmitter.

Queuing Problem

A queue is a container for data that arrives at random times to obtain service. In the context of data networks, a queue contains packets for a communication link waiting for transmission. The service time corresponds to the packet transmission time and is equal to L/C, where L is the packet length in bits and C is the link transmission rate in bits/sec.

Thus, we will consider the queue as a pipe. Packets flow in one end of the pipe and flow out the other end. The packet comes out in the same order it went in. This is known as First In, First Out (FIFO). In this framework, students are required to understand the behavior of the queue by estimating the average number of packets in the system (i.e., the "typical" number of packets either waiting in the queue or undergoing service), in terms of known information such as, the packet arrival rate (i.e., the "typical" number of packets that enter the system per unit time) and the packet service rate (i.e., the "typical" number of packets the system serves per unit of time when it is constantly busy). In LabVIEW, queues can take any data type as input and output it to a distant location. This location could be another part of the same VI or any other VI running on the same copy of LabVIEW.

For this experiment students are asked to program a queue in LabVIEW by changing the time between the addition of packets to the queue and the time between removal of packets. Then, they are required to change these parameters and observe the behavior of the queue. The LabVIEW program that our students wrote and one of the results they obtained are shown in Fig. 2.

After completing this experiment, students have a better understanding of queuing problems. From the experiment students observe that if the factor for time between removals decreases, the queue does not fill up. If this factor is decreased more the number of packet served is increased; thus the number of packets in the queue is decreased.

The decreasing service time depends on the value of this factor. In the case when the factor is increased than the queue will fill up and again the filling speed depends on the value of the factor. By changing both the time between queue additions and the factor for time between removal, students are able to understand that the time of filling and empting the queue depends on the difference between these values.

Another important result that students observed during this experiment was that it could not give them any result on the average delay per packet. In many cases the packet arrival and service rates are not sufficient to determine the delay characteristics of the system. For example, if packets arrive in groups, the average packet delay will be larger than when their arrival times are regularly spaced apart. In this case there is a need for more information on the arrival of packets. In this experiment we did not consider this case.

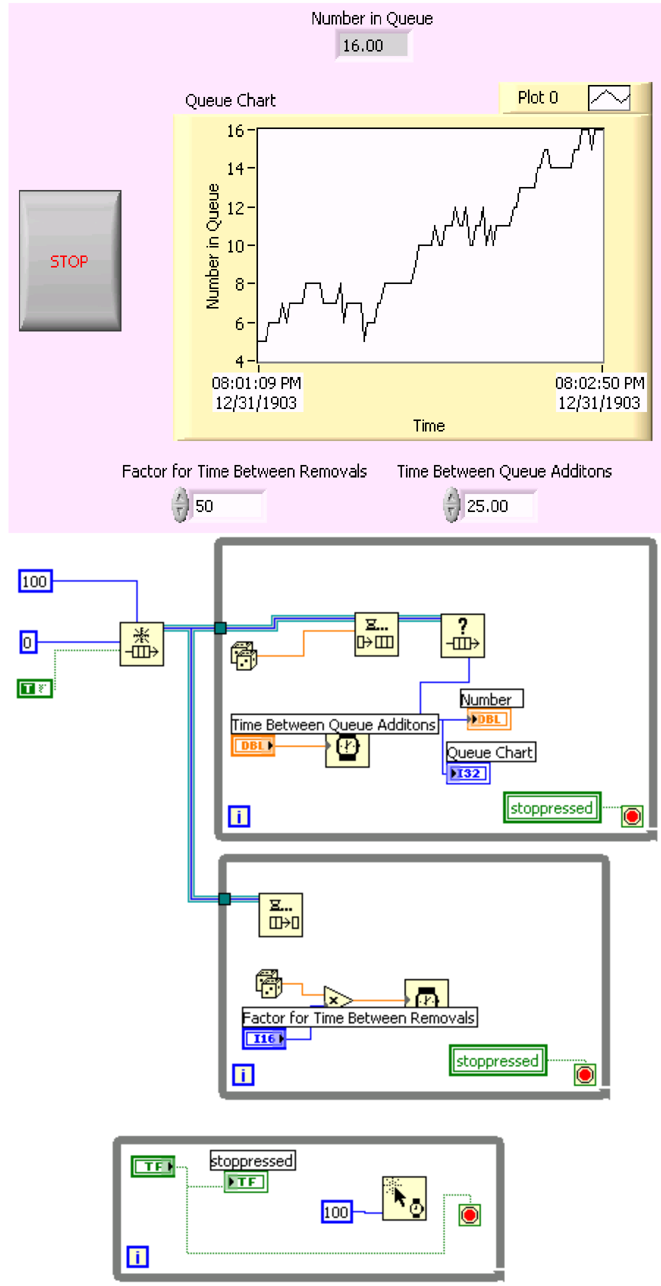

Fig. 2. Simulation of queuing programmed by students.

Results

Both labs were developed during the spring semester 2003 for the broadband optical networks course. For each lab, students required about two weeks to complete the assignment. Student response to the laboratory exercise was positive. At the beginning, students face many difficulties on using LabVIEW. Since there is no other course that introduces this software, thus, students were required to explore it themselves. They also did not find that it was helpful to use the help file that accompanies the software.

However, they were able to overcome these difficulties quickly and understand the power of using LabVIEW. Students pointed out the advantages of LabVIEW especially after the visualization of the problem. After they completed the labs they showed a better understanding of the problems and the rest of the course went very well.

Beside these results, students also gave a few suggestions for improving the lab. They mentioned the possibility of saving all the data into a file, instead of only showing them on a graph. Keeping the data in a file will help them with analysis and will enable better comparison on differences in parameters across multiple experiments.

CONCLUSIONS

In this paper, we introduced two laboratory experiments using LabVIEW for a broadband network course. The labs were focused on understanding the attenuation in optical fiber and the queuing problem. A detailed analysis of our labs is given. So far, the results have shown that the goal of improving learning was met. Students were able to learn some of the programming techniques in LabVIEW, and have a better idea of its capabilities. Thus, we plan to expand the use of these labs in our broadband network class. Additional labs such as simulating the behavior of laser diodes, photodetectors etc. are still being developed.

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