Creating and Testing VLANs using Network Switches

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Abstract

This paper presents a hands-on undergraduate computer network laboratory exercise in configuring a network switch to create and test four virtual local area networks (VLANs). The objective is to familiarize students with layer 1 (physical layer) and layer 2 (network interface layer or data link layer). The exercise is designed to allow students to discover the need for layer 3 (internet or network) and, in particular, routing protocols to allow communication among the VLANs. In addition students are introduced to a spanning tree algorithm used within a VLAN to prevent bridge loops. The exercise requires students use a network switch, such as the Cisco 3500, to make physical connections between the switch and computers.

Introduction

It is very valuable for students to be in an actual networking environment, to have hands-on experience which helps them understand the fundamentals of computer networks. The laboratory exercises demystify many of the concepts discussed in the lectures and can range from software to hardware or anywhere in between. Software exercises may include writing network applications in socket programming, tracing and analyzing network traffic, and developing a protocol stack [5, 13]. Hardware exercises may include building a network from a collection of individual pieces of hardware such as cables, connectors, network cards, computers and routers [1, 2].

Comer [5] describes a large set of laboratory exercises that can be used in various networking environments, with an emphasis on Internet programming and the protocol stack. Al-Holou [3] suggests using simulation tools as a supplement to computer network curriculum, with the advantage of such tool being the flexibility, allowing the instructor to alter network parameters, hardware and software with relative ease. Hill and Mayo [8, 10] present cases where an isolated network is needed to teach network security issues. Abraham, Bressan, Francia, and Mengel [1, 4, 7, 11] present various types of hands-on network exercises involving hardware configurations. Liu and Fabrega [9, 6] address the issues of hands-on network experiences using a Web browser to access a virtual network providing students the capability to perform a set of well-designed network exercises. This approach has elements of both a simulated environment and an actual laboratory environment.

In this paper, we describe an undergraduate network laboratory exercise to configure a network switch, create and test four virtual local area networks (VLANs). This exercise uses a laboratory

environment similar to what was described in [2] where computers are connected by three separate networks and many different experiments can be carried on without disturbing the campus network. The objective of this exercise is to familiarize students with layers 1 (physical layer) and 2 (network interface layer or data link layer). The exercise provides students with a hands-on experience by configuring a network switch, such as the Cisco 3500, making physical connections to the switch, and identifying the need for layer 2 connectivity which allows locally attached devices to communicate with each other. Using the spanning tree algorithm bridge loops are prevented [14,15]. To allow communication between VLANs, students discover the need for layer 3 (network layer) or routing protocols.

The laboratory hardware used by each student group includes a switch (Cisco 3500), two laptop computers running Windows 2000 with a 10BaseT Ethernet card, two Ethernet cables, one console cable (serial port), and one crossover cable. The exercise allows each group to develop four VLANs, all of which are connected to the switch.

The exercise introduces students to a number of other issues such as configuration common to all switches such as hostname, security, network connectivity, and the need of internet protocol (IP) routing, all within a two-hour session.

In the following sections, we will describe some background information, the general environment, and a description of major steps of the exercise. A detailed step-by-step description is in Appendix A. Instructors should be able to adopt the laboratory exercise as it is, or modify it slightly to meet the needs of their individual environment.

Some Background Information

In a typical undergraduate network course the subject of routing, various routing algorithms, and functions of a router are part of the discussion of inter-connected networks [5, 15, 17, 18]. Our students are able to actually implement a small scale inter-connected network (internet) that includes computers, network equipment including a switch (or a router), some Ethernet cables and connectors. As shown in Figure 1, students connect two computers to the switch using two Ethernet cables, effectively creating a mini-switched network. One of the two computers is used as the console, allowing the students to configure the switch. Students complete the process by physically connecting all pieces together, configuring the switch to create four VLANs and test the connectivity between VLANs. Using the console computer, students are asked to configure the switch to assign ports to different virtual networks – networks created by the internal connections within the switch. Students then use the laptop computers to test VLAN connectivity with a probing tool, *ping,* to make sure that one computer is able to reach the other through the VLAN they just created.
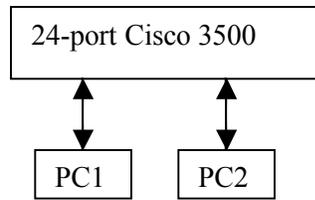
Figure 1: Connecting PCs to the Network Switch

General Environment and the Tasks for the Exercise

The laboratory exercise was conducted in an undergraduate network course in the fall semester of 2002. Twenty-six students were divided into eight groups of three and one group of two. The Cisco 3500 switch has 24 configurable ports. It has a serial port that can be used to connect to the console computer to configure the switch and monitor output. Each switch comes without a network configuration in its memory so the students were forced to start from scratch. Each laptop computer is given a temporary IP address to connect to the network. Students were temporarily granted the administrator's privilege on the Windows 2000 systems so that they could configure these computers for network operation. Initially students configured a hyper-terminal on the console computer to connect to the switch.

The exercise includes three tasks. The first is to connect the console computer to the switch via the hyper-terminal. The second task is to configure the 24-port switch into four VLANs as shown in Figure 2. VLAN 1 is required to be at Port 1 of Slot 0. Other VLANs can be configured differently. In our case, Ports 2 through 6 are assigned to VLAN 2, Ports 7 to 12 are assigned to VLAN3, and Ports 13 through 18 are assigned to VLAN 4. The third task is to test communications within and between the VLANs. Before conducting these tests, students have to set up the network configuration parameters on their Windows 2000 environment in order for the computers to communicate with the VLANs. The necessary parameters include the IP address and the network mask [5].
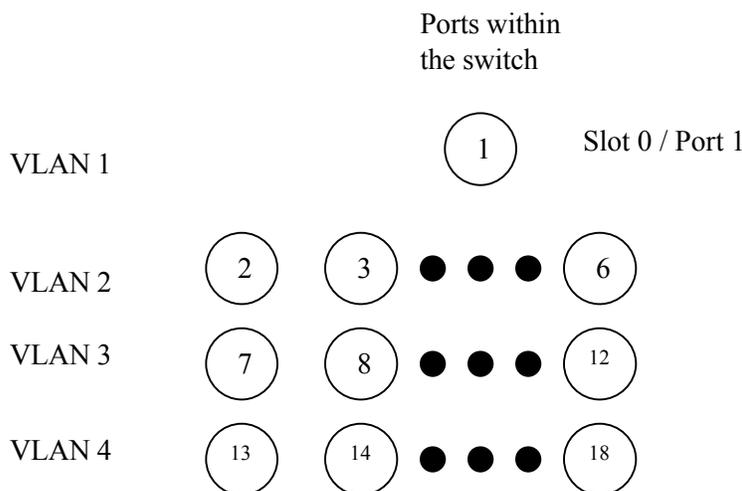
Figure 2: Port Assignment for the VLANs

Once the VLANs are created, students are asked to carry out three tests. The first test is to simply connect the two computers to any two ports within a VLAN (see Figure 3) and have these two computers *ping* each other.
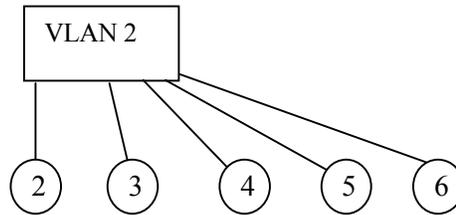
Figure 3: Communication Within a VLAN

The second test is to establish communications between the two computers when each computer is connected to a different VLAN (see Figure 4). The connectivity fails when two computers are on two different IP subnets. When the connectivity test fails, the students discover the need for layer 3 (or routing). In this case the students need to use the crossover cable between the two VLANs. The third test is to examine how a spanning tree algorithm is used to prevent the bridge loops in a VLAN (see Figure 5).
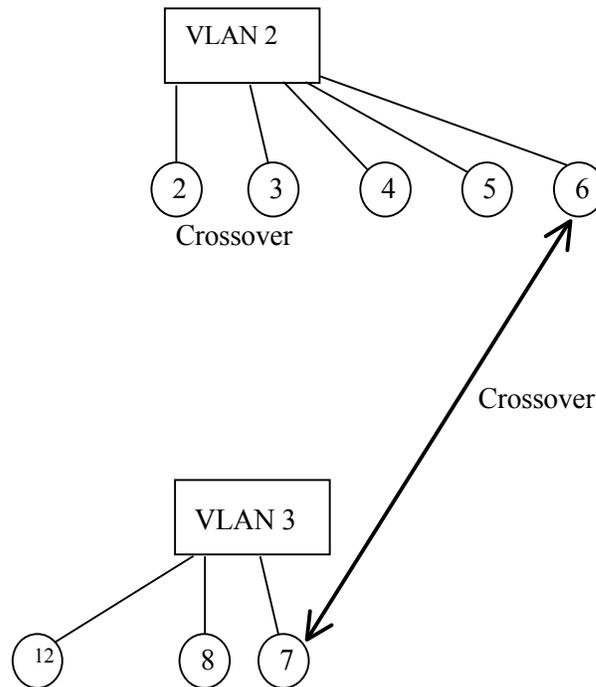
Figure 4: Using Crossover for VLAN 2 and VLAN 3 Communication
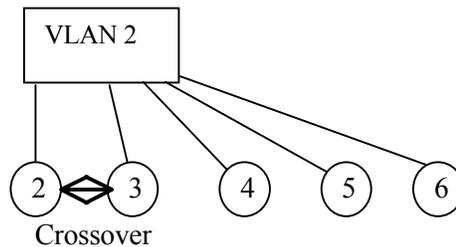
Disable Port 3

Figure 5: Crossover to Prevent Layer 2 Loops

The students discover that VLANs are isolated from each other and therefore provide security. The router (or the crossover cable used between VLANs) can be used to restrict the accesses to the VLANs.

The Student Work

The overall goal for the laboratory exercise is for students to get familiar with a network switch or router and to create and test four VLANs. To accomplish this goal, students proceed through the steps of connecting cables, configuring the switch, setting up parameters and testing various ways of communication within a VLAN and with other VLANs. The detailed steps are described in Appendix A. Here is an outline of the steps that the students are asked to follow in the laboratory.

1. Connect the serial console cable between one of the laptops and the switch so the laptop can be used as the console of the switch.
2. Set the hyper-terminal parameters in the Windows environment on the laptop for console communication.
3. Become familiar with the switch commands.
4. Select a host name for the switch and save the settings.
5. Create four VLANs and assign the port numbers for each of the VLANs.
6. Perform the spanning tree test to demonstrate the prevention of layer 2 loops.
7. Become aware of security settings within the switch.
8. Assign IP addresses and network mask.
9. Become aware the need for Layer 3 routing.
10. Communicate within and among VLANs.

Summary

We described a hands-on exercise for an undergraduate network course. Students go through a complete set of tasks to get first-hand experience of how a computer network is set up, configured and tested. Students are divided into groups, each with a Cisco switch, a set of computers, cables, connectors and necessary software. They start by connecting cables, configuring the switch, setting up VLANs, and finally testing various ways of communications

among computers within the same VLAN and with computers on different VLANs. Our experience indicates that this is a very successful exercise. Students' responses were very positive. As one Chinese proverb says, "*I see it, I forget. I hear it, I remember. I do it, I understand*." When they actually do the exercises of setting up a switch, configuring a network and testing various ways of communication, students gain an invaluable experience. The exercise demystifies many network concepts presented in the lectures and enhances students' knowledge acquired through the lectures.

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Biographical

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Appendix A: Step-by-Step Description of the Laboratory Exercise

In this section we describe a step-by-step process of the laboratory exercise. The exercise includes three parts. First you will configure a hyper-terminal to be used as the console for the switch. Second you will configure the Cisco switch and assign its 24 ports to four VLANs. Third you will configure the parameters of the computers for network operation. Then you will use these two computers to communicate within and between the VLANS.

To configure the Cisco switch the following steps are needed.

Step 1: Connect the serial console cable to the 9 pin serial port on the back of one of the laptops and connect the other end of the cable into the RJ-45 "console" port on the back of the switch

Step 2: Select Hyperterm on the laptop (note detailed instructions for 2000 for specific steps**)**

Step 3: Configure the session using the following parameters: Baud Rate of 9600 and stop bits of 1 and parity of none. Flow Control must be set to software xon/xoff

Step 4: Now press the enter key on the PC and you should obtain something similar to the prompt below.

CCS_MachRm_10_151>>

Step 5: This brings you to the user prompt of the Cisco 3500 switch. At this level you can do some very basic commands to monitor the switch, but not make critical configuration changes.

Type: sh ?

You should obtain a list of commands available at this level.

Step 6**: Type: sh v?**

This will list all commands that start with the letter 'v'.

version vlan vtp

Step 7**: Type: sh config (press the enter key)**

The following error message will occur

CCS_MachRm_10_151>>sh config
                                ^
% Invalid input detected at '^' marker.

Note: This is normal because you do not have the privilege yet.

Step 8: Now you will be entering what is called the user exec mode or enable mode.

Type: enable

You will obtain the following prompt (note the # sign).

CCS_MachRm_10_151>#

Step 9: **Type: sh ? (press the enter key)**

You should obtain a list of commands available at this level which is different from that of Step 5. Many more commands are available now.

Step 10**: Type: config terminal (press enter)**

This enters you into what Cisco calls the global configuration mode.
From this prompt you are able to enter commands that affect all users on the entire switch.

CCS_MachRm_10_151>(config)#

Step 11: **Type: hostname Team_Number (press the enter key)**

Now your switches prompt should have changed.

Step 12: **Type: exit (press the enter key)**

This should take you back to the following prompt:

CCS_MachRm_10_151>#

Step 13**: Type: write memory (press the enter key)**

This saves the configuration in NVRAM (non-volatile Random Access Memory**)**

Step 14: **Type: sh config (press the enter key)**

This shows you the configuration saved in the switch's NVRAM and is what will be used at start up.
Special note: if you forget to save your configurations you will lose them when you power cycle a switch**.**

Step 15**: Type: config t(press the tab key) (press enter)**

Note: This allows us to configure the switch from the terminal.

 Step 16: **Type: interface FastEthernet 0/1 (press enter)**

Note: 0 is the switch slot number and the 1 is the port number.

CCS_MachRm_10_151>(config-if)#   (if stands for interface)

This will put you into a specific interface for port 1 on the switch. All commands will now be unique to this port and only for the specific port you are in.

You will now be assigning the ports the following way.

Port 1 must be assigned to vlan 1
Ports 2-6 must be assigned to vlan 2
Ports 7-12 must be assigned to vlan 3
Ports 13-18 must be assigned to vlan 4

Note: Never Delete Vlan 1

Step 17: **Type: exit (press enter)**

Step 18: **Type: exit (press enter)**

You are now at the enable prompt.

Step 19: **Type: vlan database (press enter)**

Note: This step allows you to configure Virtual Local Area Network (vlan)

CCS_MachRm_10_151>(vlan)#

Step 20: **Type: vtp domain RingBarer (press enter)**

Step 21: **Type: vtp server (press enter)**

Note: This step assigns the current switch as the vlan server.

Step 22: **Type: exit (press enter)**

Step 23: **Type: sh vtp status**

CCS_MachRm_10_151>#sh vtp status
VTP Version   : 2
Configuration Revision   : 150
Maximum VLANs supported locally : 254
Number of existing VLANs   : 38
VTP Operating Mode   : Server
VTP Domain Name   : RingBarer
VTP Pruning Mode   : Disabled
VTP V2 Mode   : Disabled
VTP Traps Generation   : Disabled
MD5 digest   : 0x5D 0x99 0x29 0x0C 0x43 0x10 0x96 0xA3
Configuration last modified by 134.82.x.x 7-17-02 12:24:27

Note: The following steps allow you to define and name the vlans.

Step 24: **Type: vlan database (press enter)**

Step 25: **Type: vlan 2 name Vlan2 (press enter)**

Step 26: **Type: vlan 3 name Vlan3 (press enter)**

Step 27**: Type: vlan 4 name Vlan 4 (press enter)**

The following color code is defined for the descriptions to come in order for students to realize the different network protocol layers involved in each command.

Black – Normal Configurations
Red – Security
Blue – Layer II Network Loop Protection
Brown – Network Performance
Green – IP Routing

Step 28: **Type: exit (press enter)**

Step 28a: **Type: config t (press enter)**

Step 29: **Type: interface FastEthernet 0/1**

This will place you in specific configuration mode for port 1

Step 30: **Type the following commands in each port you will be assigning to vlan 1 (only port 1)**

port storm-control broadcast action filter
port storm-control broadcast trap
port storm-control broadcast threshold rising 250 falling 200
switchport access vlan 1
spanning-tree portfast

Note: the port storm commands relate to limiting the volume of broadcasts from one specific user or port. The spanning tree caommand finds the "best paths" in the network and ensures there are no bridge loops

Step 31: **Type: interface FastEthernet 0/2**

This will place you in specific configuration mode for port 2

Step 32: **Type the following commands for each port you will be assigning to vlan 2 (only ports 2-6).**

port storm-control broadcast action filter
port storm-control broadcast trap
port storm-control broadcast threshold rising 250 falling 200
switchport access vlan 2
spanning-tree portfast

Now repeat the previous two steps for the following interfaces:

> **interface FastEthernet 0/3**
> **interface FastEthernet 0/4**
> **interface FastEthernet 0/5**
> **interface FastEthernet 0/6**

Step 33: **Type: interface FastEthernet 0/7**

This will place you in specific configuration mode for port 7

Step 34: **Type: Type the following commands for each port you will be assigning to vlan 3 (only ports 7-12)**

port storm-control broadcast action filter
port storm-control broadcast trap
port storm-control broadcast threshold rising 250 falling 200
switchport access vlan 3
spanning-tree portfast

Step 35: **Type: interface FastEthernet 0/13**

This will place you in specific configuration mode for port 13

Step 36: **Type: Type the following commands for each port you will be assigning to vlan 4 (only ports 13-18)**

port storm-control broadcast action filter
port storm-control broadcast trap
port storm-control broadcast threshold rising 250 falling 200
switchport access vlan 4
spanning-tree portfast

Step 37: **Type: interface VLAN1**
Step 38: **(special configuration for Vlan 1)**

Note: The x in the following IP address should be your team number.

ip address 10.1.1.x 255.255.255.0
no ip directed-broadcast
no ip route-cache

Step 39: **Type: exit (press enter)**

Type: (the following commands at the CCS_MachRm_10_151>(config)# prompt)

ip default-gateway 10.1.1.254
no ip http server

Step 40: **Type: exit (press enter)**

Now you will be at the main user exec prompt.

Step 41: **Type: write memory**

Step 42: **Type: sh config**

Look at the passwords you have added (are they readable?)

Step 43: **Type: config t**

Step 44: **Type: service password-encryption (press enter)**

This adds password encryption.

Step 45: **Type: exit (press enter)**

Step 46: **Type: write memory**

Step 47: **Type: sh config**

Look at the passwords are they human readable?