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TEACHING DATA COMMUNICATION AND COMPUTER NETWORKS USINGTHE RIVERBED MODELER ACADEMIC EDITION

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Abstract

This paper shows laboratory exercises for use with data communication and networking courses. The laboratory exercises were implemented by the HND students of the Computer Science Department at the School of Technology, at the Kano State Polytechnic through the use of the Riverbed simulation Program. Today, the field of computer networks all over the world has entered an exponential growth phase. It is therefore crucial for higher institutions to offer networking courses that are both educational and up to date. However, due to different obstacles it is not practical for institutions to be able to offer several types of networks to its students. An invaluable innovation in this case consists of the network simulator Riverbed Modeler that offers the tools for model design, simulation, data mining and analysis for *considering the alternatives, at reasonable cost. It can simulate a wide variety of different networks linked to each other.*

Keywords: Riverbed, Teaching, Networking, Simulation, Scenario.

Introduction

Students tend to be motivated to do networking practically when they understood the concepts in the textbooks and from lectures. Generally, the concepts of networking are mostly in abstract form, making it difficult for most students to comprehend (Umar, 2012). The network course is done in a semester (12-15 weeks) period, making it again difficult for students to learn the terminologies, comprehend and apply the concepts learnt. Network practicals give students the opportunity to master the material and learn how to apply it in the real world.

The Challenge

Computer networks are ever-present and such a state of affairs creates a demand for qualified personnel who can work with networks. In view of this, many institutions of higher learning are teaching the relevant set of networking technologies. Many are interested in creating new programs and curricula with networking content. The question arises as to how best to teach this material.

Michael Dixon, Tanya McGill and Johann Karlsson (2007) pointed out that many of the relevant concepts are difficult to really grasp in a purely theoretical way. Lectures alone do not accomplish the task. And practical assignments in the laboratories must move beyond mere programming assignments. Although a custom communications protocol is a good exercise, it falls short if the goal is to teach the big picture of network communications and associated high-level decision making and analysis.

The nature of the technology itself is such that it is difficult to get “hands on” with it from the point of view of making it available for classroom use (Stallings, 2005). Another challenge is the issue of expense. For instance, many high schools may not have the resources to build an appropriate laboratory with all the required and relevant hardware and software. Furthermore real world networks may span for more than a laboratory or two but rather for entire buildings or even multiple global locations. In line with this, Davis, Ransbottom and Hamilton (2008) pointed out that:

> Most networks are built to accommodate the needs of a single corganization or group. Internetworking is a technology that accommodates multiple, diverse, underlying hardware by providing the means of interconnecting heterogeneous networks. Comparatively few individuals, academic institutions or corporations have networks *exclusively dedicated* for student use and experimentation. Prudent administrators limit

> student or general user access to operational networks.

The researchers made some good points here. Even if there is a network designated for student use, it is rare that the network's sole purpose is to support the teaching and learning of networking. Students may gain valuable experience managing a network, which is in deployment (for general uses); however such experience has limitations. For instance, suppose a school decides to run the Windows family of servers on their networks and the school designates a lab for networking students' use. They may learn a lot about Windows servers and associated technologies but they will not obtain hands-on training with Linux based technologies. Even if one sets aside the worry about not being able to learn the relevant range of technologies, students will likely not be allowed to change settings and reconfigure things to any significant extent in the Windows-based network.

This problem of making available appropriate hands-on computer networking training is even more acute if one considers *distance education*. In it (whether synchronous online, asynchronous online, video based), students are in disparate locations. It would be impossible to collect them together for the sake of hands-on training – unless one mandates that for brief periods of time – in which case it no longer would be really purely distance learning. Indeed, according to Cameron and Wijekumar:

> Computer networking, as defined as the interconnection of computers and computing equipment using either wires

> or radio waves over small or large geographic areas (White, 1994), has long been regarded as one of the more difficult technology related subjects to teach. Historically, this type of course was thought to require much hands-on interaction with the instructor and was not viewed as a good candidate for an online course. (Cameron and Wijekumar, 2013)

It would be hard to imagine serious educational institutions creating mini networking labs with actual hardware in every distance learning student home or workplace. The costs, even if partially to be passed on to the students, are simply too high.

The Solution

The challenges of teaching computer networking can practically be overcome through the use of modeling and simulation software. One of such software is the Riverbed modeler. Appropriate network modeling and simulation software could be used to model networks down and up to whatever scale or detail that is necessary. Students learn by creating virtual networks and devices of all kinds and are not limited by network hardware availability concerns. There is the prospect that distance students can participate fully – all it would take is student access to a workstation to run the software. Studies by Cameron and Wijekumar (2013) have shown significant improved learning outcomes in networking technology distance students, who used network modeling and simulation software and those distance students who did not. The researchers claimed that network simulation software increases student motivation in online courses. One of the biggest problems in distance education (according to them) is lack of sustained student motivation and involvement. Network simulation software gives students something tangible to do – a feeling of having accomplishing something real and hands on and thus lessens dropout rates.

As networking systems have become more complex and expensive, hands-on experiments based on networking simulation have become essential for teaching key computer networking topics to students (Kaparti and Likarish, 2010). Most institutions today cannot just offer the practical aspects of a variety of network courses to its students due to the associated cost and maintenance of laboratory facilities. As an option, they can use an invaluable tool, the RiverbedModeler Academic Edition 17.5 software package, which offers all the tools for network model design, simulation and analysis at a relatively less cost. Riverbed software can simulate a wide variety of different networks, which are linked to each other. Students can just work from their personal computers (PCs), simulate different networks, study and visualize the impact of various factors (e.g., traffic load, bandwidth, data rate, etc.) on the network.

Riverbed overview

Riverbed Modeler is a simulator built on top of a discrete event system. It simulates the system behavior by modeling each event happening in the system and processes it by user-defined processes. It uses a hierarchical strategy to organize all the models to build a whole network. The hierarchy models entities from physical link transceivers and antennas to the Central Processing Unit (CPU) running processes to manage queues or running protocols, to devices modeled by nodes with process modules and transceivers, to a network model that connects all the different kinds of nodes together. Riverbed also provides programming tools for users to define any type of packet format we need to use in our own protocols.

The modeler is a sophisticated tool that provides analysis and modeling of network performance that allows students to study data message flows, packet losses, link failures, bits uses, etc. Riverbed Modeler provides a Virtual Network Environment that models the behavior of an entire network, including its routers, switches, protocols, servers and individual applications. By working in the Virtual Network Environment, Information Technology (IT) managers, network and system planners, as well as operations staff are empowered to diagnose difficult problems more effectively, validate changes before they are implemented and plan for future scenarios including growth and failure (Kaparti and Likarish, 2010). Riverbed is a discrete network simulator, which contains a comprehensive development environment supporting the modeling and performance evaluation of communication networks and distributed systems (Peterson and Davie, 2013).

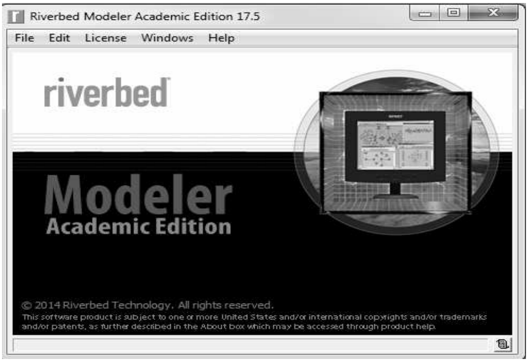


Figure 1: Riverbed Modeler Academic Edition 17.5 Startup Window (Riverbed, 2014)

The Purpose of using Riverbed

There are various simulation experiment environments. Many target a specific area of research interest – a particular network type or protocol, such as wireless networks by GloMoSIM. Some systems, such as x-Sim and Maise, focus on allowing the same code to run in simulation and on a live network. Riverbed and NS-2 (NS2, 2006) are the two most popular network simulators, targeting a wider range of networks and protocols. NS-2, derived from REAL, is an open source network simulator. NS-2 is widely used for network research in academia. NS-2 is also free. However, NS-2 is more difficult to learn and lacks a user interface. It requires the users to learn and use non-standard scripting interfaces, such as tcl. It takes a significant amount of time to get familiar with NS-2. Riverbed is the best network simulator to meet teaching goals for the following reasons (Hammoshi M. and Al-Ani R., 2010):

- Riverbed is much easier to use. It provides a very convenient Graphic User Interface (GUI) and is very easy to learn (Peterson and Davie, 2013).
- Riverbed meets all the needs for use in a different data communications course (Umar, 2012).
- Riverbed can be used to model the entire network, including its routers, switches, protocols, servers and the individual applications they support. A large range of communication systems from a single LAN to global inter-networks can be supported (Peterson and Davie, 2013).
- Riverbed software (with model source code) is available for FREE to the academic research and teaching community. Students can download and install Riverbed Modeler Academic Edition at home (Peterson and Davie, 2013).
- The Riverbed's discrete event engine for network simulations is the fastest and most scalable commercially available solution. It usually takes just a few minutes to complete simulations of most lab experiments (Peterson and Davie, 2013).
- In addition to previous reasons, Riverbed uses models that are specified in terms of objects, each with configurable sets of attributes. This allows for flexible definition of new objects with programmable characteristics and behavior in order to address the wide scope of systems that are presented in the course. Models are hierarchical to

naturally parallel the structure of actual communication networks.

The hierarchical approach allows for the deep nesting of sub networks and nodes and large networks can be efficiently modeled. Stochastic and/or deterministic models can be used to generate network traffic. Performance evaluation and trade-off analysis require large volumes of simulation results to be interpreted and Riverbed includes a tool for graphical representation and processing of simulation output. Simulation runs can be configured to automatically generate animations of the modeled system at various levels. These are used to help the student visualize how the network operates while working. Simulation results can be plotted as time series graphics, scatter plots, histograms and probability functions (Dixon and Koziniec, 2013).

Simulation Methodology

The Riverbed Modeler is based on a series of hierarchically related editors that directly parallel the structure of actual networks. To build a network model the workflow centers on the Project Editor. This is used to create network models, collect statistics directly from each network object or from the network as a hole, execute a simulation and view results.

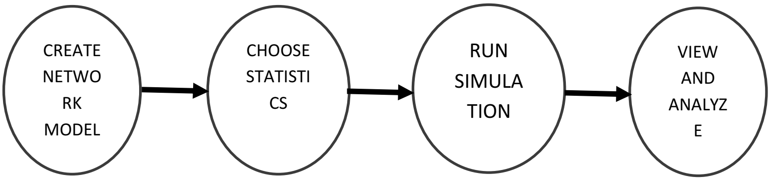


Figure 2: Riverbed Workflow (Dixon and Koziniec, 2013)

Generally, the steps one follows in making a network lab model is as shown in Figure 3 below

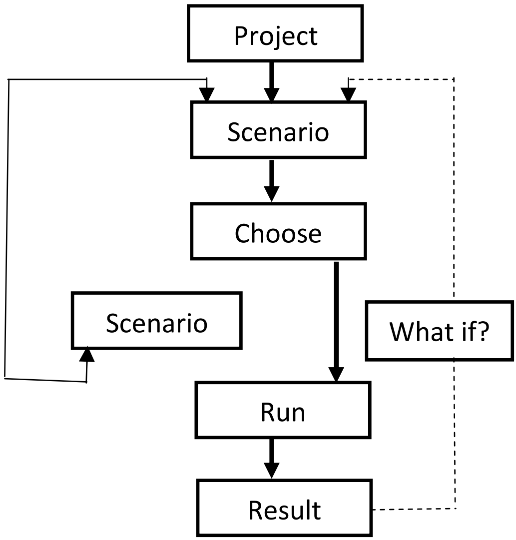


Figure 3: Laboratory Creation Steps (Dixon and Koziniec, 2013)

RIVERBED provides four editors to develop a representation of a system being modeled. These editors, the Network, Node, Process and Parameter Editors are organized in a hierarchical fashion. Each level of the hierarchy describes different aspects of the complete model being simulated. Models developed at one level of the hierarchy are used (or inherited) by models at the next higher level. This leads to a highly flexible simulation environment where generic models can be developed and used in many different scenarios.

Riverbed Labs

In this paper, a set of four laboratories is shown with appropriate screen captures from Riverbed Modeler Version 17.5, which is downloadable free for educational use. They are appropriate for someone who is at the introductory to intermediate level with networking technology. They provide a way of learning features of Riverbed in addition to being hands on review of some aspects of standard networking theory (Peterson and Davie, 2013). They are written in a generic way they are intended to be worthwhile anywhere from advanced curriculum to fundamentals. The paper started with simple network to a more complex network progressively.

Token Ring

This lab is designed to demonstrate the implementation of a token ring network. The simulation in this lab will help the student to examine the performance of the token ring network under different scenarios. A token ring network consists of a set of nodes connected in a ring. The ring is a single shared medium. The token ring technology involves a distributed algorithm that controls when each node is allowed to transmit. All nodes see all frames and the node identified as the destination in the frame header saves a copy of the frame as it flows past. With a ring topology, any link or node failure would render the whole network useless. This problem can be solved by using a star topology where nodes are connected to a token ring hub. The hub acts as a relay, known as a multi-station access unit (MSAU).

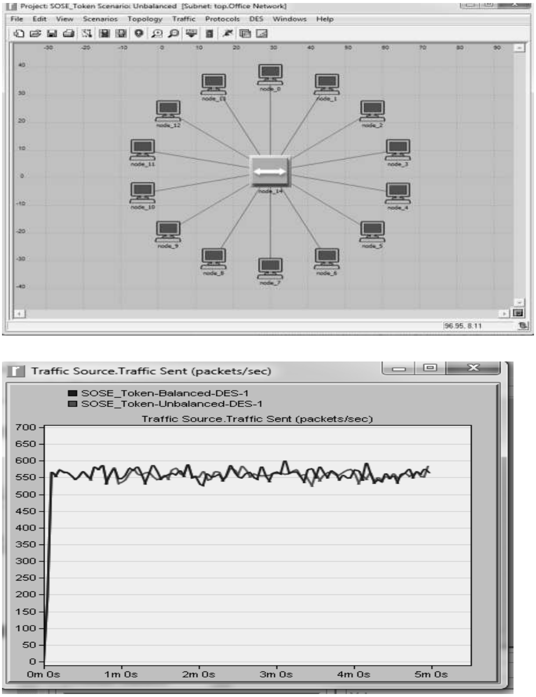


Figure 4: (a) Token ring (b) Traffic Sent in packets/sec (Riverbed, 2014)

Switched LANs

This lab is designed to demonstrate the implementation of switched local area networks. The simulation in this lab will help you examine the performance of different implementations of local area networks connected by switches and hubs. There is a limit to how many hosts can be attached to a single network and to the size of a geographic area that a single network can serve. Computer networks use switches to enable the communication between one host and another, even when no direct connection exists between those hosts. A switch is a device with several inputs and outputs leading to and from the hosts that the switch interconnects.

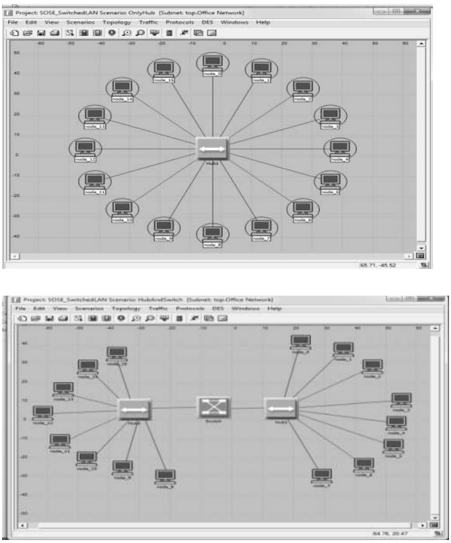
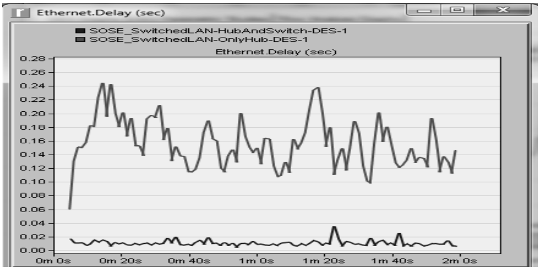


Figure 5: (a) Only Hub LAN (b) Hub and Switch LAN



(c) Ethernet Delay in seconds (Riverbed, 2014)

Multistory Building LAN

This lab teaches the application performance of two different network architectures: Daisy Chain and Collapsed Backbone Network. We show a collapsed backbone data network in which there is a core switch in the basement equipment room. The core switch is linked directly to a workgroup switch on each floor. Another option is to link the switches in a daisy chain. In this approach, the basement core switch is linked directly to the first floor switch the first floor switch is linked directly to the second floor switch, and so forth. This lab showed the application latency introduced by connecting building switches in different ways

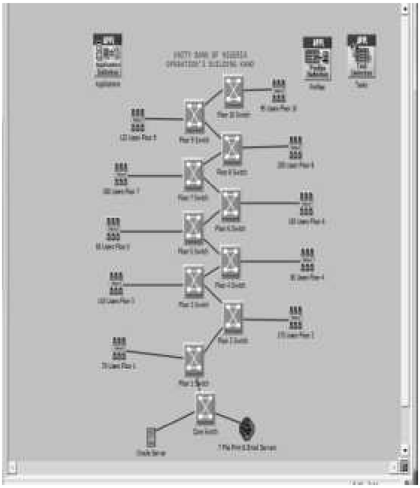
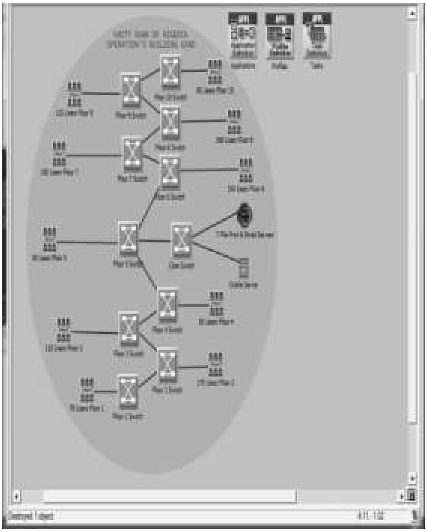
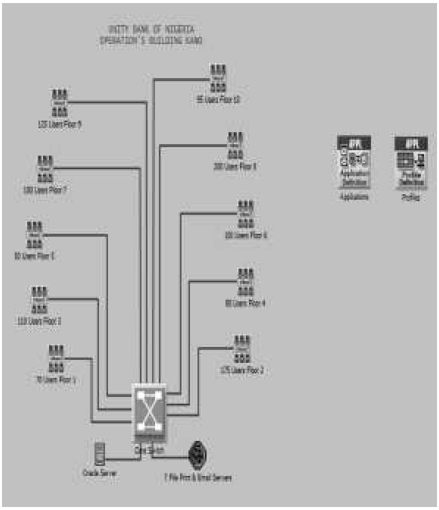


Figure 6: (a) Daisy Chain 1



(b) Daisy Chain 2



(c) Collapsed backbone

(Riverbed, 2014)

Wireless LAN Backbone Configuration Laboratory Exercise

This Lab provides an example configuration of WLAN backbone networks. Through this Exercise the students were introduced to the design of a WLAN model that supports wireless-LAN backbones that consist of routers with WLAN interfaces belonging to the same BSS (Base Service Set).These backbones can serve to WLAN EBSSs as well, where they are connected to the wireless backbone via their access points like they would be connected to a wired backbone. The lab is built to provide an example on configuring such networks.

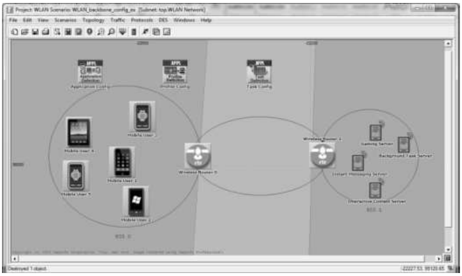
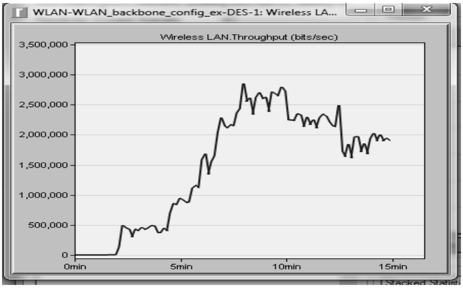


Figure 7: (a) Wireless LAN Network



(b) Wireless LAN Throughput (bits/sec)

(Riverbed, 2014)

The laboratory exercise in this paper were implemented by the HND students of the Computer Science Department at School of Technology, Kano State Polytechnic through the use of the Riverbed simulation Program in their data communication and computer networking course. After installing the Riverbed software, the Students then worked under supervision in small groups (three to four students).

For each LAB exercise the students, implement the Labs, analysis results with the researcher and wrote a report of the lab experiment in the Group. This both helped the researcher and the students to assess the efficacy of the simulation experiments in enhancing student learning. Through a questions and answer session, it was found that the Riverbed labs benefit students in deep understanding of complicated details of actual systems, encourage active learning (a group of students after ending the semester be able to design a huge computer network for technical college and evaluate the performance of their design (Umar, 2012)). This paper provided some of the results of the exercise LABs as graph and (or) a table of the values of some of the simulation parameter

Conclusions

Simulation offers significant advantages as a basis for academic projects in computer networking. Because many unimportant details can be abstracted away and also because simulations can be completely repeatable, it is possible to address the same concepts more quickly than is possible with actual networks. An important complement to classroom lectures is laboratory experiments. In networking, this often implies programming, protocol design, experiments and measurement. Simulation has an important role here since it allows students to examine problems with much less work and of much larger scope than are possible with experiments on real hardware. Therefore, students will come to understand networking theory much better than where they learn only from reading and lectures.

This paper showed that Riverbed™ Modeler Academic simulation environment is a cost effective solution for colleges and universities to demonstrate the performance of different networks and protocols. Also, this paper shows that the students will benefit from the Riverbed simulation laboratory in many ways. The Riverbed simulation labs reinforce the networking theory taught by regular lectures. The open design of the labs encourages active learning (Riverbed, 2014). In addition, students gain the knowledge of modeling and simulation technique for performance evaluation of networking systems.

The use of Riverbed simulation software in teaching Computer Networking has encouraged the students in the school of technology so much so that from 2012 to 2014 academic sessions, fifteen (15) final year students undertook their final year project using Riverbed Simulation software in the design and simulation of various aspect of Computer networks and Data communications.

References

Cameron B. H. and Wijekumar K. (2013). "The Effectiveness of Simulation in a Hybrid and On-line Networking Course," *SIGCSE'13*, Proceedings of a Conference, March 6-9, Denver, Colorado, USA, 2013, Pages 117-119.

Davis N, Ransbottom S and Hamilton D. (2008). "Teaching Computer Networks through Modeling," *Ada Letters*, (17)5, 104-110.

Dixon M. W, Tanya J. M. and Karlsson J. M (2007). "Using a Network Simulation Client-Server Package to Teach the

Model," Proceedings of a Conference, *ITiCSE'07*, Uppeala, Sweden, Pages 71-73.

Dixon M. W. and Koziniec P, (2013). Reinforced Networking Theory with OPNET Simulation. Journal of Information Technology Education (6)3 193-200

Hammoshi, M. and Al-Ani, R. (2010). Using OPNET to teach students computer networking subject. Tikrit Journal of Pure Science 1(1), 281-292

Kaparti R. and Likarish D. (2010). OPNET IT Guru: A Tool for Networking Education. Online Lab Manual, Regis University, USA. Retrieved July 16, 2015

Peterson L. L. and Davie B. S. (2013). *Computer Networks: A System Approach* 7th Edition, San Francisco: Morgan Kaufmann

Riverbed Technology, Inc (2014). Riverbed Modeler Academic Edition 17.5, www.riverbed.com_example_networks. Accessed 26/08/2015

Stallings, W. (2005). *Data and Computer Communications.* 7th Edition, New Jersey: Pearson Education

Umar, M. A. (2012) "Teaching of Computer Networking Using OPNET IT GURU Simulation Software" a paper presented at the annual conference of the School of Education FCE Kano 2011. From 16th to 20th July 2012