Lab 10 – Internetworks and Routing

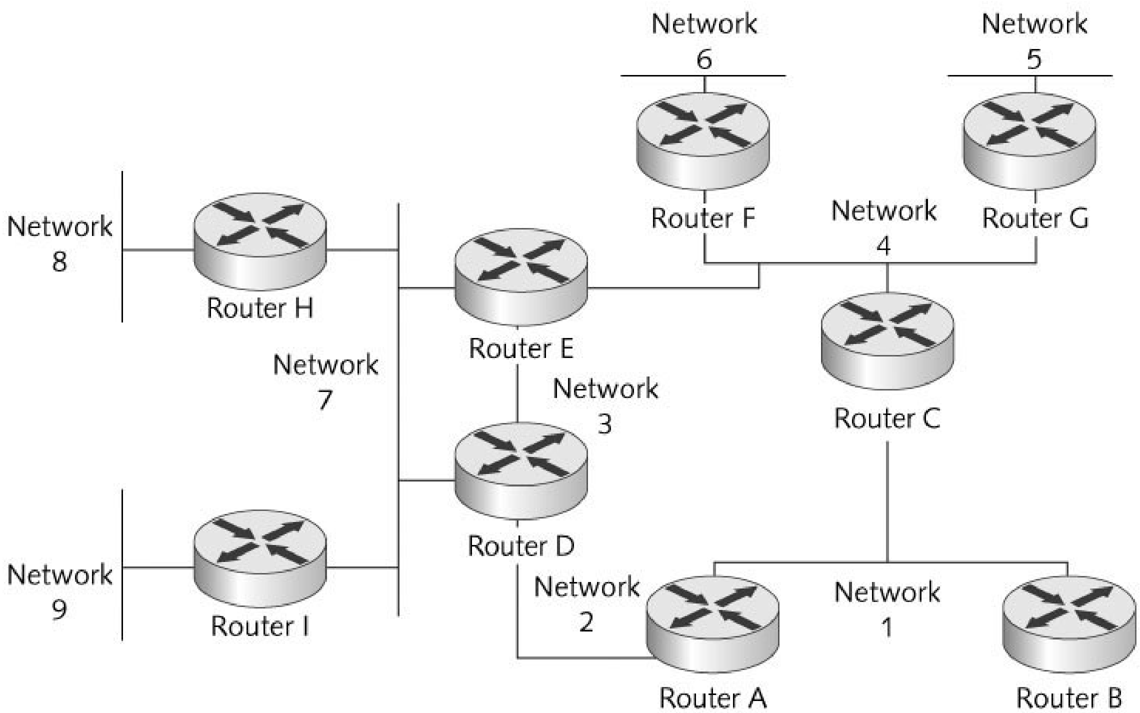
In this lab we will learn to create an "internetwork". We will do this by interconnecting a pair of LANs using a router.

Discussion

Routers operate at the Network layer (Layer 3) and work with packets. Routers connect separate logical networks to form an internetwork. Routers can be used to create complex internetworks with multiple fault tolerance paths. All processing done by routers depends on the following features:

(a) Router interfaces
(b) Routing tables
(c) Routing protocols.

An example of an internetwork is shown here – a number of LANs are connected using routers.

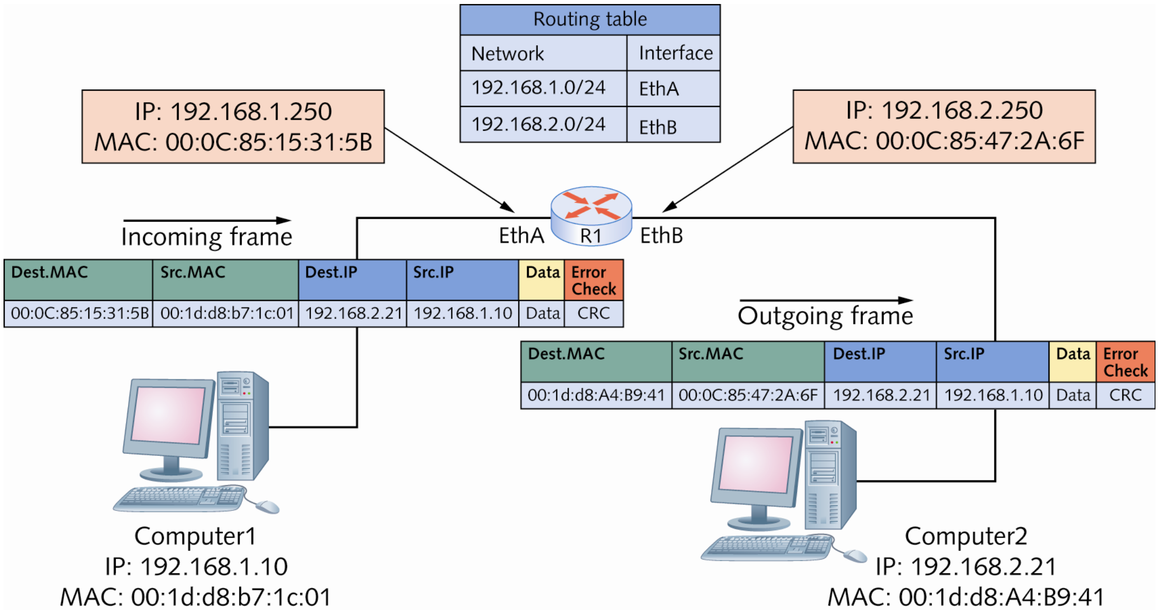


Router Interfaces

Every router has at least two more interfaces (ports) in order to take packets coming from one network and forward them to another network.

When a router interface receives a frame it compares the destination MAC address with the interface's MAC address. If they match, the router strips the frame header and trailer and reads the packet's destination IP address. The router will then consult its routing table to determine how to get the packet to its destination. The process of moving a packet from the incoming interface to the outgoing interface is called packet forwarding.

The following diagram illustrates how a packet is forwarded from one network to another using a routing table.



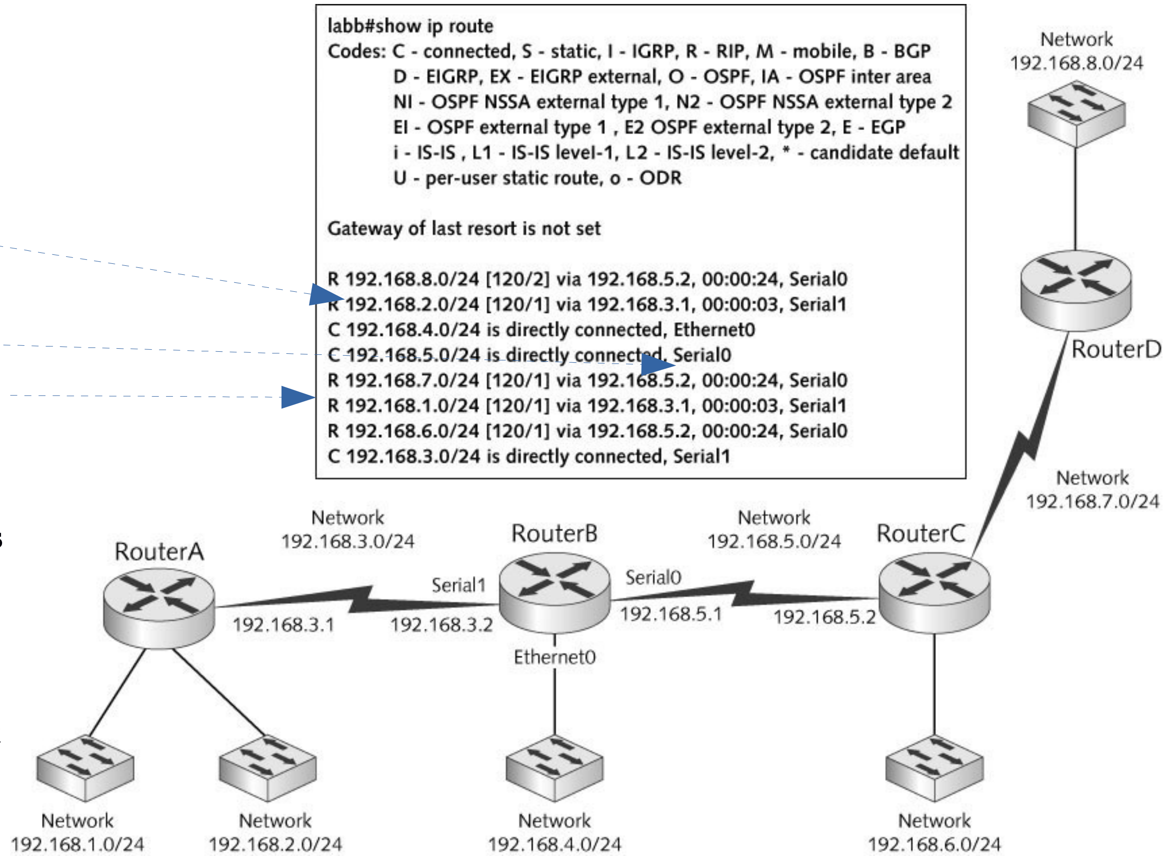
Packet forwarded from one network to another using a routing table

Broadcast frames, on the other hand, are not forwarded by routers.

Routing Tables

Routing tables are composed of rows (like the network address/interface pairs in the above diagram) that tell the router which interface a packet should be forwarded to. Actual entries in routing tables are more complex and may contain the following information:

1) Destination network address (subnet address) such as 192.168.5.0
2) Subnet mask – The mask associated with the subnet such as 255.255.255.0. Usually the subnet address and the mask are expressed in CIDR notation such as 192.168.5.0/24.
3) Next hop – The address of the next router in the path to the destination
4) The interface – The port the packet should be sent from
5) Hop Count – The total number of routers a packet must travel through before reaching the destination.
6) Metric – Numeric value that tells the router how “far away” the destination network is (also called cost or distance)
7) How the route is derived – This field tells you how the route gets into the routing table (one of 3 ways)
    i. Network is connected directly
    ii. Administrator enters the route information manually (called a static route)
    iii. Route information is entered dynamically, via a routing protocol
8) Timestamp – Tells the router how long it has been since the routing protocol updated the dynamic route



In the example on the right, we see the routing table stored in Router B.

The router uses CIDR notation – classless routing and has 3 interfaces. It uses the "RIP" protocol to forward packets to the next router.

Routing Protocols

Routing protocols are a set of rules that routers use to exchange information so that all routers have accurate information about an internetwork to set up their routing tables. There are two main types of routing protocols: **Distance-vector** and the **Link-state** protocols.

- A **distance-vector** protocol shares information about an internetwork's status by copying a router's routing table to other routers (routers sharing a network are called neighbors). The **Routing Information Protocol (RIP)** and **RIPv2** are most common examples of this type of protocol.
- A **Link-state** protocol shares information with other routers by sending the status of all their interface links to other routers. **Open Shortest Path First (OSPF)** is an example of this type of protocol.

The table below compares these two types of protocols. The "Speed of convergence" refers to how fast the routing tables of all routers in an internetwork are updated when a change occurs in the network.

Protocol type	CPU use	Network use	Memory use	Speed of convergence	Size of network	When is routing data transferred?
Distance-vector	Lower	Higher	Lower	Slower	Small	Periodically
Link-state	Higher	Lower	Higher	Faster	Large	Only when a change occurs

Routing protocols are not a necessity in all situations, as **static** routes can be entered in a routing table manually. The main considerations when choosing between static routes and a protocol are:

- Does the network change often? If so, a routing protocol is probably a good choice
- Are there several alternate paths to many of the networks in the internetwork? If so, a routing protocol can reroute around down links or congested routes automatically
- Is the internetwork large? A routing protocol will allow us to build and maintain routing tables automatically

Routers also have Access Control Lists (ACLs). An ACL is a set of rules configured on a router's interface for specifying which addresses and which protocols can pass through an interface and to which destinations. When an ACL blocks a packet it is called packet filtering. Interfaces on a router can be configured to block traffic based on Source or Destination addresses or the Protocol. Addresses can be specific IP or network addresses.

Cisco IOS

To configure a Cisco router, we generally need to establish a terminal connection with the router and then interact with it using the command line interface (CLI) known as Cisco IOS (Internetwork Operating System). Each command we enter will only execute once we press the Enter key. There are thousands of possible IOS commands and parameters. At any time, we can enter the **"?"** key to get a list of all available commands related to what we are doing. If the list is too long, we can scroll through it by hitting the space bar. ***`command ?`*** can be used to list the possible parameters of a command. For example: **`show ip ?`** will return possible parameters for **`show ip`**. If no parameters are needed, it will produce **CR** as the only option. Also, ***`<letter>?`*** can be used to list all commands that start with the particular letter. For example, **`i?`** will return a list of commands that start with the letter ***"i"***.

Some commands have default values for parameters. In such cases the default option is presented after the prompt. For instance a prompt may read, *Enter host name [Router]:* In this example, Router is the default value and hitting *Enter*, has the same effect as entering this default value.

The following is a list of commonly used IOS commands:

> **`config terminal`**, **`enable`**, **`interface`**, and **`router`**: Cisco routers have different modes. Some modes allow us to only look at settings and data and other modes allow you to change things. We move between these modes by executing these commands: **`config terminal`**, **`enable`**, **`interface`**, and **`router`**. When we log into the router, we start off in ***user mode*** in which the prompt looks like >. In *user mode*, we use the **`enable`** command to move to ***privileged mode*** in which the prompt changes to #. In *privileged mode*, we can show configuration information, but we cannot make changes. From *privileged mode* we can enter the ***global configuration mode,*** where we can make configuration changes. To enter the *global configuration mode* we execute the **`config terminal`** (or ***config t***) command. Once we are in global configuration mode, we can make global configuration changes. For example, to change a parameter on an interface (like its IP address), we need to enter the interface configuration mode with the **`interface`** command. We can also go into router configuration using the **`router`** ***{protocol}*** command. To exit from any mode, type the **`exit`** command. This will take us back to the previous mode.
>
> **`show running-configuration`** (*Short hand:* `sh run`): shows the current configuration.
>
> **`copy running-configuration startup-configuration`** (*Short hand:* `copy run start`): When we edit the configuration of a device such as a router, the changes are maintained in the RAM. This is called the running configuration. If we reboot the router the running configuration will be lost. To permanently save our configuration changes, we will need to use **`copy run start`** before rebooting the router.
>
> **`show interface`** (*Short hand:* `shint`): displays the status of the router's interfaces. Used for troubleshooting. It can also be supplied a specific interface as a parameter. For example,

`shint` **`i fa0/0`** will only produce the status of the fa0/0 interface. This command produces many things such as the Interface status (up/down), the Protocol status on the interface, interface Utilization, Errors, and many more.

`show ip interface`: provides lots of useful information about the configuration and status of the IP protocol and its services, on all interfaces

`show ip interface brief`: provides a quick status of the interfaces on the router, including their IP address, Layer 2 status, and Layer 3 status.

`no shutdown` (*Short hand: no shut)***:**   enables an interface (brings it up). This command must be used in interface configuration mode. ***Shutdown* (*Short hand:*** *shut)* has the opposite effect and will disable the interface.

`show ip route` (*Short hand: no shipro)***:** shows the router's routing table. This is the list of all networks that the router can reach, their metric (the router's preference for them), and how to get there.

`clear ip route *`: clears the routing table of all routes. To clear the entry for just one particular network you can use the **`clear ip route 1.1.1.0`**.

`show version` (*Short hand:* `shver`*)***:** displays the router's configuration register such as the last boot-up time, the IOS version, the IOS file name, the router model, and the size of RAM and Flash.

Activities

In this lab you will create an internetwork between your subnet and another team's subnet by configuring a router to filter and forward traffic across two LANs. The first thing you must do is to identify the team behind you who will be doing this lab with you as a team. If there is no team behind you, work with the team next to you or one assigned to you by the instructor or lab assistant.
Note that each pair of teams will work on one router for this lab. One team should configure one interface and the second team should configure the second interface on **one** router.

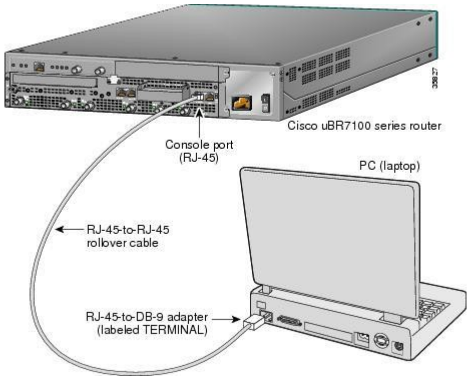
We will use a terminal emulator to connect to the router. A terminal emulator is a program that will allow us to communicate with the router through a console window using simple commands. More information about terminal emulators can be found on the wikipedia page: http://en.wikipedia.org/wiki/Terminal_emulator. The terminal emulator we will use is PuTTY - a free terminal emulator available from https://www.chiark.greenend.org.uk/~sgtatham/putty/latest.html.

Step 1: Connect your server to the router

Note: You will be working with another group. Choose one server and one router to work with, you don't need to configure both servers or routers.

To access the router's command line interface (CLI), we will use a serial cable. One end looks like an ethernet cable and the other end looks like a display adapter for a monitor. You should be able to find one in one of the drawers at your station. Your **server** has a serial cable input on the back that can be used to connect this cable to. Connect the other end to the router port labeled "Console".

Serial Port on server:



Example Diagram

Step 2: Install the terminal emulator on your server

- Use Remote Desktop to open a remote session with the server
- Download the 64-bit version of PuTTY from the link shown above – use a web browser and add the site as a trusted domain to download files in IE or Edge.
- **Once PuTTY is installed, disconnect your switch from the campus patch panel.**
  It is important that you **do this before moving to the next step or it will create problems for you and others.**

Step 3: Connect to the router using Putty

- Turn on the selected router, the power cord may need to be plugged in.
- Launch PuTTY on your server. When you first open Putty, you will see a left hand pane with many options. Scroll to the bottom of this list and click on **Serial**.
- Check to make sure the serial connection settings are correct:
    - Select a serial line: **COM1**
    - Speed (Baud): **9600**
    - Data bits: **8**
    - Stop Bits: **1**
    - Parity: **None**
    - Flow Control: **None**
- Click on **Session** in the left pane, choose the radio select "**Serial**" from the **Connection Type**.
- Click **Open**, if all went well, you should see a blank screen, with some text. If you don't see any text, its okay, just hit the Enter key once or twice.

Step 4: Reset the router

You should see a "prompt" from the router in the PuTTY window:

Router>

This means that the router is ready for you to enter commands.

If you see this message,

Would you like to enter the initial configuration dialog? [yes/no]:

type **no**:

Would you like to enter the initial configuration dialog? [yes/no]: **no**

Next, we have to get into "privileged" mode:

*Router>***enable**

If prompted for a password type **network**.

Type the following commands to reset the router configuration so that we can avoid potential problems from earlier settings:

*Router#***configure terminal**

We will change the router configuration register so that we have the following modes:

- Boot into ROM if initial boot fails
- set the console baud rate to 9600
- Ignore the contents of Non-Volatile RAM (NVRAM) for configuration

Router(config)# **config-register 0x2142**

Router(config)# **exit**
Router# **reload**
System configuration has been modified. Save? [yes/no]: **yes**
Proceed with reload? [confirm] <Enter>

You will now see the router's boot information. Be patient, this will take some time.

Step 5: Perform the system setup
There are two interfaces on the router. FastEthernet0/0 and FastEthernet0/1.
When asked to enter system config, type the following:

Would you like to enter the initial configuration dialog? [yes/no]: **yes**
Would you like to enter basic management setup? [yes/no]: **yes**
Configuring global parameters:
Enter host name [Router]: <Enter>
Enter enable secret: **network**
Enter enable password: **network1**
Enter virtual terminal password: **network**
Configure SNMP Network Management? [yes]: **no**

Current interface summary
Any interface listed with OK? value "NO" does not have a valid configuration

Interface	*IP-Address*	*OK? Method Status*	*Protocol*
FastEthernet0/0	*unassigned*	*NO unset up*	*down*
FastEthernet0/1	*unassigned*	*NO unset up*	*down*

We will first use the setup utility to configure the first interface – FastEthernet0/0 – on the router. Then we will use the configuration commands to enable the interface and configure the second interface.

Enter interface name used to connect to the
management network from the above interface summary: **FastEthernet0/0**
Configuring interface FastEthernet0/0:
Use the 100 Base-TX (RJ-45) connector? [yes]:
Operate in full-duplex mode? [no]: **yes**
Configure IP on this interface? [yes]: **yes**
IP address for this interface: **192.168.13.101** **Different for each subnet, replace 13 with your subnet #**
Subnet mask for this interface [255.255.255.0] :<Enter>
Class C network is 192.168.13.0, 24 subnet bits; mask is /24

The following configuration command script was created:

...

[0] Go to the IOS command prompt without saving this config.
[1] Return back to the setup without saving this config.
[2] Save this configuration to nvram and exit.

Enter your selection [2]: **2**
Building configuration...
Use the enabled mode 'configure' command to modify this configuration.

Step 6: Enable the FastEthernet0/0 interface

*Router>***enable**
Password: **network**
*Router#***configure terminal**
Enter configuration commands, one per line. End with CNTL/Z.
*Router(config)#***interface FastEthernet0/0**
*Router(config-if)#***no shutdown**
*Router(config-if)#***exit**

Step 7: Set up the second interface on the router for the second team

Switch places with the other team so that your team is using their server to configure the router. Make sure you are in the router's "privileged" mode – you should see this prompt on the router:

Router(config-if)#

Enter these commands to set up "your" interface (**0/1**) on the router:

*Router(config)#***interface FastEthernet 0/1**
*Router(config-if)#***ip address 192.168.14.101 255.255.255.0**
Different for each subnet, replace 14 with your subnet #
*Router(config-if)#***no shutdown**
*Router(config-if)#***full-duplex**
*Router(config-if)#***exit**

Step 8: Enable routing

*Router(config)#***ip routing**

Step 9: Save your configurations

*Router(config)#***config−register 0x2102**
*Router(config)#***exit**
*Router#***write**
*Router#***exit**

Step 10: Test your internetwork

If you have not done so already, **unplug the ethernet cable that connects your switch to the external patch panel for internet access**. **<u>This is important!</u>**

Connect the router port 0/0 with a straight-through cable to the switch on the network you configured in the previous steps.

> For example, if you configured port 0/0 to be on the subnet 192.168.13.1, then "switch 13" - the switch for server 13 – is the one you should connect it to.

Connect the router port 0/1 with a straight through cable to the switch for the **other** team's network.

Change the default gateways in the network settings on your desktop computers and your server to point to your router interface.

On the server, use the MMC to change the default gateway:

> MMC → DHCP → IPv4 → Scope → Scope options → 003 router
>
> Remove the existing default gateway from the list and add the new default gateway: 192.168.*server*.**101**

On each desktop computer, as long as you are using DHCP, the default gateway information will be obtained from the DHCP server. Use **`cmd`** → **`ipconfig /renew`**

> In case this does not work, use the network adapter properties to change the default gateway.

Test your internetwork: you should now be able to ping each other's workstations and servers across the router without changing your subnets.

Lab Exercise 1: Display the router configuration and describe it.
Draw a diagram of your LAN with the switch and the router and show the IP addresses and masks on both sides of the router.
On the router, show the output of the command "**`show ip route`**"

CONTACT ME AT THIS POINT AND DEMO YOUR SETUP. YOU WILL NEED A SIGN OFF ON THIS.

Lab Exercise 2: Use the following guidelines to create a number of subnets for your network.

You will need to reconfigure and use the router for this exercise.

- Assume you are given a network with the IP address range 10.0.0.0 to 10.255.255.255.
- You are asked to create ten equally populated subnets.
- Each subnet should be allocated maximum number of hosts.
- Answer the following questions in the Lab report:

1. What is the subnet mask of the network we are starting with?

2. What are the network addresses (in binary and decimal) for each of the ten subnets?

3. What is the new subnet mask after we divide the starting network into 10 or more subnets?

4. What is the range of IP host addresses in each subnet?

5. Which subnet and host addresses will you implement in the lab?

- Configure your server and workstation with one of the subnets you created using static IP. Test your network using ping.

CONTACT ME AT THIS POINT AND DEMO YOUR SETUP. YOU WILL NEED A SIGN OFF ON THIS.

Step 11: Cleanup

This step sets up your server for the next lab

- Once you have finished Step 10 and obtained the required sign-offs, turn off/unplug the router.
- Unplug router cables at the switch.
- Connect your switch back into the Campus patch panel so that you have internet connectivity.
- On your server, insert the Windows Server 2016 USB and restart the server.
- You will now be installing a clean version of Windows Server 2016 to be used in the next labs. Follow the steps provided in Lab 4 to reinstall Windows. You will not be providing a IP to the server so stop after naming the server.
- Be sure to shut down the server and workstations when done!

CSIS 247 Lab #10 Routing *Lab* Sign-offs Due: 9:00 am Nov 18^{th}

1 sheet per team – print this sheet and bring it to the lab.

Your Names: ______________________________________ *Server/Team #:* ___

Date: _________

Sign-offs:

Lab Exercise 1: Display router configuration and describe it

Lab Exercise 2: Test network using ping