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Chapter

1

Internetworking

THE CCNA EXAM TOPICS COVERED IN THIS CHAPTER INCLUDE THE FOLLOWING:

- ✓ **Describe how a network works**
  - Describe the purpose and functions of various network devices
  - Select the components required to meet a network specification
  - Use the OSI and TCP/IP models and their associated protocols to explain how data flows in a network
  - Describe common networked applications including web applications
  - Describe the purpose and basic operation of the protocols in the OSI and TCP models
  - Describe the impact of applications (Voice Over IP and Video Over IP) on a network
  - Interpret network diagrams
  - Describe the components required for network and Internet communications
  - Identify and correct common network problems at layers 1, 2, 3 and 7 using a layered model approach
  - Differentiate between LAN/WAN operation and features
- ✓ **Configure, verify and troubleshoot a switch with VLANs and interswitch communications**
  - Select the appropriate media, cables, ports, and connectors to connect switches to other network devices and hosts
  - Explain the technology and media access control method for Ethernet networks
  - Explain network segmentation and basic traffic management concepts

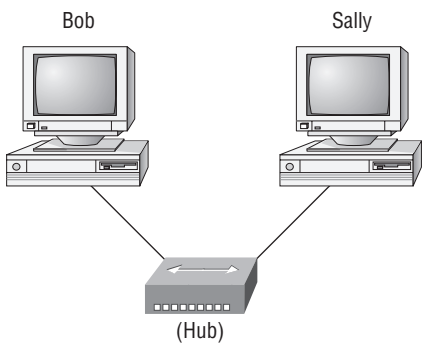
Internetworking Basics

Before we explore internetworking models and the specifications of the OSI reference model, you've got to understand the big picture and learn the answer to the key question, Why is it so important to learn Cisco internetworking?

Networks and networking have grown exponentially over the last 15 years—understandably so. They've had to evolve at light speed just to keep up with huge increases in basic mission-critical user needs such as sharing data and printers as well as more advanced demands such as videoconferencing. Unless everyone who needs to share network resources is located in the same office area (an increasingly uncommon situation), the challenge is to connect the sometimes many relevant networks together so all users can share the networks' wealth.

Starting with a look at Figure 1.1, you get a picture of a basic LAN network that's connected together using a hub. This network is actually one collision domain and one broadcast domain—but no worries if you have no idea what this means because I'm going to talk about both collision and broadcast domains so much throughout this whole chapter, you'll probably even dream about them!

FIGURE 1.1 The basic network



The basic network allows devices to share information.
The term computer language refers to binary code (0s or 1s).
The two hosts above communicate using hardware or MAC addresses.

Okay, about Figure 1.1… How would you say the PC named Bob communicates with the PC named Sally? Well, they're both on the same LAN connected with a multiport repeater (a hub). So does Bob just send out a data message, "Hey Sally, you there?" or does Bob use Sally's IP address and put things more like, "Hey 192.168.0.3, are you there?" Hopefully, you picked the IP address option, but even if you did, the news is still bad—both answers are wrong! Why? Because Bob is actually going to use Sally's MAC address (known as a hardware address), which is burned right into the network card of Sally's PC, to get ahold of her.

Great, but how does Bob get Sally's MAC address since Bob knows only Sally's name and doesn't even have her IP address yet? Bob is going to start with name resolution (hostname to

IP address resolution), something that's usually accomplished using Domain Name Service (DNS). And of note, if these two are on the same LAN, Bob can just broadcast to Sally asking her for the information (no DNS needed)—welcome to Microsoft Windows (Vista included)!

Here's an output from a network analyzer depicting a simple name resolution process from Bob to Sally:

```
   Time      Source      Destination   Protocol   Info
53.892794  192.168.0.2  192.168.0.255  NBNS  Name query NB SALLY<00>
```

As I already mentioned, since the two hosts are on a local LAN, Windows (Bob) will just broadcast to resolve the name Sally (the destination 192.168.0.255 is a broadcast address). Let's take a look at the rest of the information:

```
EthernetII,Src:192.168.0.2(00:14:22:be:18:3b),Dst:Broadcast (ff:ff:ff:ff:ff:ff)
```

What this output shows is that Bob knows his own MAC address and source IP address but not Sally's IP address or MAC address, so Bob sends a broadcast address of all *f*s for the MAC address (a Data Link layer broadcast) and an IP LAN broadcast of 192.168.0.255. Again, don't freak—you're going to learn all about broadcasts in Chapter 3, "Subnetting, Variable Length Subnet Masks (VLSMs), and Troubleshooting TCP/IP."

Before the name is resolved, the first thing Bob has to do is broadcast on the LAN to get Sally's MAC address so he can communicate to her PC and resolve her name to an IP address:

```
Time      Source     Destination Protocol Info
5.153054  192.168.0.2 Broadcast  ARP Who has 192.168.0.3? Tell 192.168.0.2
```

Next, check out Sally's response:

```
Time      Source     Destination   Protocol  Info
5.153403 192.168.0.3 192.168.0.2  ARP  192.168.0.3 is at 00:0b:db:99:d3:5e
5.53.89317  192.168.0.3 192.168.0.2 NBNS Name query response NB 192.168.0.3
```

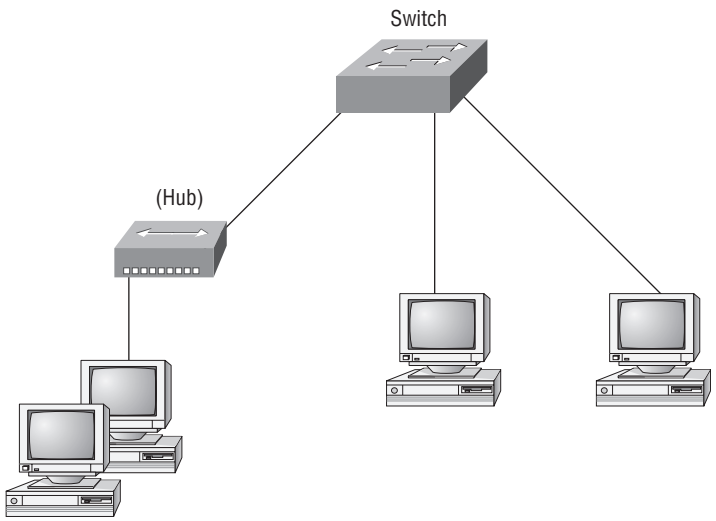
Okay sweet— Bob now has both Sally's IP address and her MAC address! These are both listed as the source address at this point because this information was sent from Sally back to Bob. So, *finally*, Bob has all the goods he needs to communicate with Sally. And just so you know, I'm going to tell you all about ARP and show you exactly how Sally's IP address was resolved to a MAC address a little later in Chapter 6, "IP Routing."

By the way, I want you to understand that Sally still had to go through the same resolution processes to communicate back to Bob—sounds crazy, huh? Consider this a welcome to IPv4 and basic networking with Windows (and we haven't even added a router yet!).

To complicate things further, it's also likely that at some point you'll have to break up one large network into a bunch of smaller ones because user response will have dwindled to a slow crawl as the network grew and grew. And with all that growth, your LAN's traffic congestion has reached epic proportions. The answer to this is breaking up a really big network into a number of smaller

ones—something called *network segmentation*. You do this by using devices like *routers*, *switches*, and *bridges*. Figure 1.2 displays a network that's been segmented with a switch so each network segment connected to the switch is now a separate collision domain. But make note of the fact that this network is still one broadcast domain.

FIGURE 1.2 A switch can replace the hub, breaking up collision domains.



Keep in mind that the hub used in Figure 1.2 just extended the one collision domain from the switch port. Here's a list of some of the things that commonly cause LAN traffic congestion:

- Too many hosts in a broadcast domain
- Broadcast storms
- Multicasting
- Low bandwidth
- Adding hubs for connectivity to the network
- A bunch of ARP or IPX traffic (IPX is a Novell protocol that is like IP, but really, really chatty. Typically not used in today's networks.)

Take another look at Figure 1.2—did you notice that I replaced the main hub from Figure 1.1 with a switch? Whether you did or didn't, the reason I did that is because hubs don't segment a network; they just connect network segments together. So basically, it's an inexpensive way to connect a couple of PCs together, which is great for home use and troubleshooting, but that's about it!

Now routers are used to connect networks together and route packets of data from one network to another. Cisco became the de facto standard of routers because of its high-quality router products, great selection, and fantastic service. Routers, by default, break up a *broadcast domain*—the set of all devices on a network segment that hear all the broadcasts sent on that segment. Figure 1.3 shows a router in our little network that creates an internetwork and breaks up broadcast domains.

frames, routers (layer 3 switches) use logical addressing and provide what is called packet switching. Routers can also provide packet filtering by using access lists, and when routers connect two or more networks together and use logical addressing (IP or IPv6), this is called an internetwork. Last, routers use a routing table (map of the internetwork) to make path selections and to forward packets to remote networks.

Conversely, switches aren't used to create internetworks (they do not break up broadcast domains by default); they're employed to add functionality to a network LAN. The main purpose of a switch is to make a LAN work better—to optimize its performance—providing more bandwidth for the LAN's users. And switches don't forward packets to other networks as routers do. Instead, they only "switch" frames from one port to another within the switched network. Okay, you may be thinking, "Wait a minute, what are frames and packets?" I'll tell you all about them later in this chapter, I promise!

By default, switches break up *collision domains*. This is an Ethernet term used to describe a network scenario wherein one particular device sends a packet on a network segment, forcing every other device on that same segment to pay attention to it. At the same time, a different device tries to transmit, leading to a collision, after which both devices must retransmit, one at a time. Not very efficient! This situation is typically found in a hub environment where each host segment connects to a hub that represents only one collision domain and only one broadcast domain. By contrast, each and every port on a switch represents its own collision domain.

Switches create separate collision domains but a single broadcast domain. Routers provide a separate broadcast domain for each interface.

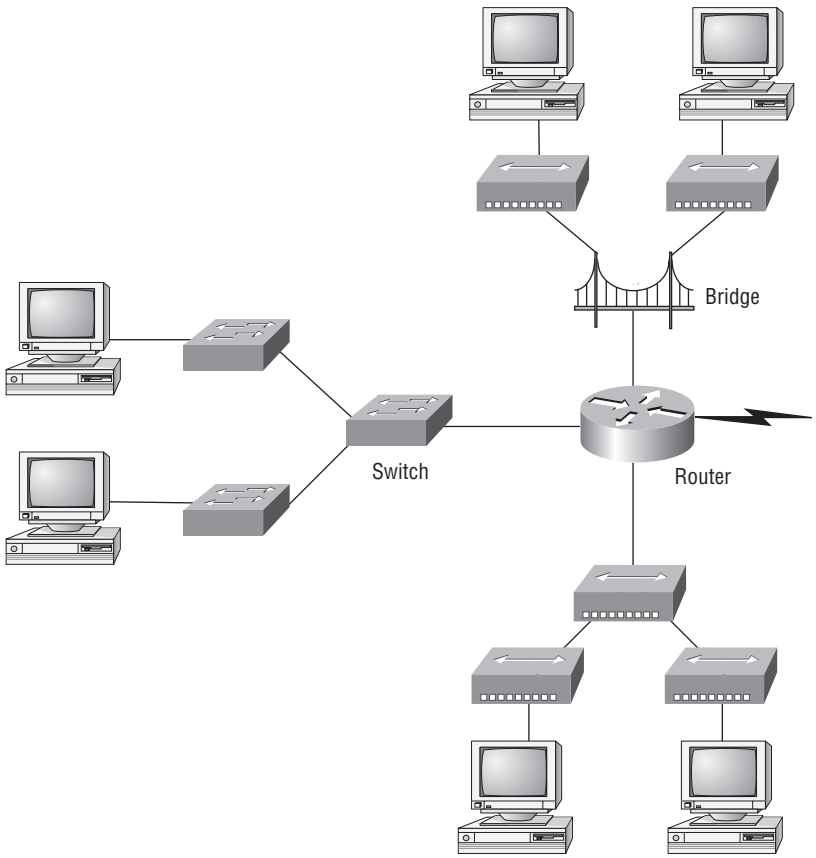
The term *bridging* was introduced before routers and hubs were implemented, so it's pretty common to hear people referring to bridges as switches. That's because bridges and switches basically do the same thing—break up collision domains on a LAN (in reality, you cannot buy a physical bridge these days, only LAN switches, but they use bridging technologies, so Cisco still calls them multiport bridges).

So what this means is that a switch is basically just a multiple-port bridge with more brainpower, right? Well, pretty much, but there are differences. Switches do provide this function, but they do so with greatly enhanced management ability and features. Plus, most of the time, bridges only had 2 or 4 ports. Yes, you could get your hands on a bridge with up to 16 ports, but that's nothing compared to the hundreds available on some switches!

You would use a bridge in a network to reduce collisions within broadcast domains and to increase the number of collision domains in your network. Doing this provides more bandwidth for users. And keep in mind that using hubs in your network can contribute to congestion on your Ethernet network. As always, plan your network design carefully!

Figure 1.4 shows how a network would look with all these internetwork devices in place. Remember that the router will not only break up broadcast domains for every LAN interface, it will break up collision domains as well.

FIGURE 1.4 Internetworking devices



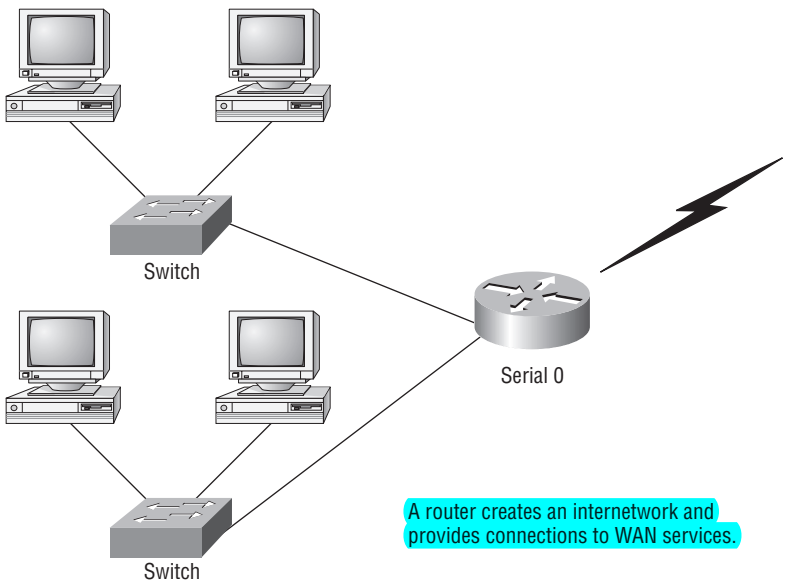
When you looked at Figure 1.4, did you notice that the router is found at center stage and that it connects each physical network together? We have to use this layout because of the older technologies involved——bridges and hubs.

On the top internetwork in Figure 1.4, you'll notice that a bridge was used to connect the hubs to a router. The bridge breaks up collision domains, but all the hosts connected to both hubs are still crammed into the same broadcast domain. Also, the bridge only created two collision domains, so each device connected to a hub is in the same collision domain as every other device connected to that same hub. This is actually pretty lame, but it's still better than having one collision domain for all hosts.

Notice something else: The three hubs at the bottom that are connected also connect to the router, creating one collision domain and one broadcast domain. This makes the bridged network look much better indeed!

Although bridges/switches are used to segment networks, they will not isolate broadcast or multicast packets.

FIGURE 1.3 Routers create an internetwork.



The network in Figure 1.3 is a pretty cool network. Each host is connected to its own collision domain, and the router has created two broadcast domains. And don't forget that the router provides connections to WAN services as well! The router uses something called a serial interface for WAN connections, specifically, a V.35 physical interface on a Cisco router.

Breaking up a broadcast domain is important because when a host or server sends a network broadcast, every device on the network must read and process that broadcast—unless you've got a router. When the router's interface receives this broadcast, it can respond by basically saying, "Thanks, but no thanks," and discard the broadcast without forwarding it on to other networks. Even though routers are known for breaking up broadcast domains by default, it's important to remember that they break up collision domains as well.

There are two advantages of using routers in your network:

- They don't forward broadcasts by default.
- They can filter the network based on layer 3 (Network layer) information (e.g., IP address).

Four router functions in your network can be listed as follows:

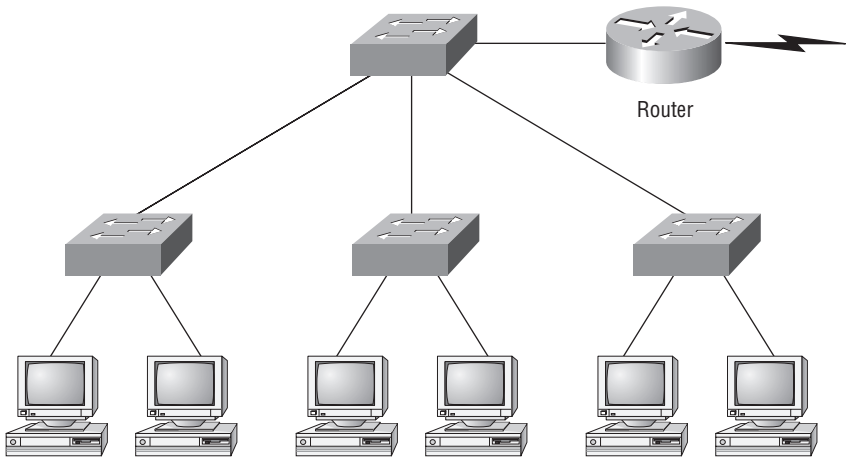
- Packet switching
- Packet filtering
- Internetwork communication
- Path selection

Remember that routers are really switches; they're actually what we call layer 3 switches (we'll talk about layers later in this chapter). Unlike layer 2 switches, which forward or filter

The best network connected to the router is the LAN switch network on the left. Why? Because each port on that switch breaks up collision domains. But it's not all good—all devices are still in the same broadcast domain. Do you remember why this can be a really bad thing? Because all devices must listen to all broadcasts transmitted, that's why. And if your broadcast domains are too large, the users have less bandwidth and are required to process more broadcasts, and network response time will slow to a level that could cause office riots.

Once we have only switches in our network, things change a lot! Figure 1.5 shows the network that is typically found today.

FIGURE 1.5 Switched networks creating an internetwork



Okay, here I've placed the LAN switches at the center of the network world so the routers are connecting only logical networks together. If I implemented this kind of setup, I've created virtual LANs (VLANs), something I'm going to tell you about in Chapter 9, "Virtual LANs (VLANs)." So don't stress. But it is really important to understand that even though you have a switched network, you still need a router to provide your inter-VLAN communication, or internetworking. Don't forget that!

Obviously, the best network is one that's correctly configured to meet the business requirements of the company it serves. LAN switches with routers, correctly placed in the network, are the best network design. This book will help you understand the basics of routers and switches so you can make tight, informed decisions on a case-by-case basis.

Let's go back to Figure 1.4 again. Looking at the figure, how many collision domains and broadcast domains are in this internetwork? Hopefully, you answered nine collision domains and three broadcast domains! The broadcast domains are definitely the easiest to see because only routers break up broadcast domains by default. And since there are three connections, that gives you three broadcast domains. But do you see the nine collision domains? Just in case that's a no, I'll explain. The all-hub network is one collision domain; the bridge network equals three collision domains. Add in the switch network of five collision domains—one for each switch port—and you've got a total of nine.

Now, in Figure 1.5, each port on the switch is a separate collision domain and each VLAN is a separate broadcast domain. But you still need a router for routing between VLANs. How many collision domains do you see here? I'm counting 10—remember that connections between the switches are considered a collision domain!

Real World Scenario

Should I Just Replace All My Hubs with Switches?

You're a network administrator at a large company in San Jose. The boss comes to you and says that he got your requisition to buy a switch and is not sure about approving the expense; do you really need it?

Well, if you can, sure—why not? Switches really add a lot of functionality to a network that hubs just don't have. But most of us don't have an unlimited budget. Hubs still can create a nice network—that is, of course, if you design and implement the network correctly.

Let's say that you have 40 users plugged into four hubs, 10 users each. At this point, the hubs are all connected together so that you have one large collision domain and one large broadcast domain. If you can afford to buy just one switch and plug each hub into a switch port, as well as plug the servers into the switch, then you now have four collision domains and one broadcast domain. Not great, but for the price of one switch, your network is a much better thing. So, go ahead! Put that requisition in to buy all new switches. What do you have to lose?

So now that you've gotten an introduction to internetworking and the various devices that live in an internetwork, it's time to head into internetworking models.

Internetworking Models

When networks first came into being, computers could typically communicate only with computers from the same manufacturer. For example, companies ran either a complete DECnet solution or an IBM solution—not both together. In the late 1970s, the *Open Systems Interconnection (OSI) reference model* was created by the International Organization for Standardization (ISO) to break this barrier.

The OSI model was meant to help vendors create interoperable network devices and software in the form of protocols so that different vendor networks could work with each other. Like world peace, it'll probably never happen completely, but it's still a great goal.

The OSI model is the primary architectural model for networks. It describes how data and network information are communicated from an application on one computer through the network media to an application on another computer. The OSI reference model breaks this approach into layers.

In the following section, I am going to explain the layered approach and how we can use this approach to help us troubleshoot our internetworks.

The Layered Approach

A *reference model* is a conceptual blueprint of how communications should take place. It addresses all the processes required for effective communication and divides these processes into logical groupings called *layers*. When a communication system is designed in this manner, it's known as *layered architecture*.

Think of it like this: You and some friends want to start a company. One of the first things you'll do is sit down and think through what tasks must be done, who will do them, the order in which they will be done, and how they relate to each other. Ultimately, you might group these tasks into departments. Let's say you decide to have an order-taking department, an inventory department, and a shipping department. Each of your departments has its own unique tasks, keeping its staff members busy and requiring them to focus on only their own duties.

In this scenario, I'm using departments as a metaphor for the layers in a communication system. For things to run smoothly, the staff of each department will have to trust and rely heavily upon the others to do their jobs and competently handle their unique responsibilities. In your planning sessions, you would probably take notes, recording the entire process to facilitate later discussions about standards of operation that will serve as your business blueprint, or reference model.

Once your business is launched, your department heads, each armed with the part of the blueprint relating to their own department, will need to develop practical methods to implement their assigned tasks. These practical methods, or protocols, will need to be compiled into a standard operating procedures manual and followed closely. Each of the various procedures in your manual will have been included for different reasons and have varying degrees of importance and implementation. If you form a partnership or acquire another company, it will be imperative that its business protocols—its business blueprint—match yours (or at least be compatible with it).

Similarly, software developers can use a reference model to understand computer communication processes and see what types of functions need to be accomplished on any one layer. If they are developing a protocol for a certain layer, all they need to concern themselves with is that specific layer's functions, not those of any other layer. Another layer and protocol will handle the other functions. The technical term for this idea is *binding*. The communication processes that are related to each other are bound, or grouped together, at a particular layer.

Advantages of Reference Models

The OSI model is hierarchical, and the same benefits and advantages can apply to any layered model. The primary purpose of all such models, especially the OSI model, is to allow different vendors' networks to interoperate.

Advantages of using the OSI layered model include, but are not limited to, the following:

- It divides the network communication process into smaller and simpler components, thus aiding component development, design, and troubleshooting.
- It allows multiple-vendor development through standardization of network components.
- It encourages industry standardization by defining what functions occur at each layer of the model.
- It allows various types of network hardware and software to communicate.
- It prevents changes in one layer from affecting other layers, so it does not hamper development.

The OSI Reference Model

One of the greatest functions of the OSI specifications is to assist in data transfer between disparate hosts—meaning, for example, that they enable us to transfer data between a Unix host and a PC or a Mac.

The OSI isn't a physical model, though. Rather, it's a set of guidelines that application developers can use to create and implement applications that run on a network. It also provides a framework for creating and implementing networking standards, devices, and internetworking schemes.

The OSI has seven different layers, divided into two groups. The top three layers define how the applications within the end stations will communicate with each other and with users. The bottom four layers define how data is transmitted end to end. Figure 1.6 shows the three upper layers and their functions, and Figure 1.7 shows the four lower layers and their functions.

FIGURE 1.6 The upper layers