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Keywords: local area network, LAN, protocols, physical layer, PHY, media access control, MAC, simulation, lab experiments

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Reconciling Principle and Practice in a LAN Course: A Simulation and Lab Mixed Approach

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Abstract

Teaching Local Area Network (LAN) may need a balance between LAN principle and LAN practice. The important principles of LAN are mostly embedded in the physical (PHY) layer and the MAC layer. MAC and PHY protocols are integrated in VLSI chips and are not accessible to ordinary users. Without a good understanding of the principle, students may not learn much about LAN. So it is crucial that a LAN course strike a balance between principle and lab practice. We present such an approach to teaching LAN, using a combination of lectures, simulation tools and lab experiments. This approach gives students both a good understanding of the LAN protocols and the use of LAN in today's data networking.

Keywords: Local area network (LAN), protocols, physical layer (PHY), media access control (MAC), simulation, lab experiments

1. INTRODUCTION

The PHY and MAC layer protocols are the most important in any LAN. In today's LAN, both PHY and MAC protocols are integrated on a single chip. The chips present simple interfaces to the outside, but the protocols are not directly inaccessible. We cannot see the inner workings of the LAN chips and this makes teaching the LAN principles a difficult task.

LAN texts tend to fall into two categories: those that emphasize on hands-on practice, for example [Regan], and those that emphasize on principles, for example [Forouzan]. University courses tend to following one of these approaches. This tendency also shows in data communication and networking courses in general, for example [Dean, White, Geier, Goldman & Rawles].

However, without a good understanding of the LAN principle, students will not be able to manage and work with LANs effectively. Trouble-shooting the LAN needs a balance of the knowledge of principles and the hands-on experience. Previous research on teaching LAN mostly focus on the design principle, for example [Carniani and Davoli] and the use of various devices [Richards and Waisbrot; Jipping, Bugaj, Mihalkova and Porter] to enhance the network experience. Some software tools were used, but mainly for the purpose of network design. Our approach differs from them in that the tools are used to help students' understanding of the operations of lower layers protocols.

A sound grasp of the LAN principle will also help students to learn new systems and new interfaces more

quickly and efficiently. Hence, we not only teach our students about connecting systems to a LAN and providing services, we also teach them the LAN principles. To achieve our goal, we use a mixed approach of lectures, simulations and lab experiments in our teaching of the LAN course.

We present our approach to teaching LAN in this paper. The paper is organized as follows:

- We first present our course organization in detail with some discussions.
- Then the set of simulation tools we use to facilitate teaching are discussed. These tools are used in different parts of the course.
- Lab experiments are integrated into our LAN course. We discuss the type of experiments and their relationship to the parts of the course.
- A summary about our course and the approach we take to teach the course is given in the end.

The LAN course is part of our telecom emphasis curriculum in our Masters program. Our telecom emphasis also requires other courses in telecommunications and data networking. The LAN course is an important and integrated part of the telecom emphasis program.

2. COURSE ORGANIZATION

Our LAN course consists of lectures, exercises, lab experiments and projects. We first give a presentation of the topics covered in the course, followed by discussions about lab experiments and projects.

LAN Topics

This course covers the following topics about LAN. The course offers a balanced blend of LAN principles and practices for today's network. The topics include,

- Data network models (OSI/Internet)
- Transmission media and techniques
- Topologies and error detection
- Flow and error control techniques
- Media access methods and LLC
- Ethernet: shared media and switches
- Token ring network
- Wireless LAN
- Interconnecting LANs
- Introduction to TCP/IP
- Network services
- Windows networking
- Linux networking
- Introduction to network management
- Installation of Ethernet LAN with several Windows workstations and Linux workstation
- Installation of Wireless LAN with wireless routers and access points. Installation of wireless cards on workstations
- Installation of Windows 2003 Servers and ASP.NET services (with SQL server), and enable file and directory sharing, etc.
- Installation of Linux Servers and Internet services (with PHP, JSP, MySQL, etc)
- Building a network of multiple LANs with switches and routers. Configuring the devices with packet filters, etc.

From the above, one can see that we cover only the widely deployed commercial LANs. One factor that influences this decision is the equipment availability.

Simulation Experiments

Since much of the inner workings of the MAC layer is integrated in a VLSI chip and hidden from the ordinary users, we have to use simulation tools to teach the principles and protocols of LAN. We use a set of tools to perform this task. We offer the following simulation experiments in our course:

- Signal transmission
- Error detection
- Flow and error control methods
- Medium access methods
- Ethernet protocols
- Token ring protocols
- Wireless LAN protocols

Through the simulation experiments, students are able to learn the protocol operations. In addition, we also give students some projects about protocol simulation.

Hands-on Experiments

The hands-on experiments depend on the equipment availability. As we mentioned in the introduction, it is difficult to set up experiments to illustrate the operation of the MAC layer. We set up experiments that reflect the routine work of IT managers.

Below are the experiments we include in our LAN course:

- Installation of Windows XP workstations and configuration of network connection
- Installation of Linux workstation, configuration of network connection, and SAMBA

The experiments are dispersed throughout the lectures of the course. Students are also encouraged to spend time in the lab after class. Details of the experiments will be presented in subsequent sections.

Assignments and Projects

An assignment is given to students for each lecture. Each assignment contains exercise questions about the lecture. Most questions concern the principles of LAN.

We view assignments as integrated parts of our course. Assignments reinforce what students learn in class. Another objective of the assignments is to prepare students for various certification exams.

In addition to experiments, simulations, and assignments, we give students sizeable projects. The projects help the students to integrate the knowledge they learned and to put it into practice. We offer simulation and hands-on projects.

3. SIMULATION TOOLS

We use simulation in a number of experiments, especially in places where we do not have the suitable instrumentation. For such situations, simulation can be highly effective learning tools. Specifically, we use simulation to cover the following topics.

Signal Transmission

Networking devices use many different types of transmission media and many different modulation/demodulation methods. This simulation tool is used to help students to understand the various transmission methods for carrying digital signals. This simulator includes various telecom line coding methods such as unipolar encoding, RZ (return-to-zero), NRZ (non-return to zero), bi-phase (Manchester and differential Manchester) encoding, etc. Analog schemes such as ASK (amplitude shift keying), FSK (frequency shift keying), PSK (phase shift keying), and QAM are also included. Multiplexing schemes are illustrated in an animated slide show.

For each input data string, the corresponding output sequences on the line/media for different encoding

schemes are generated and visualized. A snapshot of simulation is shown in Figure 1.

Error Detection

Signals may be corrupted during transmission. Hence error detection codes are commonly used in networking devices to provide reliable communications. We use this simulation tool to help students understand the various coding schemes and the corresponding algorithms. This simulator covers the vertical redundancy check (VRC), the longitudinal redundancy check (LRC), and the cyclic redundancy check (CRC). Users can type an input sequence and the simulator can generate encoded binary sequence using each of the given encoding methods. A simulation snapshot is shown in Figure 2.

Flow and Error Control Methods

Flow control and error control are important and integrated parts of a network system. This simulator is used to demonstrate the working principle of several important flow and error control algorithms, and is very important because it demonstrates the fundamental principles of protocol engineering. We simulate the stop-and-wait method and the sliding window method for flow control; the stop-and-wait ARQ, the sliding window ARQ, the go-back-n ARQ, and the selective reject ARQ for error control.

A sequence of frames is selected by the user. The user then chooses to transmit a frame at a time. The user decides when a frame is in transit and when the frame reaches the receiver. The user also decides when the receiving end sends an ACK and when a time-out is called at the transmitter. The simulator enforces the frame ordering. A simulation snapshot is shown in Figure 3.

Medium Access Methods

Media access control is the core of LAN. Understanding MAC protocols is of paramount importance in a LAN course. However, MAC controllers today are highly integrated chips that students have no way to directly experience the operations of these protocols. Hence simulation tools are highly valuable for teaching MAC.

Our simulator simulates Aloha, slotted Aloha, CSMA with various persistence strategies, CSMA/CD and CSMA/CA. Packet arrivals and packet lengths are generated using statistical models. Users may also configure the packet lengths and arrival times to test desired protocol behavior.

Ethernet Protocol

Ethernet MAC is one of the most important protocols and is also the most widely used protocol today. Our simulator is designed to help students visualize the variants of the Ethernet protocol. Ethernet uses the CSMA/CD protocol with some additional details. This simulator includes the added details. Users are also allowed to specify the details of Ethernet packets. They

can monitor the packets transmitted over the media and observe the protocol in operations.

Token Ring Protocol

The token ring protocol is another important and widely used protocol for LAN. It is fundamentally different from Ethernet. Our high level simulator is designed to enhance students understanding of token ring operations. This simulator implements a small and simplified token ring network. Traffic is randomly generated following certain arrival patterns. It also implements the IEEE 802.5 priority and reservation protocol. The state of each station is visualized and the operations of the protocol are made observable.

Wireless LAN Protocol

We simulate only the MAC layer protocols for wireless LAN. The IEEE 802.11 MAC protocols have more features than Ethernet. Its operations are highly sophisticated and are more difficult to understand than the Ethernet MAC operations. We simulate both distributed coordination function (DCF) and point coordination function (PCF). The simulator provides more information about the protocol operations and is an effective tool for learning the wireless LAN.

The suite of simulators and their functionality are presented above. We use these tools to help students understand the operations of LAN networking. Next, we describe the various lab experiments we setup for the LAN course.

4. LAB EXPERIMENTS

The design and implementation of lab experiments are crucial to a LAN course. The labs help students to digest the course material and to learn practical skills useful in the IT industry.

In our LAN course, we use a suite of lab experiments that are designed to help students to gain hands-on experience similar to typical industry environment. These experiments use common equipment such as hubs, switches, wireless access points, wireless routers, firewall routers, etc. Setup and configuration of common services on the LAN such as database, HTTP, FTP, SSH, file service and security are also included. We include a wide range of experiments so that students can gain valuable practical experience needed in the IT profession.

Some of the equipment used in our lab experiments is shown in Figure 4. Descriptions of the experiment suite are given below.

Windows XP installation

We include this experiment in our LAN course so that students have an opportunity to setup and work with the Windows XP operating system and its network configura-

ration. Windows XP professional edition is widely adopted by educational institutions and industry.

On the network side, students configure the workstation using dynamic IP addressing and static IP addressing. They also configure the wireless network card to connect with wireless routers.

Linux workstation installation

In this experiment, students install the latest Linux workstation. During the installation, they also perform network configuration. Linux is in widespread use today and this experiment provides our students with valuable practice on Linux.

Students also configure the workstations with both dynamic and static IP addressing. They test Web, email and various network services and they may need to perform diagnosis using Ping and other simple tools.

Setup of mixed workstation LAN

In this experiment, students connect several Linux workstation and XP workstations together in one LAN. They assign static addresses to the stations and manage these workstations.

In addition, students also learn to set file sharing, security configuration, and learn to use Samba. This experiment provides an environment similar to that of IT industry. Our goal is to put our students in an environment that resembles the IT industry as close as possible.

Setup of IEEE802.11 wireless LAN

This experiment involves connecting workstations into an IEEE 802.11 wireless network.

Workstations communicate with access points and wireless routers. Each station is equipped with a wireless card. Students must configure the card in order to communicate with a wireless broadband router. Connecting with an access point is straightforward and needs minimal configuration.

Students must also configure wireless broadband routers. These devices are widely available on the market and are used in many places. They also learn to configure filters and DMZ.

Installation of Windows 2003 server

Through the Microsoft alliance program, we have available the Windows 2000 and 2003 server software. We take advantage of the software and arrange to have students install and configure the servers for network operation.

Students install the servers, configure network operations, setup Web service, secure FTP, file sharing, SQL, and other services. They also setup .NET and test its services. This proves to be highly useful.

Installation of Linux server

This experiment requires that the students install Linux servers and configure HTTP, PHP, SSH, etc. They must also test the services after installation and configuration.

The service software that comes with the Linux system often is not compatible with the latest version. Hence, students may need to take extra effort to setup and configure the network service. For example, JSP requires a connector and Tomcat. Version mismatch of the software may cause many problems. Students may have to do their research in order to find compatible versions of software and to make the service work.

This experiment proves to be a highly useful one and provides valuable hands-on practice to our students.

Building a LAN with mixed technology

In this experiment, students are provided with Windows XP workstations, Windows 2003 servers, Linux workstations and Linux servers. They are also provided with hubs, switches, broadband firewall routers, wireless access points and wireless broadband routers. With these devices, they build a network and provide services such as file sharing, ftp, web, etc.

An example of a mixed technology network is shown in Figure 5. This is a comprehensive exercise that allows students to practice on building real networks.

5. SUMMARY

We have designed our local area network (LAN) course with a set of simulation tools and hands-on experiments to enhance the students' learning experience. In this course, we balance the learning of principles and practical aspects. We felt that if our students only learn the practical aspects of LAN, with technology dependent knowledge and without network principles, they will have difficulties coping with technological changes. Hence, we favor a balanced approach in teaching LAN. This approach will have a long term effect on what students learn and will make them adaptive to technological changes.

To effectively teach LAN principles, we use a set of simulation based tools and classroom lectures. The lectures and simulations are complemented with lab experiments. Since we have just adopted this approach, we need further tuning and gather students feedback. We hope that we will be able to gather interesting results soon and to perform comprehensive analysis of the results.

Preliminary study indicates that the simulation tools are very helpful in illustrating the principles and operations of LAN protocols and their use in classrooms and at home can significantly enhance students' learning experience.

6. ACKNOWLEDGMENT

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We also want to thank our students for implementing some of the simulators.

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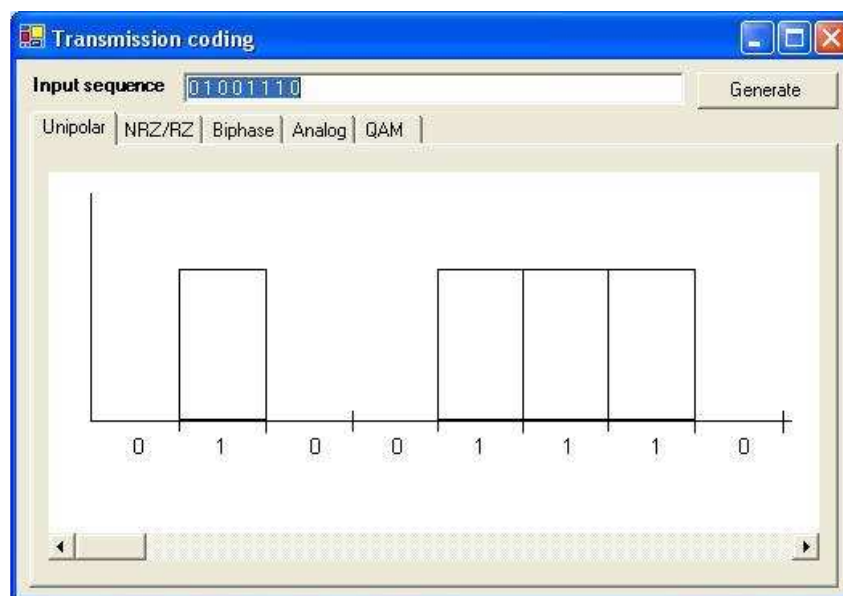


Figure 1. Transmission Signal Simulation.

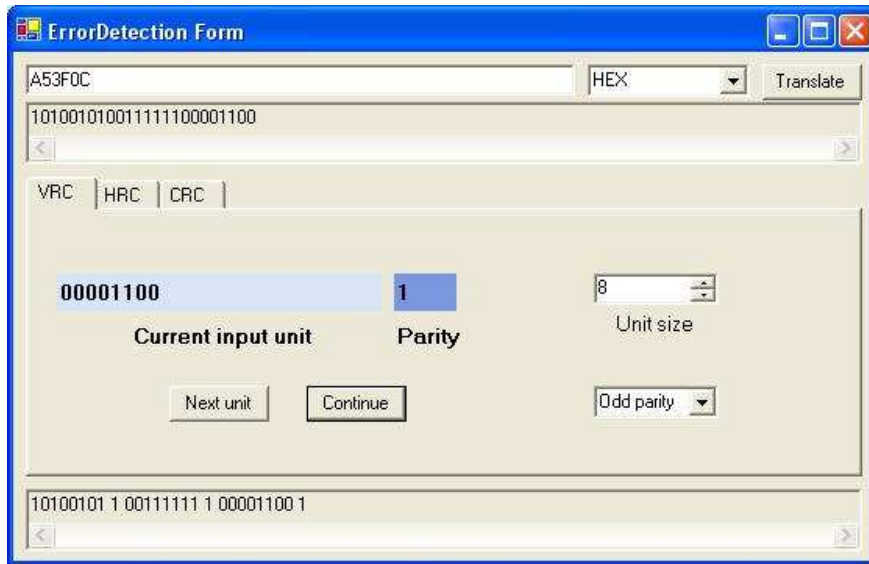


Figure 2. Error Detection Code Simulation.

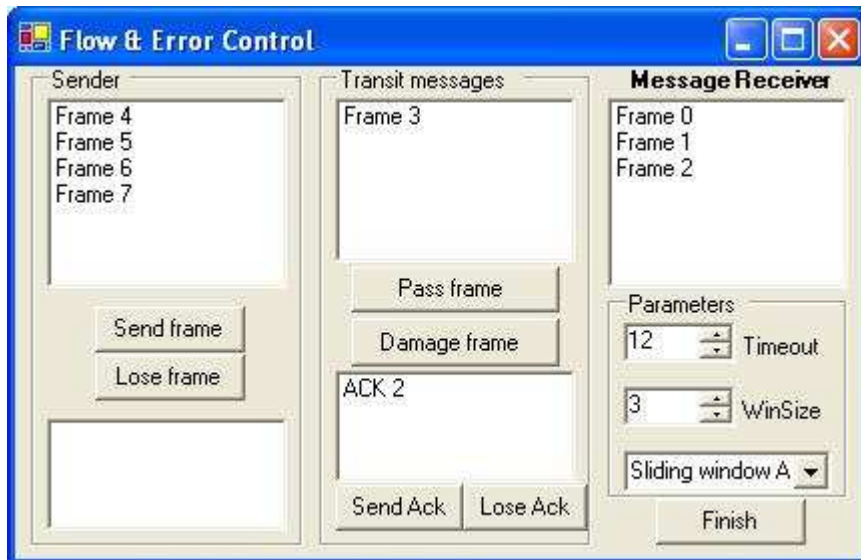


Figure 3. Flow Control and Error Control Simulation.

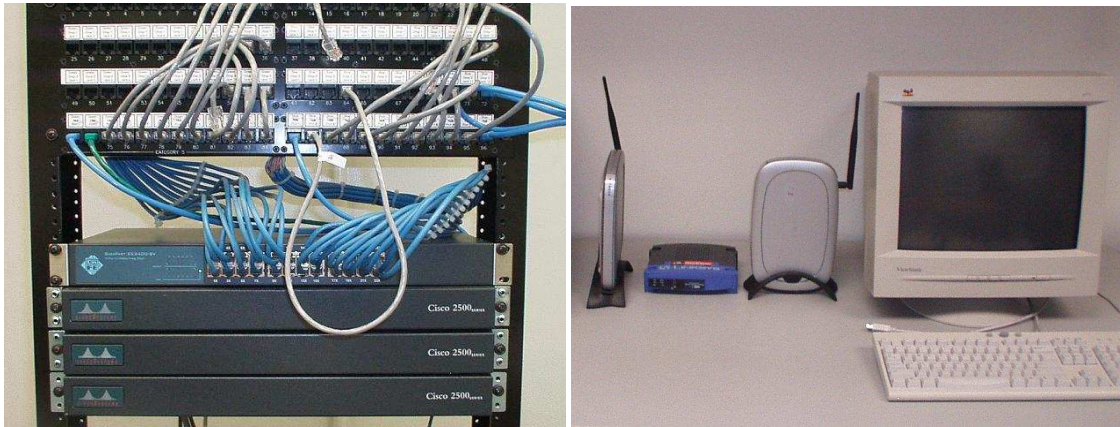


Figure 4. Some Equipment for Hands-on Experiments.

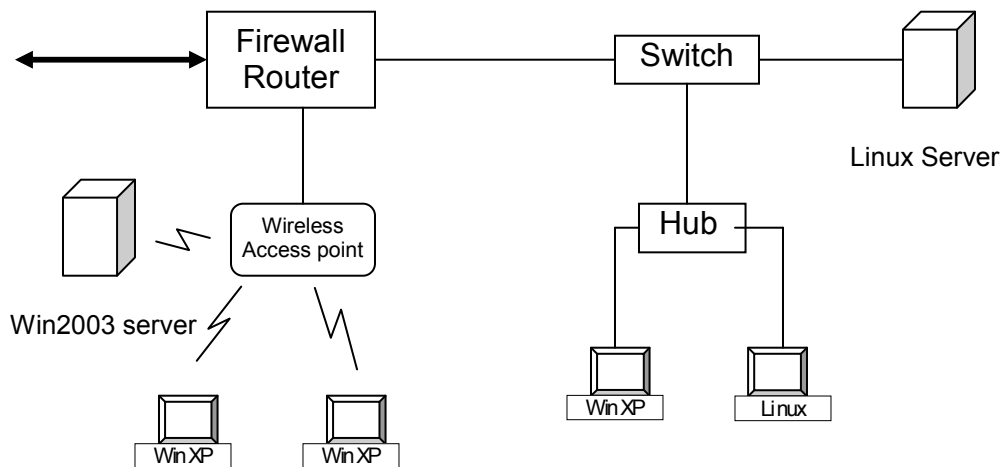


Figure 5. An Example of Mixed Technology LAN