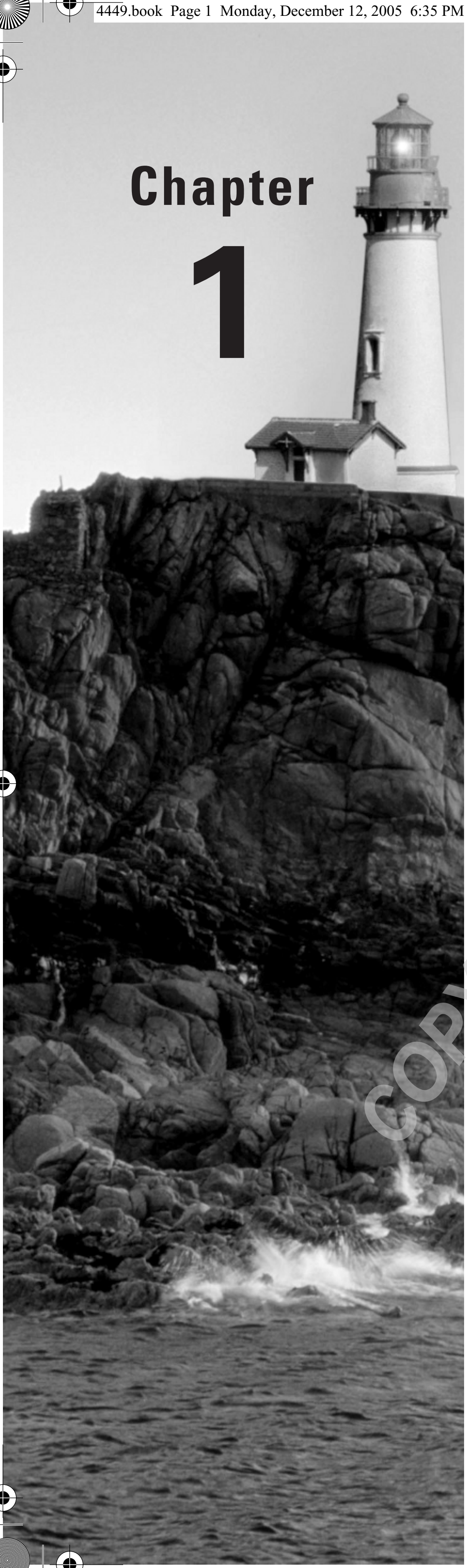

Chapter 1

Understanding Windows Server 2003 Networking

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Microsoft has put an immense amount of time and effort into building Windows Server 2003. It's not fair to say that this operating system is an entirely new product because it still retains a great deal of core code from Windows 2000 and even Windows NT, Internet Information Server, and Exchange Server. Windows Server 2003 is a large, complicated, and very powerful operating system. To use it effectively, you have to understand how it works and how to make it do what you want it to do. This book is a study guide for the Implementing, Managing, and Maintaining a Microsoft Windows Server 2003 Network Infrastructure exam, so it makes sense to lead off with a discussion of the network protocols included in Windows Server 2003—what they're for, how they work, and what you can do with them.

Having a good frame of reference helps when comparing network protocols. To establish such a frame, this chapter will begin with the Open Systems Interconnection (OSI) network model, a sort of idealized way to stack various protocols together.

NOTE This chapter covers necessary background information in order to be successful both on the 70-291 exam and as you work with Windows Server 2003 on the network.

The OSI Model

The International Organization for Standardization (ISO) began developing the *Open Systems Interconnection (OSI)* reference model in 1977. It has since become the most widely accepted model for understanding network communication; once you understand how the *OSI model* works, you can use it to compare network implementations on different systems.

When you want to communicate with another person, you need to have two things in common: a communication language and a communication medium. Computer networks are no different; for communication to take place on a network composed of a variety of different network devices, both the language and medium must be clearly defined. The OSI model (and networking models developed by other organizations) attempts to define rules that cover both the generalities and specifics of networks:

- How network devices contact each other and, if they have different languages, how they communicate with each other
- Methods by which a device on a network knows when to transmit data and when not to

- Methods to ensure that network transmissions are received correctly and by the right recipient
- How the physical transmission media is arranged and connected
- How to ensure that network devices maintain a proper rate of data flow
- How bits are represented on the network media

The OSI model isn't a product. It's just a conceptual framework you can use to better understand the complex interactions taking place among the various devices on a network. It doesn't do anything in the communication process; appropriate software and hardware do the actual work. The OSI model simply defines which tasks need to be done and which protocols will handle those tasks at each of the seven layers of the model. The seven layers are as follows:

- Application (layer 7)
- Presentation (layer 6)
- Session (layer 5)
- Transport (layer 4)
- Network (layer 3)
- Data-Link (layer 2)
- Physical (layer 1)

TIP

You can remember the seven layers using a handy mnemonic, such as "All Pitchers Sometimes Take Naps During Preseason."

Each of the seven layers has a distinct function, which we'll explore a little later in the chapter.

Real World Scenario

Real World Scenario: The True IP Protocol Suite

There is another model to represent these same concepts that is truly what the Internet was built upon. The model is known by a few names, including the TCP/IP model, the IP model, or the DoD model after its designers, the United States Department of Defense. The IP model, as we'll call it, contains only four layers: Link (also called Network Access), Network or Internet, Transport (sometimes called Host to Host), and Application. This model was the one originally used for the design of the Internet. You won't encounter this model on the 70-291 exam, but as a network administrator you should know that this model exists when you hear your peers talking about it.

Protocol Stacks

The OSI model splits communication tasks into smaller pieces called subtasks. Protocol implementations are computer processes that handle these subtasks. Specific protocols fulfill subtasks at specific layers of the OSI model. When these protocols are grouped together to complete a whole task, the assemblage of code is called a *protocol stack*. The stack is just a group of protocols, arranged in layers, that implements an entire communication process. Each layer of the OSI model has a different protocol associated with it. When more than one protocol is needed to complete a communication process, the protocols are grouped together in a stack. An example of a protocol stack is TCP/IP, which is widely used by Unix and the Internet—the TCP and IP protocols are implemented at different OSI layers.

Real World Scenario

Real World Scenario: Why You Should Care about Protocol Stacks

It may not be incredibly clear right now why you should care about protocol stacks and the OSI model. However, the OSI model and the protocol stacks for Internet communication are the basis upon which the 70-291 exam is built. All things about today's modern network stem from either the OSI or IP model.

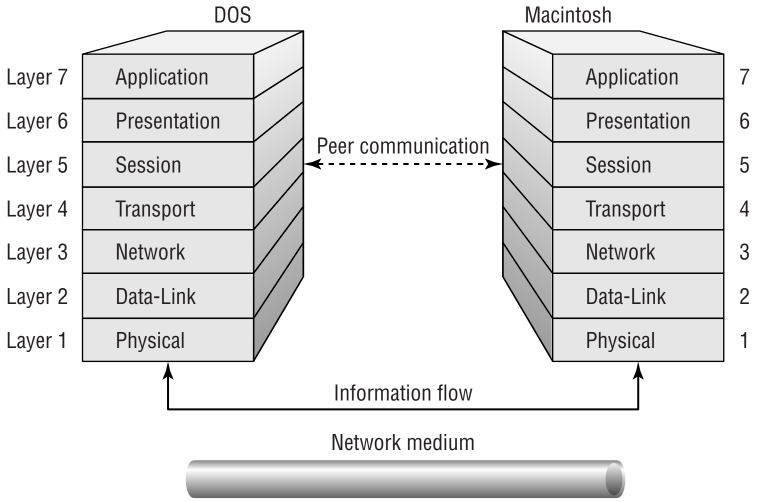
Knowing the layers of either model is essential to sound troubleshooting, and though it may not be obvious as you trudge through this background material, knowing the OSI model will help when managing a Windows network. Additional examples of how knowing the OSI model helps in troubleshooting will be given throughout this chapter.

Each layer in the protocol stack receives services from the layer below it and provides services to the layer above it. It can be better explained like this: Layer N uses the services of the layer below it (layer N – 1) and provides services to the layer above it (layer N + 1).

For two computers to communicate, the same protocol stacks must be running on each computer. Each layer on both computers' stacks must use compatible protocols in order for the machines to communicate with each other. The computers can have different operating systems and still be able to communicate if they are running the same protocol stacks. For example, a DOS machine running IP can communicate with a Macintosh machine running IP (see Figure 1.1).

When sending data, each layer in the OSI model places its own information onto the data as it passes down the stack in a process called *encapsulation*. Encapsulation takes place when each layer adds its own header and sometimes trailer information onto the data. When the data is received, it works its way back up the protocol stack and the corresponding layer of the protocol stack reads this information.

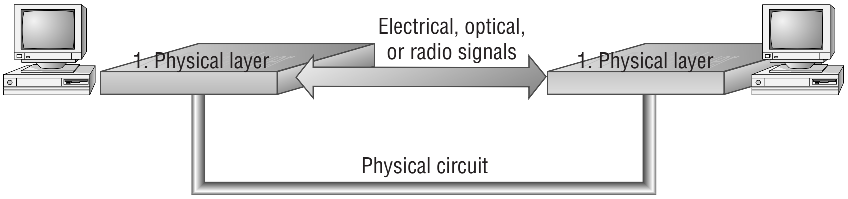
FIGURE 1.1 Each layer communicates with its counterparts on other network hosts.



The Physical Layer

The Physical layer is responsible for using electric (or sometimes other types of) signaling to get bits from one computer to another. Physical layer components don't care what the bits *mean*; their job is to get the bits from point A to point B, using whatever kind of optical, electrical, or wireless connection that connects the points. This level defines physical and electrical details, such as what will represent a 1 or a 0, how many pins a network connector will have, and when the network adapter may or may not transmit the data (see Figure 1.2).

FIGURE 1.2 The Physical layer makes a physical circuit with electrical, optical, or radio signals.



The Physical layer addresses all the minutiae of the actual physical connection between the computer and the network medium, including the following:

- Network connection types, including multipoint and point-to-point connections.
- Physical topologies, or how the network is physically laid out (e.g., bus, star, or ring topologies).

- Which analog and digital signaling methods are used to encode data in the analog and digital signals.
- Bit synchronization, which deals with keeping the sender and receiver in synch as they read and write data.
- Multiplexing, or the process of combining several data channels into one.
- Termination, which prevents signals from reflecting back through the cable and causing signal and packet errors. It also indicates the last node in a network segment.

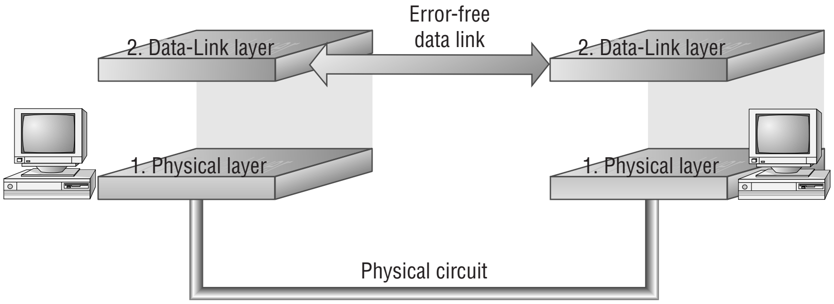
The Data-Link Layer

The Data-Link layer provides for the flow of data over a single physical link from one device to another. It accepts packets from the Network layer and packages the information into data units called frames; these frames are presented to the Physical layer for transmission. The Data-Link layer adds control information, such as frame type, to the data being sent.

This layer also provides for the error-free transfer of frames from one computer to another. A *cyclic redundancy check (CRC)* added to the data frame can detect damaged frames, and the Data-Link layer in the receiving computer can request that the CRC information be present so that it can check incoming frames for errors. The Data-Link layer can also detect when frames are lost and request that those frames be sent again.

In broadcast networks such as Ethernet, all devices on the LAN receive the data that any device transmits. (Whether a network is broadcast or point-to-point is determined by the network protocols used to transmit data over it.) The Data-Link layer on a particular device is responsible for recognizing frames addressed to that device and throwing the rest away, much as you might sort through your daily mail to separate good stuff from junk. Figure 1.3 shows how the Data-Link layer establishes an error-free connection between two devices.

FIGURE 1.3 The Data-Link layer establishes an error-free link between two devices.

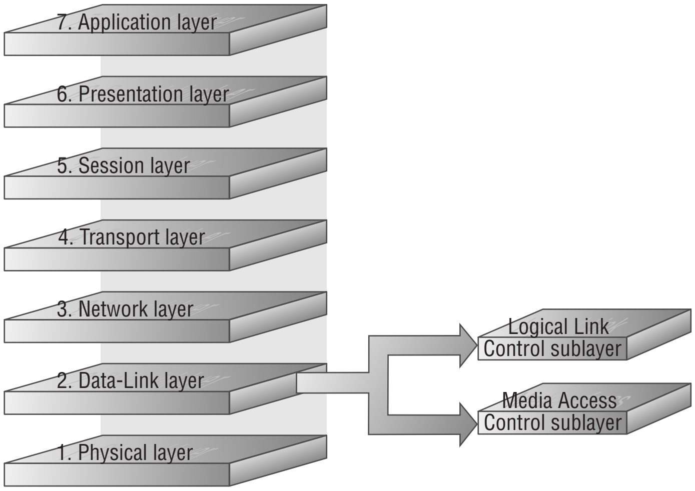


The Institute of Electrical and Electronics Engineers (IEEE) developed a protocol specification known as IEEE 802.X. (802.2 is the standard that divides this layer into two sublayers. The Media Access Control layer, more commonly called the MAC layer, varies for different network types and is described further in standards 802.3 through 802.5.) As part of that specification (which today we know as Ethernet), the Data-Link layer is split into two sublayers:

- The *Logical Link Control (LLC)* layer establishes and maintains the logical communication links between the communicating devices.
- The *Media Access Control (MAC)* layer acts like an airport control tower—it controls the way multiple devices share the same media channel in the same way that a control tower regulates the flow of air traffic into and out of an airport.

Figure 1.4 illustrates the division of the Data-Link layer into the LLC and MAC layers.

FIGURE 1.4 The IEEE split the ISO Data-Link layer into the LLC sublayer and the MAC sublayer.



The LLC sublayer provides *Service Access Points (SAPs)* that other computers can refer to and use to transfer information from the LLC sublayer to the upper OSI layers. This is defined in the 802.2 standard.

The MAC sublayer, the lower of the two sublayers, provides for shared access to the network adapter and communicates directly with network interface cards. A unique 48-bit address, commonly represented as a 12-digit hexadecimal MAC address (frequently called the hardware Ethernet address), is assigned to network interface cards before they leave the factory where they are made. The LLC sublayer uses MAC addresses to establish logical links between devices on the same LAN. Ethernet is an example of a protocol that exists at the Data-Link layer.

The Network Layer

The Network layer handles moving packets between devices. It makes routing decisions and forwards packets as necessary to help them travel to their intended destination. In larger networks,

Real World Scenario

Real World Scenario: MAC Address Conflicts and Limitations

Historically, one of the more difficult problems to diagnose and fix has been a conflict of MAC addresses between two (or more) devices on a network. Since the MAC address is specific to the hardware, it's sometimes referred to as the burned-in address. The MAC consists of 48 bits represented as a 12-digit hexadecimal number. Of that 12 digits, 6 are specific to the vendor that produced the card. For example, the first six numbers on a network card produced by Intel are 00AA00, while on Cisco devices they are 00000C.

On many network cards there is no way to change this address as it is set at the factory, though some cards do enable the administrator to change the MAC address. When two devices with the same MAC address are connected to the same network segment, a conflict will occur that can be quite difficult to diagnose. Many times the normal troubleshooting techniques won't work since things like pings respond normally. Resolving a MAC conflict sometimes comes down to looking at the MAC address for each device currently reporting problems. On Windows this is accomplished with the `ipconfig /all` command, as you'll see later.

MAC addresses don't cross network boundaries. Therefore, when troubleshooting a problem related to a MAC address with a tool called a sniffer, you might see one MAC address showing up more than others. Chances are that this is the router or gateway boundary of the network. Since all traffic coming into the network goes through the router, it assigns its own MAC address to all conversations coming into the network. This, in turn, has confused many an intrusion analyst or administrator on a network when they see large amounts of traffic coming from seemingly one MAC source.

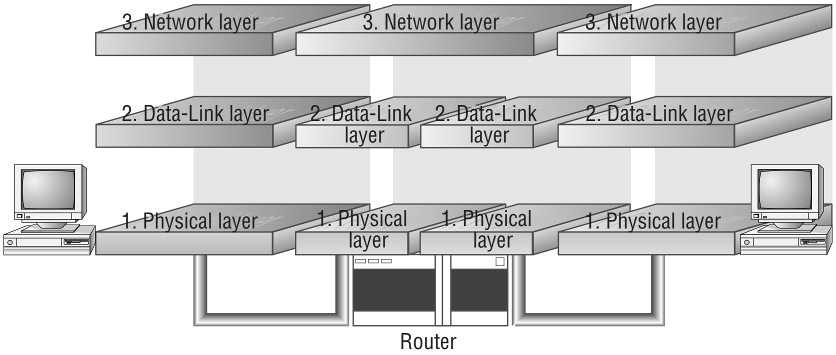
there may be intermediate devices and subnetworks between any two end systems. The network layer makes it possible for the Transport layer (and layers above it) to send packets without being concerned with whether the end system is on the same piece of network cable or on the other end of a large wide area network.

To do its job, the Network layer translates logical network addresses into physical machine addresses (MAC addresses, which operate at the Data-Link layer). The Network layer also determines the quality of service (such as the priority of the message) and the route a message will take if there are several ways a message can get to its destination.

The Network layer also may split large packets into smaller chunks if the packet is larger than the largest data frame the Data-Link layer will accept. The Network layer reassembles the chunks into packets at the receiving end.

Intermediate systems that perform only routing and relaying functions and do not provide an environment for executing user programs can implement just the first three OSI network layers. Figure 1.5 shows how the Network layer moves packets across multiple links in a network.

FIGURE 1.5 The Network layer moves packets across links to their destination.



The Network layer performs several important functions that enable data to arrive at its destination. The protocols at this layer may choose a specific route through an internetwork to avoid the excess traffic caused by sending data over networks and segments that don't need access to it. The Network layer serves to support communications between logically separate networks. This layer is concerned with the following:

- Addressing, including logical network addresses and service addresses
- Circuit, message, and packet switching
- Route discovery and route selection
- Connection services, including Network layer flow control, Network layer error control, and packet sequence control
- Gateway services

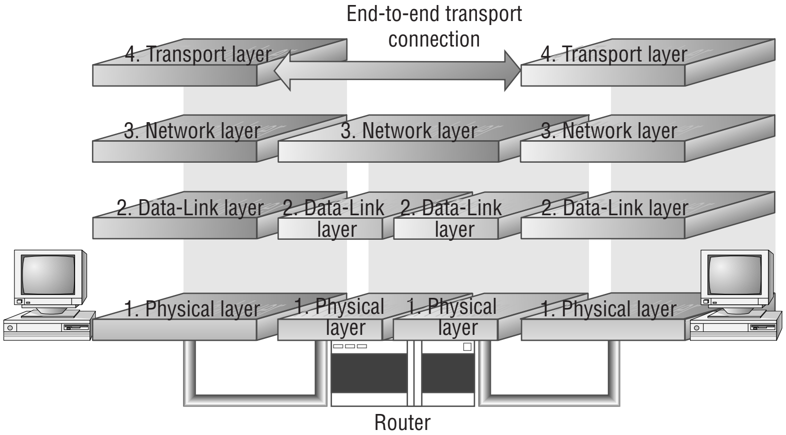
In Windows Server 2003, the various routing services for TCP/IP, AppleTalk, and Internetwork Packet Exchange/Sequenced Packet Exchange (IPX/SPX) perform Network layer services (see Chapter 9, "Managing IP Routing," for more on these services). In addition, the TCP/IP, AppleTalk, and IPX stacks provide routing capacity for those protocols.

The Internet Protocol (IP) itself resides on the Network layer.

The Transport Layer

The Transport layer ensures that data is delivered error free, in sequence, and with no losses or duplications. This layer also can break large messages from the Session layer into smaller segments to be handed down to the Network layer and sent to the destination computer and then reassemble segments into messages to be presented to the Session layer. The Transport layer can send an acknowledgment to the originator for messages received (as in Figure 1.6). Most of these services are optional and are not required in the implementation of all Transport-layer protocols. The one feature common to all protocols at the Transport layer is upper-layer protocol multiplexing, allowing multiple higher-layer protocol flows to operate simultaneously. In terms of TCP/IP, this means you could, for example, navigate to a website and download a file at the same time.

FIGURE 1.6 The Transport layer provides end-to-end communication with integrity and performance guarantees.



Transmission Control Protocol (TCP) and User Datagram Protocol (UDP) are examples of protocols that exist at the Transport layer.

The Session Layer

The Session layer allows applications on separate computers to share a connection called a session. This layer provides services that allow two programs to find each other and establish the communication link, such as name lookup and security. The Session layer also provides for data synchronization and checkpointing so that in the event of a network failure, only the data sent after the point of failure would need to be resent. This layer also controls the dialog between two processes and determines who can transmit and who can receive at what point during the communication (see Figure 1.7).

NetBIOS, RPC, and SQL are examples of protocols on the Session layer.

The Presentation Layer

The Presentation layer translates data between the formats the network requires and the formats the computer expects. The Presentation layer performs protocol conversion; data translation, compression, and encryption; character set conversion; and the interpretation of graphics commands.

The network redirector, long a part of Windows networking, operates at this level. The redirector is what makes the files on a file server visible to the client computer. The network redirector also makes remote printers act as though they were attached to the local computer. Figure 1.8 shows the Presentation layer's role in the protocol stack.

Graphic formats such as PICT, TIFF, and JPEG are examples of Presentation layer protocols.

FIGURE 1.7 The Session layer allows applications to establish communication sessions with each other.

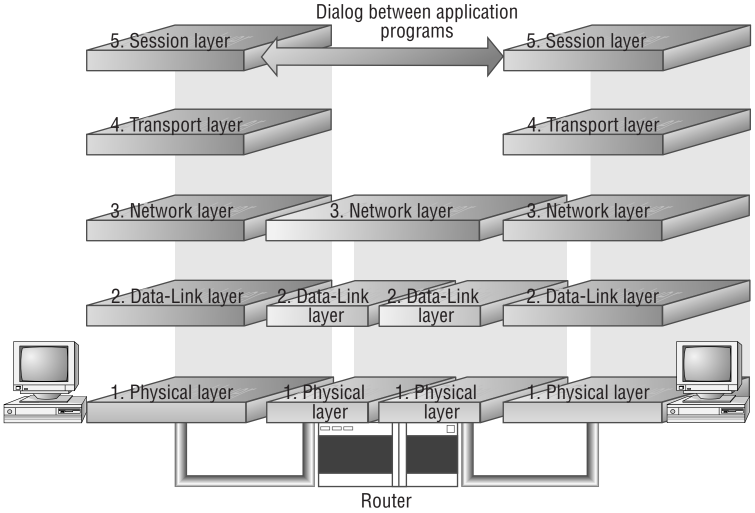
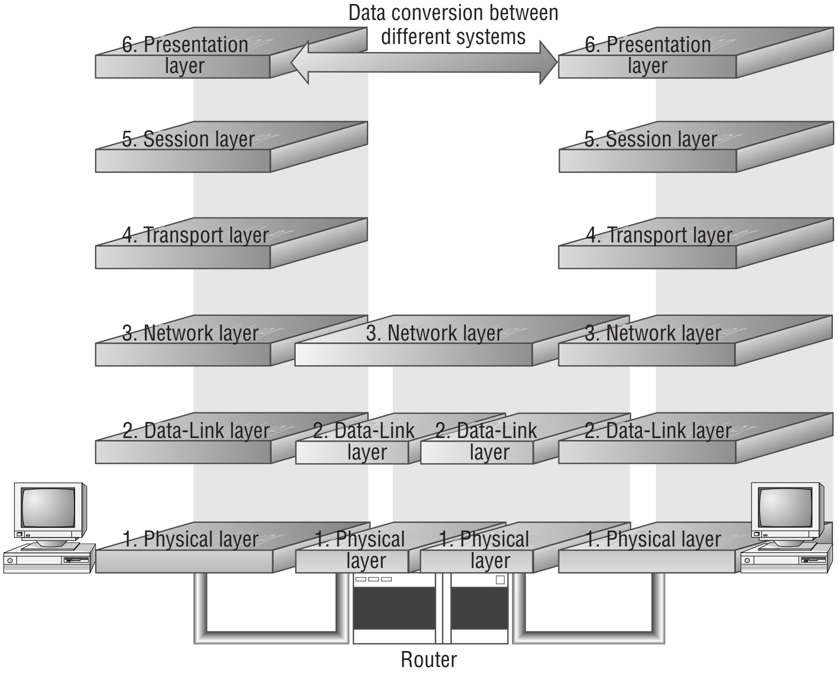


FIGURE 1.8 The Presentation layer allows applications to establish communication sessions with each other.

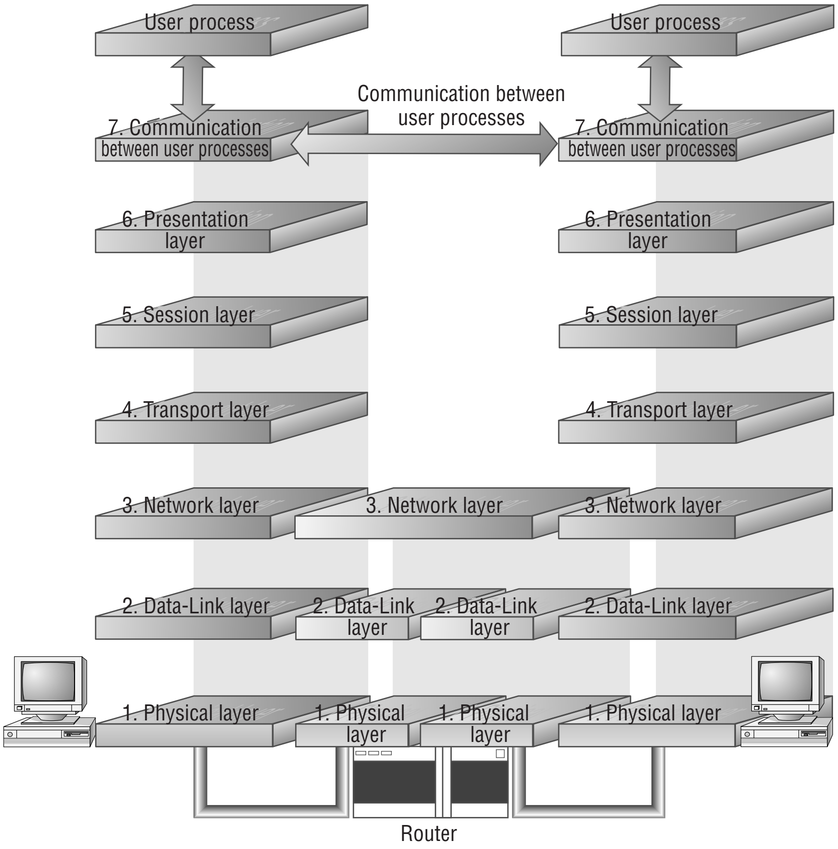


The Application Layer

The Application layer is the topmost layer of the OSI model, and it provides services that directly support user applications, such as database access, e-mail, and file transfers. It also allows applications to communicate with applications on other computers as though they were on the same computer. When a programmer writes an application program that uses network services, this is the layer the application program will access. For example, Internet Explorer uses the Application layer to make its requests for files and web pages; the Application layer then passes those requests down the stack, with each succeeding layer doing its job (as in Figure 1.9).

File Transfer Protocol (FTP), Hypertext Transfer Protocol (HTTP), Simple Mail Transfer Protocol (SMTP), and others are examples of protocols at the Application layer.

FIGURE 1.9 The Application layer is where the applications function, using lower levels to get their work done.



Communication between Stacks

When a message is sent from one machine to another, it travels down the layers on one machine and then up the layers on the other machine, as shown in Figure 1.10.

As the message travels down the first stack, each layer it passes through (except the Physical layer) adds a header. These headers contain pieces of control information that are read and processed by the corresponding layer on the receiving stack. As the message travels up the stack of the other machine, each layer removes the header added by its peer layer and uses the information it finds to figure out what to do with the message contents (see Figure 1.11).

As an example, consider the network we're using while writing this book. It's a TCP/IP network containing several Windows 2000, Windows Server 2003, Macintosh, and Windows NT machines, all connected using Ethernet and the IP protocol. When we mount a share from our Windows Server 2003 file server on the Mac desktop, at layer 7, the Mac Finder requests something from the Windows Server 2003 computer. This request is sent to the Mac's layer 6, which receives the request as a data packet, adds its own header, and passes the packet down to layer 5. At layer 5, the process is repeated, and it continues until the packet makes it to the Physical layer. The physical layer is responsible for actually moving the bits across the network wiring in the office, so it carries the request packet to a place where the Windows Server 2003 machine can "hear" it. At that point, the request packet begins its journey up the layers on the Windows Server 2003 file server. The header that was put on at the Data-Link layer of the Mac OS is stripped off at the Data-Link layer on the Windows Server 2003 machine. The Windows Data-Link layer driver performs the tasks requested in the header and passes the requests to the next, higher layer. This process is repeated until the Windows Server 2003 file server receives the packet and interprets the request. The Windows Server 2003 file server would then formulate an appropriate response and send it to the Mac.

FIGURE 1.10 Traffic flows down through the stack on one computer and up the stack on the other.

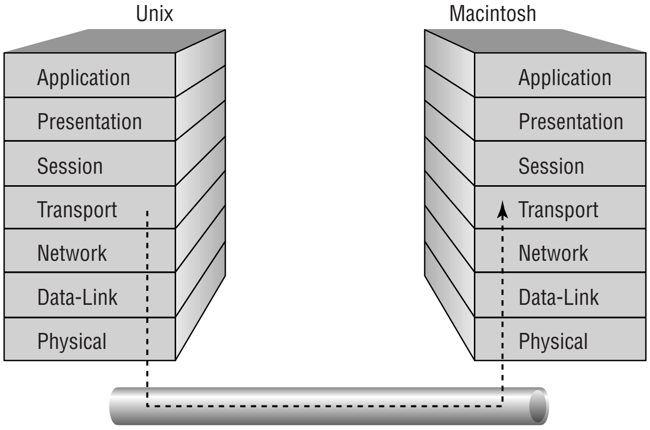
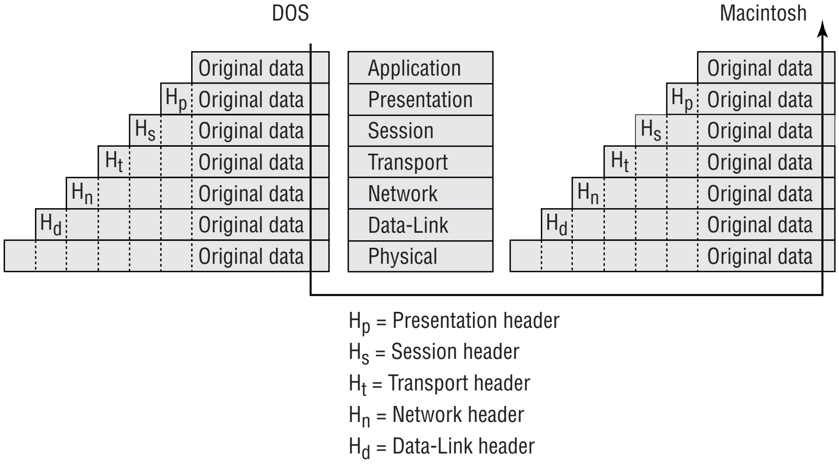


FIGURE 1.11 As packets flow up and down the stacks, each layer adds or removes necessary control information.



Microsoft's Network Components and the OSI Model

Because the OSI model is so abstract, it can be hard to tell how its concepts relate to the actual network software and hardware you use in the real world. The following sections will make the link clearer. We will introduce you to the specific protocols that are included with Windows Server 2003 and see how they apply to the various layers of the OSI model.

Device Drivers and the OSI Model

Every hardware device in a computer requires a software-based device driver to make it work. Some drivers—for instance, the driver for an integrated device electronics (IDE) hard disk or for the keyboard—are built into the operating system. Other devices require that drivers be installed separately when the device is attached or installed in the computer. Windows Server 2003 really blurs this distinction because it includes drivers for several hundred different network cards, but if your card isn't on the list, you will need to install drivers provided by the manufacturer.

In the past (e.g., when Windows 3.11 was introduced), network drivers were vendor specific, for both the operating system and the card. You might, for instance, have a difficult time if you wanted to put a 3Com Ethernet card and an IBM Token Ring card in the same server. Worse yet, most drivers could only be bound to a single protocol stack and a single card, so you couldn't have two cards using TCP/IP on one server.

A variety of vendors tried to solve this problem by developing driver interfaces that allowed multiple cards to be bound to multiple protocols. Apple and Novell developed the *Open Datalink Interface (ODI)*, and Microsoft countered with the *Network Driver Interface Specification (NDIS)*. Microsoft's operating systems have supported NDIS ever since, making it possible to bind either multiple protocols to one card or the same protocol to multiple cards.

Network adapter cards and drivers provide the services corresponding to the Data-Link layer in the OSI model. In the IEEE model, the Data-Link layer is split into the Logical Link Control (LLC) sublayer—which corresponds to the software drivers—and the Media Access Control (MAC) sublayer—which corresponds to the network adapter. You can think of the drivers as intermediaries between the higher layers and the card hardware that handles the business of forming packets and stuffing them into a wire.

The Basics of Network Protocols

Protocols are nothing more than an agreed-upon way in which two objects (people, computers, home appliances, etc.) can exchange information. There are protocols at various levels in the OSI model. In fact, it is the protocols at a particular level in the OSI model that provide that level's functionality. Protocols that work together to provide a layer or layers of the OSI model are known as a protocol stack or protocol suite. The following sections explain how network protocols move data between machines.

How Protocols Work

A protocol is a set of basic steps two or more parties perform according to a predefined or agreed-upon set of standards. A good example of a protocol that follows some unwritten but largely agreed-upon standards is a telephone conversation. When one person places a phone call, they dial the number of another party. The person on the other end answers the phone and says something akin to "Hello," at which point the calling party responds with a similar greeting. The conversation ensues from there. When the conversation is complete, each party (usually) ends the call with some parting words such as "Good-bye." This telephone call followed a routine protocol, say "Hello," converse, say "Goodbye."

In the realm of computers, a protocol follows the same concept. A protocol is a set of predefined standards that both computers must perform in the right order. For instance, for one computer to send a message to another computer, the first computer must perform the steps given in the following general example:

1. Break the data into small sections called packets (or segments, or another name depending on the layer involved).
2. Add addressing information to the packets, identifying the destination computer.
3. Deliver the data to the network card for transmission over the network.

The receiving computer must perform these steps:

1. Accept the data from the network adapter card.
2. Remove the transmitting information that was added by the transmitting computer.
3. Reassemble the packets of data into the original message.

Each computer needs to perform the same steps, in the same way and in the correct order, so that the data will arrive and be reassembled correctly. If one computer uses a protocol with different steps or even the same steps with different parameters (such as different sequencing, timing, or error correction), the two computers won't be able to communicate with each other.

Network Packets

Ethernet networks running IP and using TCP as the transport protocol primarily send and receive small chunks of data called *packets*. Network protocols construct, modify, and disassemble packets as they move data down the sending stack, across the network, and back up the OSI stack of the receiving computer. An IP packet has the following components:

- A source address specifying the sending computer
- A destination address specifying where the packet is being sent
- Instructions that tell the computer how to pass the data along
- Reassembly information (if the packet is part of a longer message)
- The data to be transmitted to the remote computer (often called the *packet payload*)
- Error-checking information to ensure that the data arrives intact

These components are assembled into slightly larger chunks; each packet contains three distinct parts (listed here and seen in Figure 1.12), and each part contains some of the components listed previously:

Header A typical header might include an identifier, source and destination addresses, and other options, depending on the protocol.

Data This is the actual data being sent.

Trailer The contents of the trailer (or even the existence of a trailer) vary among network types, but it typically includes a CRC. The CRC helps the network determine whether or not a packet has been damaged in transmission.

FIGURE 1.12 A packet consists of a header, the data, and a trailer.

Header
Data
Trailer

Protocols and Binding

Many different protocol stacks can perform network functions, and many different types of network interface cards can be installed in a computer. A computer may have more than one card, and a computer may use more than one protocol stack at the same time.

The *binding* process is what links the protocol stack to the network device driver for the network interface adapter. Several protocols can be bound to the same card; for instance, both TCP/IP and AppleTalk can be bound to the same Ethernet adapter. In addition, one computer with several interface adapters—for instance, a server that must be able to communicate with both a local area network and a network backbone—can have the same protocol bound to two or more network cards.

The binding process can be used throughout the OSI layers to link one protocol stack to another. The device driver (which implements the Data-Link layer) is bound to the network interface card (which implements the Physical layer). TCP/IP can be bound to the device driver, and the NWLink Session layer can be bound to the device driver.

Bindings are particularly important to Windows Server 2003 because you'll often want to change the bindings so that protocols you don't need on a particular network aren't bound to some network adapters. For example, it's very common to unbind the NWLink protocol from the network card connected to a web server's Internet connection.

Determining Connections

There are two ways that communication between computers can be arranged: using connectionless protocols and using connection-oriented protocols. It's important to understand the differences between them because different Windows Server 2003 services use both types.

Connectionless Protocols

It might seem odd to talk about a connectionless protocol for networks, but you use at least two of them just about every day: radio and television. Connectionless systems assume that all data will get through, so the protocol doesn't guarantee delivery or correct packet ordering. Think of shouting a message out of your window to someone walking by outside—there's no guarantee that they'll hear you, but it's quick and easy. These optimistic assumptions mean that there's no protocol overhead spent on these activities, so connectionless protocols tend to be fast. The *User Datagram Protocol (UDP)*, which is part of the IP protocol suite, is an example of a connectionless Internet transport protocol. In fact, IP itself is connectionless, relying on upper-layer protocols such as TCP to provide the connection.

Connection-Oriented Protocols

Connection-oriented systems work more like your telephone—you have to dial a number and establish a connection to the other end before you can send a message. Connection-oriented protocols pessimistically assume that some data will be lost or disordered in most transmissions. They guarantee that transmitted data will reach its destination in the proper sequence and that all data will get through. To accomplish this, connection-oriented protocols that also are considered *reliable* retain the transmitted data and negotiate for a retransmission when needed. Once all the needed data has arrived at the remote end, it can be reassembled into its proper sequence and passed to the higher-level protocols. This means that any application can depend on a connection-oriented transport to reliably deliver data exactly as it was transmitted. Transmission Control Protocol (TCP) is an example of a reliable connection-oriented Internet protocol. Frame Relay is an example of an *unreliable* connection-oriented protocol.

Unreliable does not imply undependable, just that it does not support retransmission of lost or errored data. DNS, for example, uses UDP, a connectionless protocol.

For local area systems where data isn't likely to be dropped, it makes sense to push serialization and guaranteed delivery up to higher-level protocols that are less efficient because they won't be used often anyway. But in wide area networks like the Internet, it would simply take too much time for higher-level protocols to sort out what data had been sent and what was missing, so the transport protocol simply takes measures to guarantee that all the data gets through in order.

Network Protocols and Windows Server 2003

So far, you've been reading a lot of abstract material that might not seem pertinent to Windows Server 2003. Now we'll show you the network protocols included with Windows Server 2003 and how each fits into the models you've read about up to this point.

There are a number of protocol stacks used in the world's networks today. Besides NetWare, AppleTalk, NetBIOS, and TCP/IP, there are a bunch of specialty protocols like IBM's Systems Network Architecture (SNA), Digital's (now HP/Compaq's) DECnet, and others. Even though these protocols actually work at different levels of the OSI model, they fall neatly into three distinct groups, as seen in the following list and in Figure 1.13:

- Application protocols provide for application-to-application interaction and data exchange.
- Transport protocols establish communication sessions between computers.
- Network protocols handle issues such as routing and addressing information, error checking, and retransmission requests.

Microsoft networking products come with three network transports—NWLink IPX/SPX, AppleTalk, and TCP/IP—and each is intended for networks of different sizes with different requirements. Each network transport has different strengths and weaknesses. *NWLink* is intended for medium-sized networks (in a single facility, perhaps) or for networks that require access to Novell NetWare file servers. AppleTalk's primary use is interoperating with Macintosh computers (a topic that's too specialized to discuss further here). *TCP/IP* is a complex transport sufficient for globe-spanning networks such as the Internet, and Microsoft is doing everything possible to position TCP/IP as a one-size-fits-all network protocol. TCP/IP is required to use Active Directory and is the default protocol for Windows Server 2003.

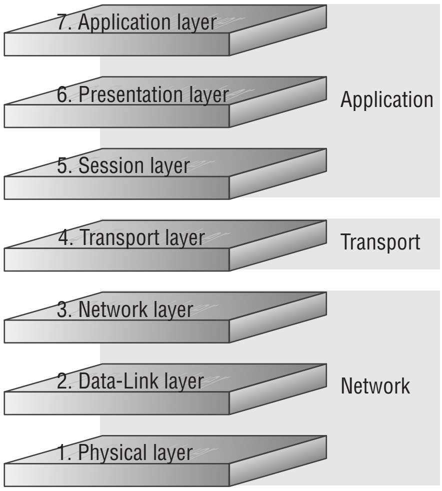
NOTE

Windows Server 2003 does not include support for the now defunct NetBEUI protocol. NetBEUI was not routable and Microsoft deemed the protocol unsuitable for enterprise-scale networks.

NWLink

NWLink IPX/SPX is Microsoft's implementation of Novell's IPX/SPX protocol stack, which is used in Novell NetWare. In fact, it's fair to say that NWLink IPX/SPX is nothing more than IPX for Windows.

FIGURE 1.13 The OSI protocol stack can be simplified by grouping its layers into three new categories.



NWLink IPX/SPX is included with Windows Server 2003 primarily to allow Windows Server 2003 to interconnect with legacy Novell NetWare servers and clients. Microsoft clients and servers can then be added to existing network installations, over time easing the migration between platforms and obviating the need for a complete cutover from one networking standard to another.

The advantages of NWLink IPX/SPX include the following:

- It's easy to set up and manage.
- It's routable.
- It's easy to connect to installed NetWare servers and clients.

However, NWLink IPX/SPX has some disadvantages:

- With NWLink IPX/SPX, it is difficult to exchange traffic with other organizations.
- It has limited support in Windows Server 2003.
- It doesn't support standard network management protocols.

Truly large networks (networks that connect many organizations) may find that NWLink IPX/SPX is difficult to use because there is no effective central IPX addressing scheme—as there is with TCP/IP—to ensure that two networks don't use the same address numbers. IPX doesn't support the wide range of network management tools available for TCP/IP.

TCP/IP

TCP/IP is actually two sets of protocols bundled together: The *Transmission Control Protocol (TCP)* and the *Internet Protocol (IP)*. TCP/IP, and a suite of related protocols, were developed by the Department of Defense's Advanced Research Projects Agency (ARPA, or later DARPA) beginning in 1969. The original goal was to develop network protocols that were robust enough to route communications around damage caused by nuclear war. That design goal was never tested, but some aspects of that design have led to the redundant, distributed whole we call the Internet.

IP is by far the most widely used protocol for interconnecting computers, and it is the protocol of the Internet. This is because, although ARPA originally created IP to connect military networks together, it provided the protocol standards to government agencies and universities free of charge. The academic world leapt at the chance to use a robust protocol to interconnect their networks, and the Internet was born. Many organizations and individuals collaborated to create higher-level protocols for everything from newsgroups, mail transfer, and file transfer to printing, remote booting, and even document browsing.

NOTE

Although you'll see it commonly referred to as TCP/IP in Windows and throughout this book, realize that TCP/IP really means the TCP/IP or IP protocol suite, and not necessarily TCP as the Transport layer protocol. UDP is used everywhere, thus making it sort of a misnomer to say TCP/IP while ignoring UDP/IP.

IP is currently the protocol of choice for most networks because of its rapid and widespread adoption. IP is used for networks that span more than one metropolitan area or to connect to (or over) the Internet.

IP has some significant advantages:

- Broad connectivity among all types of computers and servers, including direct access to the Internet
- Strong support for routing, using a number of flexible routing protocols (see Chapter 9 for more on these protocols)
- Support for advanced name and address resolution services (which will be covered in more depth later in this book): the Domain Name System (DNS), the Dynamic Host Configuration Protocol (DHCP), and the Windows Internet Name Service (WINS)
- Support for a wide variety of Internet-standard protocols, including protocols for mail transport, web browsing, and file and print services
- Centralized network number and name assignment, which facilitates internetworking between organizations

IP has some disadvantages:

- It's harder to set up than IPX.
- Its routing and connectivity features impose relatively high overhead.
- It's slower than IPX.

Even given these disadvantages, it's the core protocol that Windows Server 2003 depends on for all its network services. In fact, most of this book focuses on TCP/IP and related services.

TCP (and UDP) relies on port numbers assigned by the Internet Assigned Numbers Authority (IANA) to forward packets to the appropriate application process. Port numbers are 16-bit integers that are part of a message header and identify the application software process that the packet should be associated with.

For example, let's say that a client has a copy of Internet Explorer and a copy of Outlook Express open at the same time. Both applications are sending TCP requests across the Internet to retrieve web pages and e-mail, respectively. How does the computer know which return packets to forward to Internet Explorer and which packets to forward to Outlook Express? When making a connection, the client chooses a source port for the communication that is usually in the range from 1024 to 65535 (it could be in the range of 1 to 65535). This source port then communicates with a destination port of 80 or 110 on the server side. Every packet destined for Internet Explorer has a source port number of 80 in the header, and every packet destined for Outlook Express has a source port number of 110 in the header.

Table 1.1 contains a list of the well-known port numbers you might need to know for the exam. You can also visit `www.iana.org` to get the most current full list of port numbers. Being able to determine from memory the ports to allow or block specific protocols in a firewall, for example, is an asset. Be aware that allowing only port 80, for instance, does not ensure that all web traffic will be allowed. You must also allow port 443 for certain secure web traffic.

TABLE 1.1 Well-known Port Numbers

Port Number	Description
20	File Transfer Protocol (FTP) data
21	File Transfer Protocol (FTP) control
23	Telnet
25	Simple Mail Transfer Protocol (SMTP)
53	Domain Name System (DNS)
80	Hypertext Transfer Protocol (HTTP), Web
88	Kerberos
110	Post Office Protocol v3 (POP3)
443	Secure HTTP (HTTPS)

Real World Scenario

Real World Scenario: Ports

Simply because the port is “well-known” doesn’t mean that a given service must run on it. It’s technically valid to run any service on any port, but doing so is usually a bad idea. For example, if you chose to run your web server on TCP port 25, clients would need to type in `www.example.com:25` in order to reach your website from most browsers.

Real World Scenario

Understanding the OSI Model and Troubleshooting

The company you work for has several regional offices spread around the country. Your job is to make sure the resources on the Windows Server 2003 network, which include manufacturing, inventory, and sales information, are available at all times. If the sales information from the regional offices isn’t collected and updated to the manufacturing and inventory programs, the company won’t be able to supply its customers effectively. The users of the network aren’t particularly interested in the technical nuts and bolts of the system, but they do care when the system is down.

At the same time, you’re studying for your MCSE and wondering how the abstract notions of the OSI model are relevant to your job. A support call comes in from a user who can’t connect to a printer on a Windows Server 2003 machine in another region where an executive management meeting is taking place. The user is down the hall from you, so you drop everything and run down to take a look.

With the OSI model fresh in mind, you approach the problem in terms of layers of functionality. You ping the address of your router, and it comes back fine. You now know that the Physical, Data-Link, and Network layers are working fine, which means that you have eliminated cable and basic protocol problems. Your browser also seems to work fine because you can reach random sites. When you ping the name of the Windows Server 2003 machine that hosts the printer, you get the “request timed out” message. But when you ping the IP address directly, the reply shows a healthy connection, implying that you have a name resolution problem. You connect to the printer using a Net Use command with the IP address and begin the task of looking at your WINS server.

By breaking down your troubleshooting tactics into the general OSI layers, you can get a better gauge of where the problem lies and which services to look at, depending on where in the OSI model the symptoms appear. Although the OSI model is fairly abstract, when it’s applied appropriately, it gives you a structure for thinking about your overall network and provides a framework for following methodical troubleshooting tactics.

Understanding IP Addressing

Understanding IP addressing is critical to understanding how IP works. An IP address is a numeric identifier assigned to each machine on a IP network. It designates the location of the device it is assigned to on the network. This type of address is a logical software address, not a physical hardware address hard-coded in the machine or network interface card.

In the following sections, you will see how IP addresses are used to uniquely identify every machine on a network.

NOTE We're going to assume you're comfortable with binary notation and math for the remainder of this discussion.

The Hierarchical IP Addressing Scheme

An IP address is made up of 32 bits of information. These bits are divided into four sections (sometimes called octets or quads) containing 1 byte (8 bits) each. There are three common methods for specifying an IP address:

- Dotted-decimal, as in 130.57.30.56
- Binary, as in 10000010.00111001.00011110.00111000
- Hexadecimal, as in 82 39 1E 38

All of these examples represent the same IP address.

The 32-bit IP address is a structured address, or *hierarchical address*, as opposed to a flat address, or nonhierarchical one. Although IP could have used either flat or hierarchical addressing, its designers chose hierarchical addressing—for a very good reason, as you will see.

What's the difference between these two types of addressing? A good example of a flat addressing scheme is a driver's license number. There's no partitioning to it; the range of legal numbers isn't broken up in any meaningful way (say, by county of residence or date of issuance). If this method had been used for IP addressing, every machine on the Internet would have needed a totally unique address, just as each driver's license number is unique. The good news about flat addressing is that it can handle a large number of addresses, namely 4.3 billion (a 32-bit address space with two possible values for each position—either 0 [zero] or 1 [one]—giving you 2^{32}, which equals approximately 4.3 billion). The bad news—and the reason why flat addressing isn't used in IP—relates to routing. If every address were totally unique, every router on the Internet would need to store the address of each and every other machine on the Internet. It would be fair to say that this would make efficient routing impossible, even if only a fraction of the possible addresses were used.

The solution to this dilemma is to use a hierarchical addressing scheme that breaks the address space up into ordered chunks. Telephone numbers are a great example of this type of addressing. The first section of a telephone number, the area code, designates a very large area; the area code is followed by the prefix, which narrows the scope to a local calling area. The final segment, the customer number, zooms in on the specific connection. By looking at a number like 256-233-*xxxx*, you can quickly determine that the number is located in the northern part of Alabama (area code 256) in the Athens/East Limestone area (the 233 exchange).

IP addressing works the same way. Instead of treating the entire 32 bits as a unique identifier, one part of the IP address is designated as the *network address* (or network ID) and the other part as a *node address* (or host ID), giving it a layered, hierarchical structure.

The network address uniquely identifies each network. Every machine on the same network shares that network address as part of its IP address, just as the address of every house on a street shares the same street name. In the IP address 130.57.30.56, for example, 130.57 is the network address.

The node address is assigned to, and uniquely identifies, each machine in a network, just as each house on the same street has a different house number. This part of the address must be unique because it identifies a particular machine—an individual, as opposed to a network. This number can also be referred to as a host address. In the sample IP address 130.57.30.56, *.30.56* is the node address. Together as the IP address, the network address and the node address uniquely identify a device within an internetwork.

The designers of the Internet decided to create classes of networks based on network size. For the small number of networks possessing a very large number of nodes, they created the Class A network. At the other extreme is the Class C network, reserved for the numerous networks with a small number of nodes. The class distinction for networks in between very large and very small is predictably called a Class B network. The default subdivision of an IP address into a network and node address is determined by the class designation of your network. However, Classless Inter-Domain Routing (CIDR) has effectively done away with these classful designations. You will still hear and should still know the meaning behind the classful designations of addresses because they are important to understanding IP addressing. However, when working with IP addressing in practice, CIDR is more important to know. Table 1.2 provides a summary of the three classes of networks, which will be described in more detail in the following sections.

TABLE 1.2 Network Address Classes

Class	Mask Bits	Leading Bit Pattern	Decimal Range of First Octet of IP Address	Assignable Networks	Maximum Nodes per Network
A	8	0	1–126	126	16,777,214
B	16	10	128–191	16,384	65,534
C	24	110	192–223	2,097,152	254

To ensure efficient routing, Internet designers defined a mandate for the leading bits section of the address for each different network class. For example, because a router knows that a Class A network address always starts with a 0, the router can quickly apply the default mask, if necessary, after reading only the first bit of the address. Table 1.2 illustrates how the leading bits of a network address are defined. When considering the subnet masking between network and host addresses, the number of bits to mask is important. For example, in a Class A network, 8 bits are masked, making the default subnet mask 255.0.0.0, while in a Class C, 24 bits are masked, making the default subnet mask 255.255.255.0.

Some IP addresses are reserved for special purposes and shouldn't be assigned to nodes by network administrators. Table 1.3 lists some of the reserved IP addresses. See RFC 3330 for others.

TABLE 1.3 Special Network Addresses

Address	Function
Entire IP address set to all 0s	Depending on the mask, this network (i.e., the network or subnet that you are currently a part of) or this host on this network
A routing table entry of all 0s with a mask of all 0s	Used as the default gateway entry. Any destination address masked by all 0s produces a match for the all 0s reference address. Because the mask has no 1s, this is the least desirable entry but will be used when no other match exists.
Network address 127	Reserved for loopback tests. Designates the local node and allows that node to send a test packet to itself without generating network traffic.
Node address of all 0s	Used when referencing a network without referring to any specific nodes on that network. Usually used in routing tables.
Node address of all 1s	Broadcast address for all nodes on the specified network, also known as a directed broadcast; for example, 128.2.255.255 means all nodes on the Class B network 128.2. Routing this broadcast is configurable on certain routers.
169.254.0.0 with a mask of 255.255.0.0	The "link local" block used for auto-configuration and communication between devices on a single link. Communication cannot occur across routers. Microsoft uses this block for Automatic Private IP Addressing (APIPA).
Entire IP address set to all 1s (same as 255.255.255.255)	Broadcast to all nodes on the current network; sometimes called a limited broadcast or an "all 1s broadcast." This broadcast is not routable.

10.0.0.0/8;
172.16.0.0 to 172.31.255.255;
192.168.0.0/16
	The private-use blocks for Classes A, B, and C. As noted in RFC 1918, the addresses in these blocks must never be allowed into the Internet, making them acceptable for simultaneous use behind NAT servers and non-Internet-connected internetworks.

In the following sections, we will look at the three different network types.

Class A Networks

In a Class A network, the first byte is the network address, and the three remaining bytes are used for the node addresses. The Class A format is `Network.Node.Node.Node`.

For example, in the IP address 49.22.102.70, 49 is the network address and *22.102.70* is the node address. Every machine on this particular network would have the distinctive network address of 49; within that network, though, you could have a large number of machines.

The length of a Class A network address is a byte, and the first bit of that byte is reserved, so 7 bits in the first byte remain for manipulation. That means that the maximum number of Class A networks that could be created is 128. Why? Each of the seven manipulatable bit positions can be either a 0 or a 1; this gives you a total of 2^7 positions: a total of 128. To complicate things further, it was also decided that the network address of all 0s (0000 0000) would be reserved. This means the actual number of usable Class A network addresses is 128 minus 1, or 127. There's actually another reserved Class A address too—127—which consists of a network address of 0 followed by all 1s (0111 1111). Because you start with 128 addresses and two are reserved, you're left with 126 possible Class A network addresses.

Each Class A network has 3 bytes (24 bit positions) for the node address of a machine, which means that there are 2^{24}—or 16,777,216—unique combinations. Therefore, there are precisely that many possible unique node addresses for each Class A network. Because addresses with the two patterns of all 0s and all 1s in the node bits are reserved, the actual maximum usable number of nodes for a Class A network is 2^{24} minus 2, which equals 16,777,214.

Class B Networks

In a Class B network, the first 2 bytes are assigned to the network address, and the remaining 2 bytes are used for node addresses. The format is `Network.Network.Node.Node`.

For example, in the IP address 130.57.30.56, the network address is 130.57 and the node address is 30.56.

The network address is 2 bytes, so there would be 2^{16} unique combinations. But the Internet designers decided that all Class B networks should start with the binary digits 10. This leaves 14 bit positions to manipulate; therefore, there are 16,384 (or 2^{14}) unique Class B networks.

This gives you an easy way to recognize Class B addresses. If the first 2 bits of the first byte can only be 10, that gives us a decimal range from 128 up to 191 in the first octet of the IP address. Remember that you can always easily recognize a Class B network by looking at its first byte—even though there are 16,384 different Class B networks. If the first octet in the address falls between 128 and 191, it is a Class B network, regardless of the value of the second octet.

A Class B network has 2 bytes to use for node addresses. This is 2^{16} minus the two patterns in the reserved-exclusive club (all 0s and all 1s in the node bits), for a total of 65,534 possible node addresses for each Class B network.

Class C Networks

The first 3 bytes of a Class C network are dedicated to the network portion of the address, with only 1 byte remaining for the node address. The format is `Network.Network.Network.Node`.

In the example IP address 198.21.74.102, the network address is 198.21.74 and the node address is *102*.

In a Class C network, the first three bit positions are always binary 110. The calculation is such: 3 bytes, or 24 bits, minus 3 reserved positions leaves 21 positions. There are therefore 2^{21} or 2,097,152 possible Class C networks.

The lead bit pattern of 110 equates to decimal 192 and runs through 223. Remembering our handy easy-recognition method, this means that (although there are a total of 2,097,152 possible Class C networks) you can always spot a Class C address if the first byte is between 192 and 223, inclusive, regardless of the values of the second and third bytes of the IP address.

Each unique Class C network has 1 byte to use for node addresses. This leads to 2^8, or 256, minus the two special patterns of all 0s and all 1s, for a total of 254 node addresses for each Class C network.

NOTE

Class D networks, used for multicasting only, use the address range 224.0.0.0 to 239.255.255.255 and are used, as in broadcasting, as destination addresses only. Class E networks (reserved for future use at this point) cover 240.0.0.0 to 255.255.255.255. Addresses in the Class E range are considered within the experimental range.

Subnetting a Network

If an organization is large and has lots of computers, or if its computers are geographically dispersed, it makes good sense to divide its colossal network into smaller ones connected by routers. These smaller networks are called *subnets*. The benefits to using subnets include the following:

Reduced network traffic We all appreciate less traffic of any kind, and so do networks. Without routers, packet traffic could choke the entire network. Most traffic will stay on the local network—only packets destined for other networks will pass through the router and over to another subnet. This traffic reduction also improves overall performance.

Simplified management It's easier to identify and isolate network problems in a group of smaller networks connected together than within one gigantic one.

The original designers of the IP protocol envisioned a small Internet with only mere tens of networks and hundreds of hosts. Their addressing scheme used a network address for each physical network. As you can imagine, this scheme and the unforeseen growth of the Internet created a few problems.

To name one, a single network address can be used to refer to multiple physical networks, but an organization can request individual network addresses for each one of its physical networks. If these requests were granted, there wouldn't be enough addresses to go around. Another problem relates to routers—if each router on the Internet needed to know about every physical network, routing tables would be impossibly huge. There would be an overwhelming amount of administrative overhead to maintain those tables, and the resulting physical overhead on the routers would be massive (CPU cycles, memory, disk space, and so on). Because routers exchange routing information with each other, an additional, related consequence is that a terrific overabundance of network traffic would result.

Although there's more than one way to approach this problem, the principal solution is the one that will be covered in this book—subnetting. As you might guess, subnetting is the process of carving a single IP network into smaller logical subnetworks. This trick is achieved by subdividing the host portion of an IP address to create something called a *subnet address*. The actual subdivision is accomplished through the use of a *subnet mask*—more on that later.

In the following sections, you will see exactly how to calculate and apply subnetting.

Implementing Subnetting

Before you can implement subnetting, you need to determine your current requirements and plan on how best to implement your subnet scheme. Follow these guidelines:

- Determine the number of required network IDs: one for each subnet and one for each WAN connection.
- Determine the number of required host IDs per subnet: one for each TCP/IP device, including, for instance, computers, network printers, and router interfaces.

Based on these two data points, create the following:

- One subnet mask for your entire network
- A unique subnet ID for each physical segment
- A range of host IDs for each unique subnet

An organization with a single network address can have a subnet address for each individual physical network. It's important to remember that each subnet is still part of the shared network address but it also has an additional identifier denoting its individual subnetwork number. This identifier is called a subnet address. For example, consider a hotel or office building. Say a hotel has 1000 rooms, with 75 rooms to a floor. You start at the first room on the first floor and number it 1. When you get to the first room on the second floor, you number it 76, and you would keep going until you reach room 1000. Now someone looking for room 521 would have to guess approximately which floor the room was on. If you were to "subnet" the hotel, you would identify the first room on the first floor with the number 101 (1 = Floor 1 and 01 = Room 1), the first room on the second floor with 201, and so on. The guest looking for room 521 would go to the fifth floor and look for room 21.

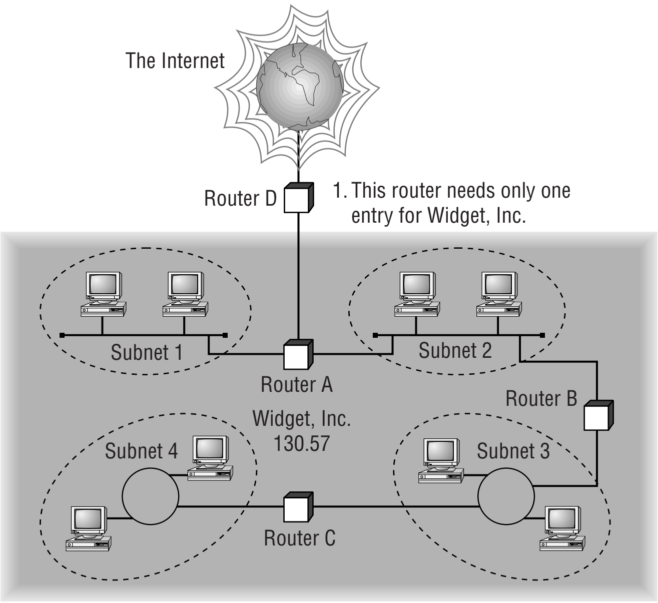
Subnetting solves several addressing problems. First, if an organization has several physical networks but only one IP network address, it can handle the situation by creating subnets. Next, because subnetting allows many physical networks to be grouped together, fewer entries in a routing table are required, notably reducing network overhead. Finally, these things combine to collectively yield greatly enhanced network efficiency.

Next, you will see how you can benefit from the features of subnetting in your network.

How to Implement Subnetting

Subnetting is implemented by assigning a subnet address to each machine on a given physical network. For example, in Figure 1.14, each machine on subnet 1 has a subnet address of 1.

FIGURE 1.14 A sample subnet



The default network portion of an IP address can't be altered without encroaching on another administrative domain's address space, unless you are assigned multiple consecutive classful addresses. In order to maximize efficient use of the assigned address space, machines on a particular network share the same network address. In Figure 1.14, you can see that all of Widget, Inc.'s machines have a network address of 130.57. That principle is constant. In subnetting, it's the host address that's manipulated; the network address doesn't change. The subnet address scheme takes a part of the host address and recycles it as a subnet address. Bit positions are stolen from the host address to be used for the subnet identifier. Figure 1.15 shows how an IP address can be given a subnet address.

Because the Widget, Inc. network is a Class B, the first 2 bytes specify the network address and are shared by all machines on the network—regardless of their particular subnet. Here, every machine's address on the subnet must have its third byte read 0000 0001. The fourth byte, the host address, is the unique number that identifies the actual host within that subnet. Figure 1.16 illustrates how a network address and a subnet address can be used together.

FIGURE 1.15 Network vs. host addresses

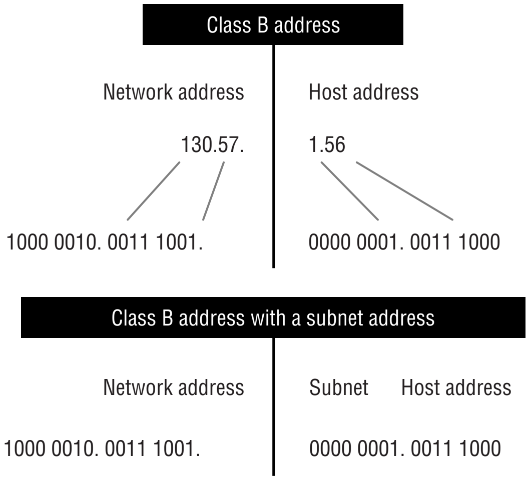
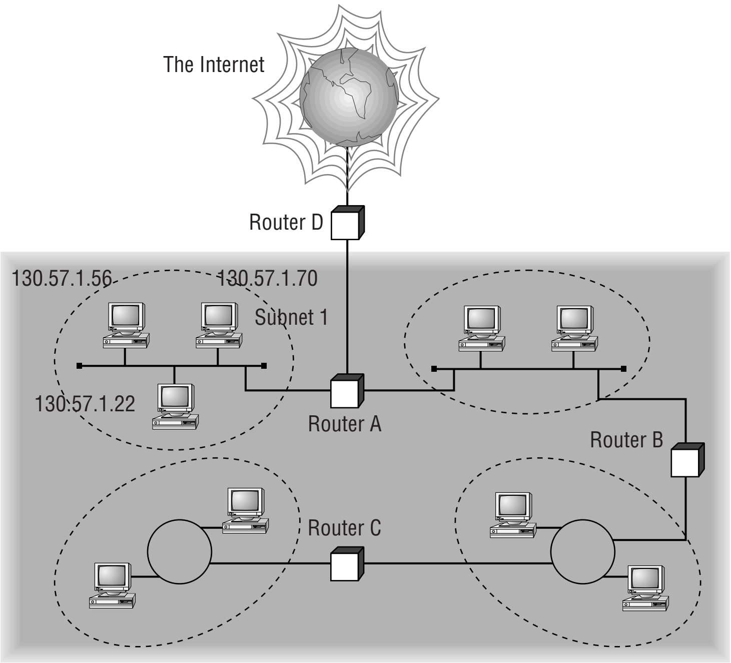


FIGURE 1.16 The network address and its subnet

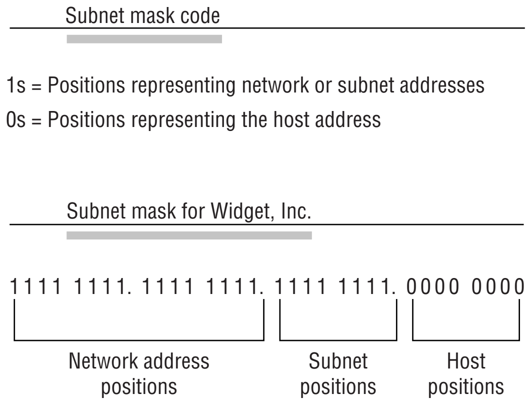


How to Use Subnet Masks

For the subnet address scheme to work, every machine on the network must know which part of the host address will be used as the network address. This is accomplished by assigning each machine a subnet mask.

The network administrator creates a 32-bit subnet mask comprising 1s and 0s. The 1s in the subnet mask represent the positions in the IP address that refer to the network and subnet addresses. The 0s represent the positions that refer to the host part of the address. This combination is illustrated in Figure 1.17.

FIGURE 1.17 The subnet mask revealed


Subnet mask code
1s = Positions representing network or subnet addresses
0s = Positions representing the host address
Subnet mask for Widget, Inc.
1111 1111. 1111 1111. 1111 1111. 0000 0000
Network address positions
Subnet positions
Host positions

In our Widget, Inc. example, the first two bytes of the subnet mask are 1s because Widget's network address is a Class B address, formatted as `Network.Network.Node.Node`. The third byte, normally assigned as part of the host address, is now used to represent the subnet address. Hence, those bit positions are represented with 1s in the subnet mask. The fourth byte is the only part in our example that represents the host address.

The subnet mask can also be expressed using the decimal equivalents of the binary patterns. The binary pattern of 1111 1111 is the same as decimal 255. Consequently, the subnet mask in our example can be denoted in two ways, as shown in Figure 1.18.

FIGURE 1.18 Different ways to represent the same mask

```
Subnet mask in binary:   1111 1111. 1111 1111. 1111 1111. 0000 0000
Subnet mask in decimal:     255     .    255    .    255    .     0
```

(The spaces in the above example are only for illustrative purposes.
The subnet mask in decimal would actually appear as 255.255.255.0.)

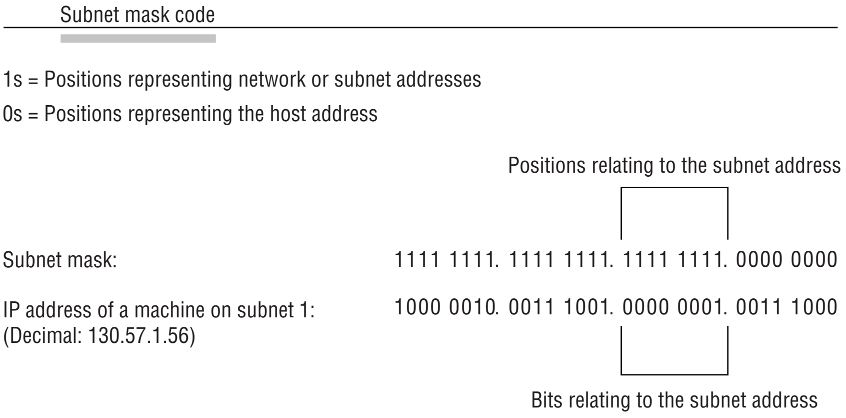
Not all networks need to have subnets and therefore don't need to use custom subnet masks. In this case, they are said to have a *default subnet mask*. This is basically the same as saying they don't have a subnet address. The default subnet masks for the different classes of networks are shown in Table 1.4.

TABLE 1.4 Special Network Addresses

Class	Format	Default Subnet Mask
A	`Network.Node.Node.Node`	255.0.0.0
B	`Network.Network.Node.Node`	255.255.0.0
C	`Network.Network.Network.Node`	255.255.255.0

Once the network administrator has created the subnet mask and assigned it to each machine, the IP software applies the subnet mask to the IP address to determine its subnet address. The word *mask* carries the implied meaning of "lens" in this case—the IP software looks at its IP address through the lens of its subnet mask to see its subnet address. An illustration of an IP address being viewed through a subnet mask is shown in Figure 1.19.

FIGURE 1.19 Applying the subnet mask


Subnet mask code
1s = Positions representing network or subnet addresses
0s = Positions representing the host address
Positions relating to the subnet address
Subnet mask:
1111 1111. 1111 1111. 1111 1111. 0000 0000
IP address of a machine on subnet 1:
(Decimal: 130.57.1.56)
1000 0010. 0011 1001. 0000 0001. 0011 1000
Bits relating to the subnet address

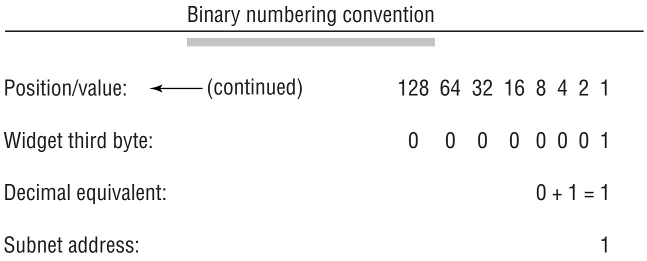
In this example, the IP software learns through the subnet mask that, instead of being part of the host address, the third byte of its IP address is now going to be used as a subnet address. The IP software then looks in its IP address at the bit positions that correspond to the mask, which are 0000 0001.

The final step is for the subnet bit values to be matched up with the binary numbering convention and converted to decimal. In the Widget, Inc. example, the binary-to-decimal conversion is simple, as illustrated in Figure 1.20.

By using the entire third byte of a Class B address as the subnet address, it is easy to set and determine the subnet address. For example, if Widget, Inc. wants to have a subnet 6, the third byte of all machines on that subnet will be 0000 0110 (decimal 6 in binary).

Using the entire third byte of a Class B network address for the subnet allows for a fair number of available subnet addresses. One byte dedicated to the subnet provides eight bit positions. Each position can be either a 1 or a 0, so the calculation is 2^8, or 256. Thus, Widget, Inc. can have up to 256 total subnetworks, each with up to 254 hosts.

FIGURE 1.20 Converting the subnet mask to decimal



Binary numbering convention

Position/value:	← (continued)	128 64 32 16 8 4 2 1
Widget third byte:		0 0 0 0 0 0 0 1
Decimal equivalent:		0 + 1 = 1
Subnet address:		1

Although RFC 950 prohibits the use of binary all 0s and all 1s as subnet addresses, almost all products actually permit this usage today. Microsoft's TCP/IP stack allows it, as does the software in most routers (provided you enable this feature, if it's not enabled by default). This gives you two additional subnets. However, you should not use a subnet of 0 (all 0s) unless all of the software on your network recognizes this convention.

How to Calculate the Number of Subnets

The formulas for calculating the maximum number of subnets and the maximum number of hosts per subnet are as follows:

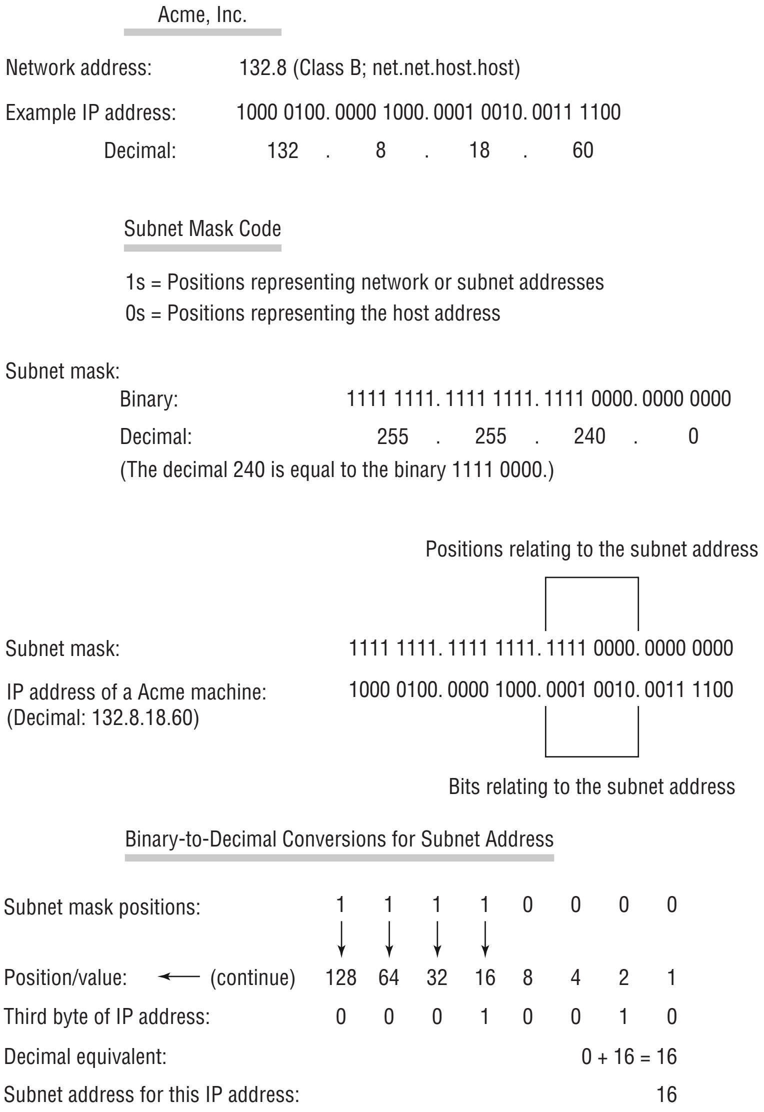
- 2x number of masked bits in subnet mask = maximum number of subnets
- 2*x* number of unmasked bits in subnet mask – 2 = maximum number of hosts per subnet

In the formulas, *masked* refers to bit positions of 1, and *unmasked* refers to positions of 0. The downside to using an entire byte of a node address as your subnet address is that you reduce the possible number of node addresses on each subnet. As explained earlier, without a subnet, a Class B address has 65,534 unique combinations of 1s and 0s that can be used for node addresses. The question is, why would you ever want 65,534 hosts on a single physical network? The trade-off is acceptable to most who ask themselves this question.

If you use an entire byte of the node address for a subnet, you then have only 1 byte for the host addresses, leaving only 254 possible host addresses. If any of your subnets will be populated with more than 254 machines, you have a problem. To solve it, you would then need to shorten the subnet mask, thereby lengthening the number of host bits and increasing the number of host addresses; this gives you more available host addresses on each subnet. A side effect of this solution is that it shrinks the number of possible subnets.

Figure 1.21 shows an example of using a smaller subnet address. A company called Acme, Inc. expects to need a maximum of 14 subnets. In this case, Acme does not need to take an entire byte from the host address for the subnet address. To get its 14 different subnet addresses, it needs to snatch only 4 bits from the host address ($2^4 = 16$). The host portion of the address has 12 usable bits remaining ($2^{12} - 2 = 4094$). Each of Acme's 16 subnets could then potentially have a total of 4094 host addresses; 4094 machines on each subnet should be plenty.

FIGURE 1.21 An example of a smaller subnet address



Acme, Inc.

Network address: 132.8 (Class B; net.net.host.host)

Example IP address: 1000 0100. 0000 1000. 0001 0010. 0011 1100

Decimal: 132 . 8 . 18 . 60

Subnet Mask Code

1s = Positions representing network or subnet addresses
0s = Positions representing the host address

Subnet mask:

Binary: 1111 1111. 1111 1111. 1111 0000. 0000 0000

Decimal: 255 . 255 . 240 . 0

(The decimal 240 is equal to the binary 1111 0000.)

Subnet mask: 1111 1111. 1111 1111. 1111 0000. 0000 0000

IP address of a Acme machine: 1000 0100. 0000 1000. 0001 0010. 0011 1100
(Decimal: 132.8.18.60)

Binary-to-Decimal Conversions for Subnet Address

Subnet mask positions:	1	1	1	1	0	0	0	0
	↓	↓	↓	↓				
Position/value: ⟵ (continue)	128	64	32	16	8	4	2	1
Third byte of IP address:	0	0	0	1	0	0	1	0
Decimal equivalent:						0 + 16 = 16		
Subnet address for this IP address:								16

Applying Subnetting

Sometimes subnetting can be confusing. It can be quite difficult to remember all those numbers. You can step back a minute and take a look at the primary classes of networks and how to subnet each one. You'd start with Class C because it uses only 8 bits for the node address, so it's the easiest to calculate. In the following sections, we will look at how to subnet the various types of networks.

Class C

If you recall, a Class C network uses the first 3 bytes (24 bits) to define the network address. This leaves you 1 byte (8 bits) with which to address hosts. So, if you want to create subnets, your options are limited because of the small number of bits left available.

If you break down your subnets into chunks smaller than the default Class C, then figuring out the subnet mask, network number, broadcast address, and router address can be kind of confusing. To build a sturdy base for subnetting, study and understand the following techniques for determining these special values for each subnet, but learn and use the more efficient technique presented later in this chapter in the section "Quickly Identifying Subnet Characteristics." Table 1.5 summarizes how you can break a Class C network down into one, two, four, or eight smaller subnets, with the subnet masks, network numbers, broadcast addresses, and router addresses. The first 3 bytes have simply been designated x.y.z. (Note that the table assumes you can use the all-0s and all-1s subnets, too.)

TABLE 1.5 Class C Subnets

Number of Desired Subnets	Subnet Mask	Network Number	Router Address	Broadcast Address	Remaining Number of IP Addresses
1	255.255.255.0	x.y.z.0	x.y.z.1	x.y.z.255	253
2	255.255.255.128	x.y.z.0	x.y.z.1	x.y.z.127	125
	255.255.255.128	x.y.z.128	x.y.z.129	x.y.z.255	125
4	255.255.255.192	x.y.z.0	x.y.z.1	x.y.z.63	61
	255.255.255.192	x.y.z.64	x.y.z.65	x.y.z.127	61
	255.255.255.192	x.y.z.128	x.y.z.129	x.y.z.191	61
	255.255.255.192	x.y.z.192	x.y.z.193	x.y.z.255	61
8	255.255.255.224	x.y.z.0	x.y.z.1	x.y.z.31	29

TABLE 1.5 Class C Subnets *(continued)*

Number of Desired Subnets	Subnet Mask	Network Number	Router Address	Broadcast Address	Remaining Number of IP Addresses
	255.255.255.224	x.y.z.32	x.y.z.33	x.y.z.63	29
	255.255.255.224	x.y.z.64	x.y.z.65	x.y.z.95	29
	255.255.255.224	x.y.z.96	x.y.z.97	x.y.z.127	29
	255.255.255.224	x.y.z.128	x.y.z.129	x.y.z.159	29
	255.255.255.224	x.y.z.160	x.y.z.161	x.y.z.191	29
	255.255.255.224	x.y.z.192	x.y.z.193	x.y.z.223	29
	255.255.255.224	x.y.z.224	x.y.z.225	x.y.z.255	29

For example, suppose you want to chop up a Class C network, 200.211.192.x, into two subnets. As you can see in the table, you'd use a subnet mask of 255.255.255.128 for each subnet. The first subnet would have network number 200.211.192.0, router address 200.211.192.1, and broadcast address 200.211.192.127. You could assign IP addresses 200.211.192.2 through 200.211.192.126—that's 125 additional different IP addresses. (Notice that heavily subnetting a network results in the loss of a progressively greater percentage of addresses to the network number, broadcast address, and router address.) The second subnet would have network number 200.211.192.128, router address 200.211.192.129, and broadcast address 200.211.192.255.

When subnetting a Class C network using the method in Table 1.5, if you use the $2x - 2$ calculation, the subnet 128 in the table doesn't make sense. It turns out that there's a legitimate and popular reason to do it this way, however:

1. Remember that using subnet zero is not allowed according to the RFCs, but by using it you can subnet your Class C network with a subnet mask of 128. This uses only 1 bit, and according to your calculator, $2^1 - 2 = 0$, giving you zero subnets.
2. By using routers that support subnet zero, you can assign 1–126 for hosts and 129–254 for hosts, as stated in the table. This saves a bunch of addresses! If you were to stick to the method defined by RFC standards, the best you could gain is a subnet mask of 192 (2 bits), which allows you only two subnets ($2^2 - 2 = 2$).

To determine the incremental value for the octet that has an interesting value (other than 0 or 255) in the subnet mask, subtract the interesting value from 256. If we again use the network 200.211.192.x and a mask of 255.255.255.192, our example yields the following equation: 256 – 192 = 64. So 64 is your incremental value in the interesting octet, the fourth octet. Why the fourth octet? Because that's the octet with the interesting value, 192, in the mask. The first subnet always has a 0 in the interesting or significant octet, making it 200.211.192.0, the same as the original non-subnetted network address.

To determine a second subnet number, add the incremental value to the 0 in the fourth octet of the first subnet. To determine a third subnet number, add the incremental value to the interesting or significant octet of the second subnet number. To determine a fourth subnet number, add the incremental value to the interesting octet of the third subnet number. Keep adding the incremental value in this fashion until you reach the actual subnet number. For example, 0 plus 64 equals 64, so your second subnet is 64. And 64 plus 64 is 128, so your third subnet is 128. And 128 plus 64 is 192, so your fourth subnet is 192. Because 192 is the subnet mask, this is your last subnet. Even if you tried to add 64 again, you come up with 256, an unusable octet value, which is always what you end up with when you've gone too far. This means your valid subnets are 0, 64, 128, and 192.

The numbers between the subnets are your valid hosts and broadcasts. For example, the following are valid hosts for two of the subnets in a Class C network with a subnet mask of 192:

- The valid hosts for subnet 64 are in the range 65–126, which gives you 62 hosts per subnet (using 127 as a host would mean your host bits would be all 1s). That's not allowed because the all-1s format is reserved as the broadcast address for that subnet.
- The valid hosts for subnet 128 are in the range 129–190, with a broadcast of 191.

As you can see, this solution wastes a few addresses: six more than not subnetting at all, to be exact. In a Class C network, this should not be hard to justify. The 255.255.255.128 subnet mask is an even better solution if you only need two subnets and expect to need close to 126 host addresses per subnet.

But what happens if you need eight subnets in your Class C network?

By using the calculation of 2x, where x is the number of subnet bits, you would need 3 subnet bits to get eight subnets ($2^3 = 8$). What are the valid subnets and what are the valid hosts of each subnet? Let's figure it out.

11100000 is 224 in binary and would be the interesting value in the fourth octet of the subnet mask. This must be the same on all workstations.

NOTE

You're likely to see test questions that ask you to identify the problem with a given configuration. If a workstation has the wrong subnet mask, the router could "think" the workstation is on a different subnet than it actually is. When that happens, the misguided router won't forward packets to the workstation in question. Similarly, if the mask is incorrectly specified in the workstation's configuration, that workstation will observe the mask and send packets to the default gateway when it shouldn't.

To figure out the valid subnets, subtract the interesting octet value from 256; 256 – 224 = 32, so 32 is your incremental value for the fourth octet. Of course, the 0 subnet is your first subnet, as always. The other subnets would be 32, 64, 96, 128, 160, 192, and 224. The valid hosts are the numbers between the subnet numbers, except the numbers that equal all 1s in the host bits. These numbers would be 31, 63, 95, 127, 159, 191, 223, and 255. Remember that using all 1s in the host bits is reserved for the broadcast address of each subnet.

The valid subnets, hosts, and broadcasts are as follows:

Subnet	Hosts	Broadcast
0	1–30	31
32	33–62	63
64	65–94	95
96	97–126	127
128	129–158	159
160	161–190	191
192	193–222	223
224	225–254	255

You can add one more bit to the subnet mask just for fun. You were using 3 bits, which gave you 224. By adding the next bit, the mask now becomes 240 (11110000).

By using 4 bits for the subnet mask, you get 14 subnets because $2^4 = 16$. This subnet mask also gives you only 4 bits for the host addresses, or $2^4 - 2 = 14$ hosts per subnet. As you can see, the amount of hosts per subnet gets reduced rather quickly for each host bit that gets reallocated for subnet use.

The first valid subnet for subnet 240 is 0, as always. Because 256 – 240 = 16, your remaining subnets are then 16, 32, 48, 64, 80, 96, 112, 128, 144, 160, 176, 192, 208, 224, and 240. Remember that the actual interesting octet value also represents the last valid subnet, so 240 is the last valid subnet number. The valid hosts are the numbers between the subnets, except for the numbers that are all 1s—the broadcast address for the subnet.

The following are valid subnets, hosts, and broadcasts:

Subnet	Hosts	Broadcast
0	1–14	15
16	17–30	31
32	33–46	47
48	49–62	63
64	65–78	79
80	81–94	95
96	97–110	111
112	113–126	127
128	129–142	143

Subnet	Hosts	Broadcast
144	145–158	159
160	161–174	175
176	177–190	191
192	193–206	207
208	209–222	223
224	225–238	239
240	241–254	255

Class B

Because a Class B network has 16 bits for host addresses, you have plenty of available bits to play with when figuring out a subnet mask. Remember that you have to start with the leftmost bit and work toward the right. For example, a Class B network would look like x.y.0.0, with the default mask of 255.255.0.0. Using the default mask would give you one network with 65,534 hosts.

The default mask in binary is 11111111.11111111.00000000.00000000. The 1s represent the corresponding network bits in the IP address, and the 0s represent the host bits. So when creating a subnet mask, the leftmost bit(s) will be borrowed from the host bits (0s turned into 1s) to become the subnet mask. You use the remaining bits that are still set to 0 for host addresses.

If you use only 1 bit, you have a mask of 255.255.128.0. If you use 2 bits, you have a mask of 255.255.192.0, or 11111111.11111111.11000000.00000000.

As with subnetting a Class C address, you now have three parts of the IP address: the network address, the subnet address, and the host address. A 192 mask is figured out the same way it's figured out when it appears in the fourth octet of a Class C subnet mask, but this time you'll end up with a lot more hosts per subnet.

There are four subnets because $2^2 = 4$. The valid third-octet values for the subnets are 0, 64, 128, and 192 (256 – 192 = 64, so the incremental value of the third octet is 64). However, there are 14 bits (0s) left over for host addressing. This gives you 16,382 hosts per subnet ($2^{14} - 2 = 16,382$).

The valid subnets and hosts are as follows:

Subnet	Hosts	Broadcast
X.Y.0.0	X.Y.0.1 through X.Y. 63.254	X.Y.63.255
X.Y.64.0	X.Y.64.1 through X.Y.127.254	X.Y.127.255
X.Y.128.0	X.Y.128.1 through X.Y.191.254	X.Y.191.255
X.Y.192.0	X.Y.192.1 through X.Y.255.254	X.Y.255.255

You can add another bit to the subnet mask, making it 11111111.11111111.11100000 .00000000 or 255.255.224.0. There are eight subnets ($2^3 = 8$). The valid subnets are 0, 32, 64, 96, 128, 160, 192, and 224 (256 – 224 = 32). The subnets, valid hosts, and broadcasts are listed here:

Subnet	Hosts	Broadcast
X.Y.0.0	X.Y.0.1 through X.Y.31.254	X.Y.31.255
X.Y.32.0	X.Y.32.1 through X.Y.63.254	X.Y.63.255
X.Y.64.0	X.Y.64.1 through X.Y.95.254	X.Y.95.255
X.Y.96.0	X.Y.96.1 through X.Y.127.254	X.Y.127.255
X.Y.128.0	X.Y.128.1 through X.Y.159.254	X.Y.159.255
X.Y.160.0	X.Y.160.1 through X.Y.191.254	X.Y.191.255
X.Y.192.0	X.Y.192.1 through X.Y.223.254	X.Y.223.255
X.Y.224.0	X.Y.224.1 through X.Y.255.254	X.Y.255.255

Therefore, if you use a 255.255.224.0 subnet mask, you can create eight subnets, each with 8190 hosts.

You can add a few more bits to the subnet mask and see what happens. If you use 9 bits for the mask, it gives you 512 subnets (2^9). With only 7 bits for hosts, you still have 126 hosts per subnet ($2^7 - 2 = 126$). The mask looks like this:

11111111.11111111.11111111.10000000 or 255.255.255.128

You could add even more bits and see what you get. If you use 14 bits for the subnet mask, you get 16,384 subnets (2^{14}), but this gives you only two hosts per subnet ($2^2 - 2 = 2$). The subnet mask would look like this:

11111111.11111111.11111111.11111100 or 255.255.255.252

You may be wondering why you would ever use a 14-bit subnet mask with a Class B address. This approach is actually very common. Think about having a Class B network and using a subnet mask of 255.255.255.0. You'd have 256 subnets and 254 hosts per subnet. Imagine also that you are an ISP and have a network with many WAN links, a different one between you and each customer. Typically, you'd have a direct connection between each site. Each of these links must be on its own subnet or network. There will be two hosts on these subnets—one address for each router port. If you used the mask described earlier (255.255.255.0), you would waste 252 host addresses per subnet. Using the 255.255.255.252 subnet mask, you have more subnets available, which means more customers—each subnet with only two hosts, which is the maximum allowed on a point-to-point circuit.

You can use this approach only if you are running a routing algorithm like Enhanced Interior Gateway Routing Protocol (EIGRP) or Open Shortest Path First (OSPF), which we will talk about later in this book. These routing protocols allow what is called Variable Length Subnet Masking (VLSM). VLSM allows you to run the 255.255.255.252 subnet mask on your interfaces to the WANs and run 255.255.255.0 on your router interfaces in your LAN, using the same classful network address for all subnets. It works because routing protocols like EIGRP and OSPF transmit the subnet mask information in the update packets that they send to the other routers. Classful routing protocols, such as RIP version 1, don't transmit the subnet mask and therefore cannot employ VLSM.

Class A

Class A networks have even more bits available. A default Class A network subnet mask is only 8 bits, or 255.0.0.0, giving you a whopping 24 bits for hosts to play with.

If you use a mask of 11111111.1111111.00000000.00000000, or 255.255.0.0, you'll have 8 bits for subnets, or 256 subnets (2^8). This leaves 16 bits for hosts, or 65,534 hosts per subnet ($2^{16} – 2 = 65534$). Instead, you could split the 24 bits evenly between subnets and hosts, giving each one 12 bits. The mask would look like this: 11111111.11111111.11110000.00000000, or 255.255.240.0. How many valid subnets and hosts would you have?

The answer is 4096 subnets each with 4094 hosts ($2^{12} – 2 = 4094$). Knowing which hosts and subnets are valid is a lot more complicated than it was for either Class B or C networks.

The second octet will be somewhere between 0 and 255. However, the third octet you will need to figure out. Because the third octet has a 240 mask, you'll get 16 (256 – 240 = 16) as your incremental value in the third octet. The third octet must start with 0 for the first subnet, the second subnet will have 16 in the third octet, and so on. This means that your valid subnets are as follows (not in order):

Subnet	Hosts	Broadcast
X.0-255.0.0	X.0-255.0.1 through X.0-255.15.254	X.0-255.15.255
X.0-255.16.0	X.0-255.16.1 through X.0-255.31.254	X.0-255.31.255
X.0-255.32.0	X.0-255.32.1 through X.0-255.47.254	X.0-255.47.255
X.0-255.48.0	X.0-255.48.1 through X.0-255.63.254	X.0-255.63.255

They go on in this way for the remaining third-octet values through 224 in the subnet column.

TIP

Microsoft uses an alternate way to write address ranges. For example, an address of 131.107.2.0 with a subnet mask of 255.255.255.0 is listed as 131.107.2.0/24 because the subnet mask contains 24 1s. An address listed as 141.10.32.0/19 would have a subnet mask of 255.255.224.0, or 19 1s (default subnet mask for a Class B plus 3 bits). This is the nomenclature used in all Microsoft exams and is referred to as Classless Inter-Domain Routing (CIDR) notation.

Quickly Identifying Subnet Characteristics

Given the limited time you have to dispatch questions in a structured environment, every shortcut to coming up with the correct answer is a plus. There is a method using CIDR notation that, once learned, shaves minutes, sometimes, off of the completion of a single question. You have been exposed to the underlying binary technology at the heart of subnetting. Now, consider the following shortcut shown with each address class that allows you to come up with the correct answer without working in binary.

Class C

Consider the host address 192.168.10.50/27. The following steps flesh out the details of the subnet of which this address is a member:

1. Obtain the CIDR-notation prefix length for the address. This step is as simple as converting the dotted-decimal mask to CIDR notation. In this case, the CIDR notation is part of the question, but /27 would have been the end result of a mask of 255.255.255.224, as well. Practice converting between these notations until it becomes second nature.
2. Using the multiple of 8 that is greater than or equal to the prefix length, compute the interesting octet, the octet that increases from one subnet to the next in increments other than 1 or 0. Divide this multiple by 8, resulting in a number that corresponds to the octet that is interesting. In this case, the next multiple of 8 greater than 27 is 32. Dividing 32 by 8 produces the number 4, pointing to the fourth octet as the interesting one.
3. To compute the incremental value in the octet that you just labeled interesting, subtract the prefix length from the next higher multiple of 8, which in this case is 32. The result is the value 32 – 27 = 5. Raise 2 to the computed value, 5 in this case, and the result, 2^5 = 32, is the incremental value of the interesting octet, the fourth, in this case.
4. Recall the value of the interesting octet from the original address in question, 50 in this case. Starting with 0, increment by the incremental value until the value is exceeded. The values, then, are 0, 32, 64, and so on.
5. The subnet in question extends from the increment that is immediately less than or equal to the address's interesting octet value to the address immediately before the next increment. In this example, the subnet that 192.168.10.50/27 belongs to is 192.168.10.32, and this subnet extends to the address immediately preceding 192.168.10.64, which is the broadcast address, 192.168.10.63, of the subnet in question. Note that if the interesting octet is not the fourth octet, all octets after the interesting octet must be set to 0 for the subnet address.
6. The usable range of addresses for the subnet in question extends from one higher than the subnet address to one less than the broadcast address, making the range for the subnet in question 192.168.10.33 through 192.168.10.62. As you can see, 192.168.10.50/27 definitely falls within the subnet 192.168.10.32/27.

Class B

Using the preceding steps, find the subnet in which the address 172.16.76.12 with a mask of 255.255.240.0 belongs:

1. The corresponding CIDR notation prefix length is /20.
2. The next multiple of 8 that is greater than 20 is 24. 24 ÷ 8 = 3. Octet 3 is interesting.

3. 24 – 20 = 4, so the incremental value is 2^4 = 16.
4. The increments in the third octet are 0, 16, 32, 48, 64, 80, and so on.
5. The increments of 64 and 80 bracket the address's third-octet value of 76, making the subnet in question 172.16.64.0, after setting all octets after the interesting octet to 0. This subnet's broadcast address is 172.16.79.255, which comes right before the next subnet address of 172.16.80.0.
6. The usable address range, then, extends from 172.16.64.1 through 172.16.79.254.

Class A

Try it one more time with 10.6.127.255/14. Combine some of the related steps, if possible:

1. The prefix length is given and is 14. When given this much information up front, simply combine steps 1 and 2. The next multiple of 8 that is greater than or equal to 14 is 16. 16 ÷ 8 = 2, so the second octet is interesting.
2. 16 – 14 = 2, so the incremental value in the second octet is 2^2 = 4.
3. If you are able to combine steps 4 and 5, that will speed up the process. The corresponding second-octet value of 6 in the address falls between the 4 and 8 increments. This means that the subnet in question is 10.4.0.0 (setting octets after the second one to 0) and its broadcast address is 10.7.255.255.
4. The usable address range is from 10.4.0.1 through 10.7.255.254.

Determining Quantities of Subnets and Hosts

This general technique also is useful when trying to determine the total number of subnets and hosts produced by a given mask with respect to the default mask of the class of address in question. Consider, for example, the Class B address 172.16.0.0 with a subnet mask of 255.255.254.0.

This is a prefix length of 23 bits. When you subtract the default prefix length for a Class B address of 16 from 23, you get the value 7. Raising 2 to the 7th power results in the value 128, which is the number of subnets you get when you subnet a Class B address with the 255.255.254.0 mask.

Determining the number of hosts available in each of these 128 subnets is rather simple because you always subtract the prefix length the subnet mask produces, 23 in this example, from the value 32, which represents the total number of bits in any IP address. The difference, 9, represents the remaining number of 0s, or host bits, in the subnet mask. Raising 2 to this value produces the total possible number of host IDs per subnet this subnet mask allows. Remembering to subtract 2 from this result to account for the subnet and broadcast addresses for each subnet gives you the actual number of usable host IDs per subnet. In this case, this value is 2^9 – 2 = 510.

Repeated practice with this technique will reduce your time to obtain the desired answer to mere seconds, leaving more time for the more challenging tasks in each question. You have a wealth of examples and scenarios in this chapter, as well as in the review questions, on which to try out your technique, not to mention alternative methods with which to check your work and build your faith in this faster method.

Summary

Some of the important topics covered in this chapter included how the OSI networking model is organized into seven layers including Physical, Data-Link, Network, Transport, Session, Presentation, and Application and a description of each level of the OSI stack. You also learned that Windows Server 2003 includes support for AppleTalk, NWLink, and TCP/IP. TCP/IP is the primary protocol in use today, and Microsoft encourages you to use TCP/IP exclusively, if possible. Finally, you also learned that the 32-bit IP address is a structured and hierarchical address that is used to uniquely identify every machine on a network. You learned how to determine available IP addresses and implement subnetting.

Exam Essentials

Understand what subnetting is and when to use it. If an organization is large and has many computers, or if its computers are geographically dispersed, it's sensible to divide its large network into smaller ones connected by routers. These smaller networks are called subnets. Subnetting is the process of carving a single IP network into smaller, logical subnetworks.

Understand subnet masks. For the subnet address scheme to work, every machine on the network must know which part of the host address will be used as the subnet address. The network administrator creates a 32-bit subnet mask consisting of 1s and 0s. The 1s in the subnet mask represent the positions that refer to the network or subnet addresses. The 0s represent the positions that refer to the host portion of the address.

Review Questions

1. You have a large IP routed network using the address 137.25.0.0; it is composed of 20 subnets, with a maximum of 300 hosts on each subnet. Your company continues on a merger and acquisitions spree, and your manager has told you to prepare for an increase to 50 subnets, with some of them containing more than 600 hosts. Using the existing network address, which of the following subnet masks would work for that requirement from your manager?

   A. 255.255.252.0

   B. 255.255.254.0

   C. 255.255.248.0

   D. 255.255.240.0

2. You are brought into a small company that occupies two floors of a building that has had two separate networks for some time. The company now wants these two networks to share some information files such as documents, spreadsheets, and databases. You determine that one of the networks is a NetWare 3.x LAN and the other is a Windows NT peer-to-peer network running NetBEUI. The NetWare LAN has a printer that you want users on the NT network to be able to use. Other than any client software, what protocol will you have to install for the Windows NT workstations to be able to access the NetWare printer?

   A. NetBEUI

   B. TCP/IP

   C. AppleTalk

   D. NWLink

   E. DLC

3. The company you work for is growing dramatically via acquisitions of other companies. As the network administrator, you need to keep up with the changes because they affect the workstations and you need to support them. When you started, there were 15 locations connected via routers, and now there are 25. As new companies are acquired, they are migrated to Windows Server 2003 and brought into the same domain as another site. Management says that they are going to acquire at least 10 more companies in the next 2 years. The engineers have also told you that they are redesigning the company's Class B address into an IP addressing scheme that will support these requirements and that there will never be over 1000 network devices on any subnet. What will be the appropriate subnet mask to support this network when the changes are completed?

   A. 255.255.252.0

   B. 255.255.248.0

   C. 255.255.255.0

   D. 255.255.255.128

4. You work for a small printing company that has 75 workstations. Most of them run standard office applications like word processing, spreadsheet, and accounting programs. Fifteen of the workstations are constantly processing huge graphics files and then sending print jobs to industrial-size laser printers. The performance of the network has always been an issue, but you have never addressed it. You have now migrated your network to Windows XP and Windows Server 2003 and have decided to take advantage of the routing capability built into Windows Server 2003. You choose the appropriate server and place two NICs in the machine, but you realize that you have only one network address, 201.102.34.0, which you obtained years ago. How should you subnet this address to segment the bandwidth hogs from the rest of the network while giving everyone access to the entire network?

A. 255.255.255.192

B. 255.255.255.224

C. 255.255.255.252

D. 255.255.255.240

5. A packet is sent from one computer to another across a network. Various protocols move the packet down the OSI stack from the sending computer and up the OSI stack to the receiving computer. How do the protocols know where to send the packet?

A. Each packet has a trailer that contains source and destination addresses.

B. Each packet has a header that contains an alert signal and source and destination addresses.

C. The data portion of every packet stores all the source and destination information.

D. Special packets, called header packets, that contain only source and destination addresses are sent first. Every packet that follows the header packet is sent to the destination address contained in the header packet.

6. You have been engaged at a large automobile manufacturing organization to help company officials understand and alleviate their network traffic overutilization rates. After discussions with the network administrator, you discover that the organization was initially running only TCP/IP but it recently installed NetBEUI as well. After some investigation, you are told the reason for the dual protocols: The administrator was told that they were going to have to support several NetBIOS applications on the network. To permit this NetBIOS support, the administrator then directed several staff members to add the NetBEUI stack to the workstations and, in the bindings, to place NetBEUI first. Now the network is having performance problems. What mistake did this administrator make?

A. Because NetBEUI was placed at the top of the binding list, the workstations are trying to communicate through NetBEUI first, even though the resource to which they are trying to connect uses only TCP/IP.

B. Because NetBEUI was placed at the top of the binding list, NetBEUI is being used to communicate with the TCP/IP-based servers and is less efficient in communicating with a different protocol.

C. NetBEUI is unnecessary for a client's communication with a NetBIOS program.

D. Although TCP/IP needs NetBEUI in order to communicate with a NetBIOS program, NetBEUI needs to be bound directly to the TCP/IP stack so that they will work together properly.

7. The Integrated Network Computing company is a software development house that writes small utility programs for a wide range of networks. In addition to supporting its Windows Server 2003 network, you are responsible for verifying that some of the applications that are developed function properly. During these tests, you have to install transport protocols from other development houses that are used by various systems. You have worked out the issues surrounding the different protocols working on Windows Server 2003 by requiring the protocol developers to make sure their protocols are compliant with what standard?

A. ODI

B. DLC

C. NDIS

D. NetBIOS

8. You work for Carpathian Worldwide Enterprises, which has more than 50 administrative and manufacturing locations around the world. The size of these organizations varies greatly, with the number of computers per location ranging from 15 to slightly fewer than 1000. The sales operations use more than 1000 facilities, each of which contains 2 to 5 computers. Carpathian is also in merger talks with another large organization; if the merger materializes as planned, you will have to accommodate another 100 manufacturing and administrative locations, each with a maximum of 600 computers, as well as 2000 additional sales facilities. You don't have any numbers for the future growth of the company, but you are told to keep growth in mind. You decide to implement a private addressing plan for the entire organization. More than half of your routers don't support Variable Length Subnet Masking. What subnet masks would work for this situation? (Choose all that apply.)

A. 255.255.224.0

B. 255.255.240.0

C. 255.255.248.0

D. 255.255.252.0

E. 255.255.254.0

9. You administer a very large network that consists of Windows 2000 and XP Professional and Windows Server 2003 computers. You want to implement DNS, DHCP, and WINS, and every computer must have access to the Internet and services on non-Windows machines. You want to be able to configure the network from a central location. Which network protocol provides the ability to do all these things?

A. NetBEUI

B. NWLink

C. TCP

D. TCP/IP

10. You are the administrator for a Windows NT network that has been internally focused on basic file and print services. You have been charged with upgrading your network to Windows Server 2003 and also allowing the users of the network to find information on the Internet. Currently, the network is running NWLink because of routing needs between two locations and a lack of IP experience. You need to change the network protocol to TCP/IP to support Internet connectivity. What layers in the OSI model do you need to consider to allow the workstations to access the Internet for simple browsing? (Choose all that apply.)

A. Network layer

B. Application layer

C. Presentation layer

D. Transport layer

11. You have just been asked to troubleshoot intermittent communication problems on a fairly old network for a company that builds and repairs elevator motors. You have determined that the network is a straightforward thin-coax Ethernet Windows NT LAN running TCP/IP. The company wants to upgrade to Windows Server 2003, hoping that the now-stable platform will resolve the intermittent problems. You perform the upgrade; all goes smoothly, and initially everything seems to function properly. However, the intermittent problems show up again. What layer in the OSI model is the most likely place for the problems to be occurring?

A. Physical layer

B. Data-Link layer

C. Network layer

D. Transport layer

E. Session layer

12. You are working at a manufacturing company that occupies an entire city block. Management informs you that they have acquired another business on the other side of town that previously had been a supplier to your company. The Windows Server 2003 network that you have been supporting now needs to be connected to the new location through a router. You also have several NetBIOS applications that need to continue functioning properly. What protocols are available for you to use to ensure that these criteria are met? (Choose all that apply.)

A. NWLink

B. TCP/IP

C. XNS

D. NetBEUI

13. The company you work for manufactures handballs and has an Intel PC–based Windows Server 2003 network. To cut packaging costs, the management of the company has acquired a graphics arts company. Its network is entirely Macintosh based and is currently using AppleTalk as the protocol to communicate among workstations. You have to integrate the two networks so that they can easily share information. What protocols should you have on your network for communication among all the workstations on this network?

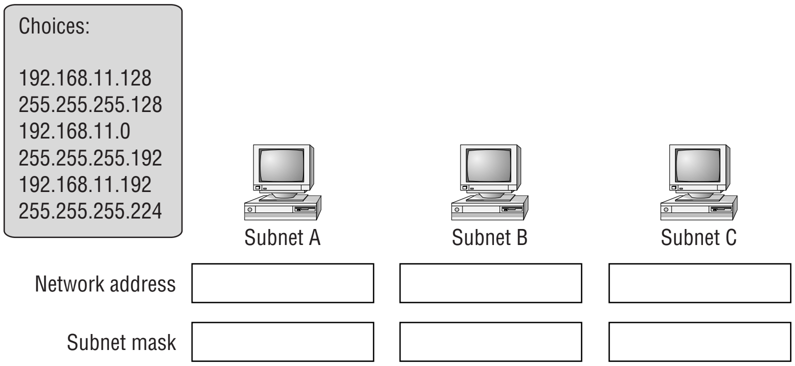
A. AppleTalk

B. TCP/IP

C. NWLink

D. NetBEUI

14. You administer a network that contains 175 machines. Your manager has assigned the network the IP address 192.168.11.0 with the default subnet mask of 255.255.255.0. A router that has one WAN interface and eight LAN interfaces connects this network to the corporate WAN. You want to subnet the network into three subnets, and you want to reserve a few addresses for a fourth subnet, just in case you need it later. You decide that Subnet A will contain 25 computers, Subnet B will contain 50 computers, and Subnet C will contain 100 computers. In the following exhibit, select the network addresses and subnet masks in the Choices column and place them in the appropriate boxes in the other three columns. Each item may be used only once.



15. Your multinational company has a Windows NT and Novell NetWare network that is built on several subnetworks. To provide interoperability, you have been using NWLink on the NT network and IPX for the NetWare network. You have been told that the Windows NT network must be migrated to Windows Server 2003 because it's less expensive to administer. You know that the administrative cost benefits are a result of utilizing Active Directory, so you include this service in your migration plan. What are you going to have to do immediately in order to install and begin using Active Directory on this network?

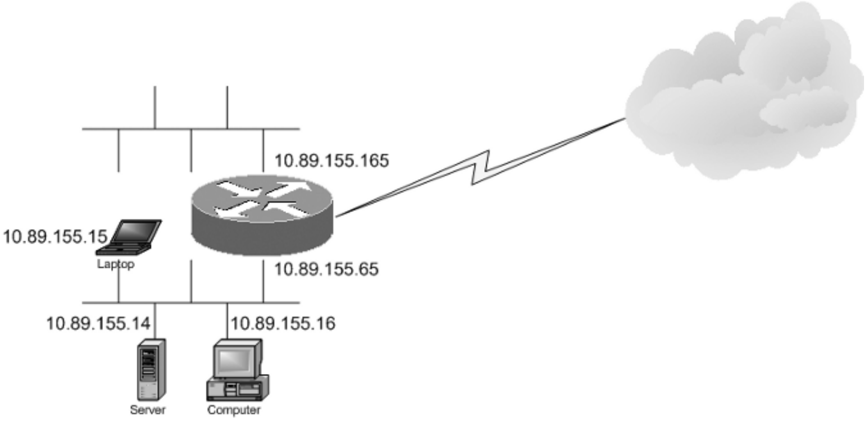
A. Change the protocol to TCP/IP.

B. Make sure that you install a copy of Active Directory on the NetWare servers as well as on the Windows 2003 Server computers.

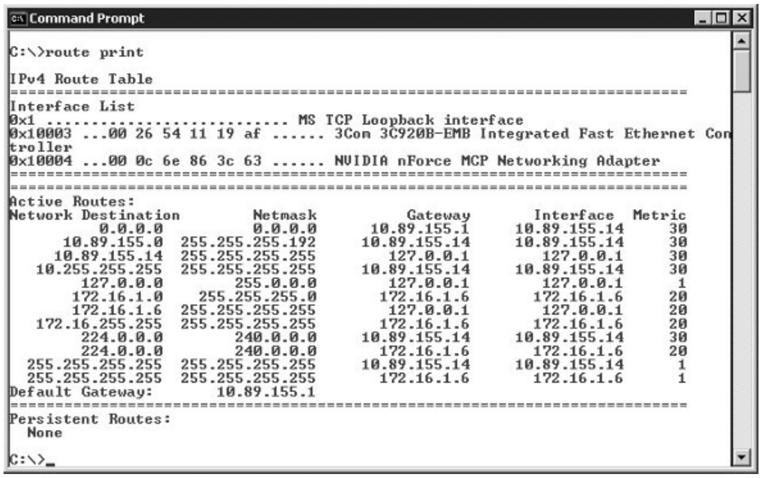
C. As you upgrade the Windows NT servers, make sure that you choose to upgrade some of them as domain controllers so that you can install Active Directory on them.

D. Install NetBEUI in order to provide connectivity for the NetBIOS components of Windows Server 2003.

16. You are the administrator of a large internetwork that consists of Windows Server 2003 and Windows XP Professional computers with statically assigned IP addresses. One of your servers has IP connectivity issues. There are two other computers on the same LAN as the server, each of which reaches the server and the rest of the internetwork with no trouble. The following diagram shows the layout of the LAN in question. The server's IP address is 10.89.155.14.



The following output was generated by the server and shows the IP routing table that the server uses to make routing decisions.



```
C:\>route print

IPv4 Route Table
===========================================================================
Interface List
0x1 ........................... MS TCP Loopback interface
0x10003 ...00 26 54 11 19 af ...... 3Com 3C920B-EMB Integrated Fast Ethernet Con
troller
0x10004 ...00 0c 6e 86 3c 63 ...... NVIDIA nForce MCP Networking Adapter
===========================================================================
===========================================================================
Active Routes:
Network Destination        Netmask          Gateway       Interface  Metric
          0.0.0.0          0.0.0.0      10.89.155.1    10.89.155.14      30
      10.89.155.0  255.255.255.192     10.89.155.14    10.89.155.14      30
     10.89.155.14  255.255.255.255        127.0.0.1       127.0.0.1      30
   10.255.255.255  255.255.255.255     10.89.155.14    10.89.155.14      30
        127.0.0.0        255.0.0.0        127.0.0.1       127.0.0.1       1
       172.16.1.0    255.255.255.0       172.16.1.6      172.16.1.6      20
       172.16.1.6  255.255.255.255        127.0.0.1       127.0.0.1      20
   172.16.255.255  255.255.255.255       172.16.1.6      172.16.1.6      20
        224.0.0.0        240.0.0.0     10.89.155.14    10.89.155.14      30
        224.0.0.0        240.0.0.0       172.16.1.6      172.16.1.6      20
  255.255.255.255  255.255.255.255     10.89.155.14    10.89.155.14       1
  255.255.255.255  255.255.255.255       172.16.1.6      172.16.1.6       1
Default Gateway:       10.89.155.1
===========================================================================
Persistent Routes:
  None

C:\>_
```

Which of the following two solutions work together to allow the server to have complete connectivity across the internetwork and not affect any other part of the LAN? (Choose two.)

A. Change the IP address of the server to 10.89.155.66.

B. Change the default gateway of the server to 10.89.155.65.

C. Change the local IP address of the router to 10.89.155.1.

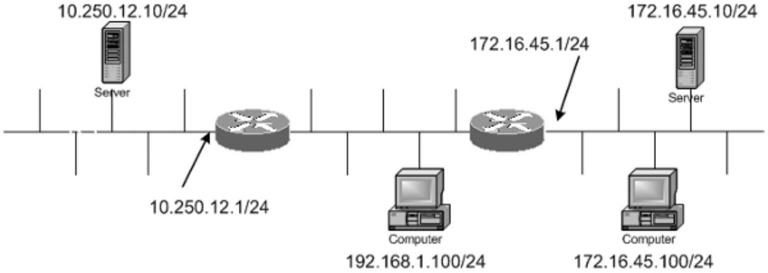
D. Change the subnet mask of the server to 255.255.255.128.

E. Change the subnet mask of the server to 255.255.255.0.

F. Change the local subnet mask of the router to 255.255.255.192.

G. Change the IP address of the laptop to 10.89.155.67.

17. You are the administrator of an internetwork that consists of Windows Server 2003 and Windows XP Professional computers. You are experiencing partial IP connectivity loss. Refer to the following diagram.



None of the servers or other computers have any static routes configured on them. The server at address 10.250.12.10 has 10.250.12.1 configured as its default gateway. The hosts on the 172.16.45.0 subnet have 172.16.45.1 configured as their default gateway. You execute some pings and trace routes and notice the following results: Host 10.250.12.10 and the hosts on the 172.16.45.0 subnet are able to reach host 192.168.1.100. The hosts on the 172.16.45.0 subnet are able to reach one another. The hosts on the 172.16.45.0 subnet are not able to reach host 10.250.12.10. Upon establishing a Telnet session with the router at 10.250.12.1, you discover that this router is configured with a static route to the 172.16.45.0/24 subnet. Which one of the following steps will most likely resolve the connectivity issue you are experiencing?

A. Remove the static route you noticed in the router.

B. Add static routes in the hosts on the 172.16.45.0 subnet to the 10.250.12.0/24 subnet.

C. Add a static route to the 10.250.12.0/24 subnet in the other router.

D. Add two static routes to host 192.168.1.100, each directed toward one of the other two subnets.

E. Configure the hosts on the 172.16.45.0 subnet with the correct default gateway.

18. Which of the following subnet masks produce 8 subnets and 30 hosts per subnet for a Class C network? (Choose all that apply.)

A. /27

B. /28

C. 255.255.255.240

D. 255.255.255.192

E. 255.255.255.224

19. With a /28 mask, which of the following addresses can be assigned to hosts on the same subnet? (Choose all that apply.)

A. 192.168.1.0

B. 192.168.1.17

C. 192.168.1.31

D. 192.168.1.16

E. 192.168.1.25

20. Which of the following are subnet boundary addresses that result from the use of the /29 mask? (Choose all that apply.)

A. 172.20.73.12

B. 10.8.1.212

C. 192.168.0.0

D. 192.168.1.16

E. 192.168.164.208

Answers to Review Questions

1. A. A Class B address with a default subnet mask of 255.255.0.0 will support up to 65,534 hosts. To increase the number of networks that this network will support, you need to subnet the network by borrowing bits from the host portion of the address. The subnet mask 255.255.252.0 uses 6 bits from the hosts area and will support 64 subnetworks while leaving enough bits to support 1022 hosts per subnet. The subnet mask 255.255.248.0 uses 5 bits from the hosts and will support 32 subnetworks while leaving enough bits to support 2046 hosts per subnet. 255.255.252.0 is probably the better answer because it leaves quite a bit of room for further growth in the number of networks while still leaving room for more than 1000 hosts per subnet, which is a fairly large number of devices on one subnet. The subnet mask 255.255.254.0 uses 7 bits from the hosts area and will support more than 120 networks, but it will leave only enough bits to support 500 hosts per subnet. The subnet mask 255.255.240.0 uses 4 bits from the hosts and will support only 16 subnetworks, even though it will leave enough bits to support more than 4000 hosts per subnet.

2. D. Older NetWare networks are based on the IPX protocol. There must be a common protocol in order for two network devices to communicate. Because there is no server to run the gateway for NetWare services, each NT workstation must have NWLink loaded. Also, the NetWare client must be installed on the workstations so that they will be able to connect to the printer.

3. A. The network mask applied to an address determines which portion of that address reflects the number of hosts available to that network. The balance with subnetting is always between the number of hosts and individual subnetworks that can be uniquely represented within one encompassing address. The number of hosts and networks that are made available depends upon the number of bits that can be used to represent them. This scenario requires more than 35 networks and fewer than 1000 workstations on each network. If you convert the subnet masks as described in the chapter, you will see that the mask in option A allows for more than 60 networks and more than 1000 hosts. All of the other options are deficient in either the number of networks or hosts that they represent.

4. A. The subnet mask 255.255.255.192 borrows 2 bits from the hosts, which allows you to build four separate networks that you can route through the Windows server. This will allow you to have 62 hosts on each segment. A mask of 255.255.255.128 would have been even better, with two subnets of 126 hosts each, but that wasn't an option, and this solution gives you room for growth in the number of subnets. The subnet mask 255.255.255.224 borrows 3 bits from the hosts; this allows you to create 8 networks, which you don't need, and leaves only enough bits for 30 hosts. The subnet mask 255.255.255.252 borrows 6 bits from the hosts; this allows you to create more than 60 networks, which you don't need, and leaves only enough bits for 2 hosts. The subnet mask 255.255.255.240 borrows 4 bits from the hosts; this allows you to create 16 networks, which you don't need, and leaves only enough bits for 14 hosts per subnet.

5. B. Each packet has a header and data and is typically placed in a frame that consists of three parts: a header, data, and a trailer. The packet header includes the source and destination logical addresses.

6. C. NetBEUI and NetBIOS are separate entities. NetBEUI is a transport protocol that has a NetBIOS interface. However, each protocol that comes with Windows Server 2003 has a NetBIOS component and can be used to communicate with NetBIOS programs. Although the binding order of protocols can have a performance effect on communication across the network, it has nothing to do with the problem described here. The extra protocol is simply consuming unnecessary network bandwidth.

7. C. Network Driver Interface Specification (NDIS) provides a standard way for protocols to bind to the data link drivers in Windows Server 2003. This is what allows Windows Server 2003 to support so many protocols. As long as a developer supports NDIS, the protocol will load in Windows Server 2003. However, this will not make it interoperate with the Windows Server 2003 services. The applications will have to be written to the specific protocols.

8. B, C, D. When you add up the locations that currently need to be given a network address, the total is 3150, and the maximum number of hosts at any one of these locations is less than 1000. The subnet masks need to support those requirements. Assuming you choose the Class A private address space 10.0.0.0/8, the subnet masks given in options B, C, and D will provide the address space to support the outlined requirements. The subnet mask 255.255.240.0 supports more than 4000 subnets and more than 4000 hosts. The subnet mask 255.255.248.0 supports more than 8000 subnets and more than 2000 hosts. The subnet mask 255.255.252.0 supports more than 16,000 subnets and more than 1000 hosts. Although each of these subnet masks will work, at the rate that this company is growing, 255.255.252.0 is probably the best mask to prepare for the future. It's unlikely that there will ever be more than 1000 hosts on any given network. In fact, that number would probably cause performance problems on that subnet. Therefore, it's better to have more subnets available to deploy as the company grows. The subnet mask 255.255.224.0 supports more than 2000 subnets—an insufficient number to cover the locations. The subnet mask 255.255.254.0 supports more than 32,000 subnets but only 500 hosts per subnet, which are not enough hosts to cover all the locations.

9. D. TCP/IP is the most widely used protocol for interconnecting computers and networks, and it is the only protocol used on the Internet and the only one compatible with the other protocols mentioned in the question. It works well with very large internetworks.

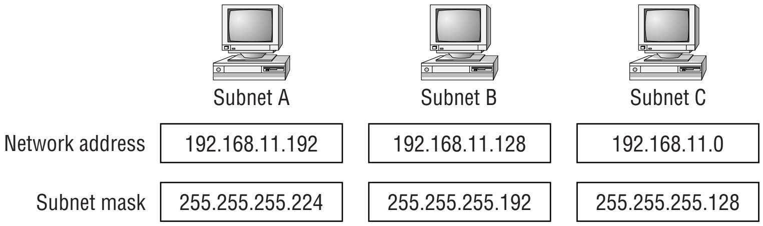
10. A, B, C, D. TCP sits at the Transport layer, and IP at the Network layer, and both are necessary to route requests through the Internet. However, you also need a browser such as Netscape or Internet Explorer to provide the HTTP calls to actually connect to the various websites; the browser sits at the Application layer. But any end-to-end communication uses all the levels of the OSI model at some point because each layer communicates with the layer below and the layer above to form the complete chain.

11. A. The Physical layer is concerned with signaling, specifically through electrical, optical, or radio signals. The high voltage associated with large motors can easily cause an interruption in the signaling of coax cable. There have been many cases of people running network cable through elevator shafts in a building because of their ease of access only to have the network malfunction every time someone summons the car. The other layers are associated with software and are beyond the reach of most electrical interference unless it affects the entire workstation.

12. A, B. Both NWLink and TCP/IP are routable and both can function properly with NetBIOS applications because they are both Microsoft's versions and have the interface for proper communication. XNS is a routable protocol but is not provided with Windows Server 2003, and with the overwhelming popularity of TCP/IP, XNS is generally no longer used in networks. NetBEUI, although it supports the NetBIOS programs, is not routable.

13. B. Although Macintosh computers can use AppleTalk to communicate with each other, these computers can also run TCP/IP, so AppleTalk won't be necessary when these two networks are merged. You could add AppleTalk to the servers in the network, and the two machine types could share files back and forth, but if you can reduce the number of protocols on any network, it's a best practice to do so.

14. The network address 192.168.11.192 with a subnet mask of 255.255.255.224 is perfect for Subnet A because it supports up to 30 hosts. The network address 192.168.11.128 with a subnet mask of 255.255.255.192 is perfect for Subnet B because it supports up to 62 hosts. The network address 192.168.11.0 with a subnet mask of 255.255.255.128 is perfect for Subnet C because it supports up to 126 hosts.



	Subnet A	Subnet B	Subnet C
Network address	192.168.11.192	192.168.11.128	192.168.11.0
Subnet mask	255.255.255.224	255.255.255.192	255.255.255.128

15. A. Active Directory requires TCP/IP in order to function. Even though you can have TCP/IP and IPX coexisting on the same network, it's not beneficial to have multiple protocols because they increase the level of support necessary for the network. Active Directory does not run on NetWare, and NetBEUI is not required for NetBIOS communication. Finally, Active Directory can be installed and uninstalled on any Windows Server 2003 computer. It's a service that is added rather than a particular type of server that is installed.

16. B, D. The best way to solve this problem within the parameters of the question is to point the server to the appropriate address to reach the rest of the internetwork, 10.89.155.65. In order for this to work, however, the server must believe this address is on the same subnet as itself. With the server's current /26 mask, hosts with a fourth-octet value from 1 to 62 are in a different subnet from those with a fourth-octet value from 65 to 126. If the server keeps such a mask, it will always think its default gateway is on a different subnet, which would be poor design if true. In fact, the router is on the same layer-2 segment, so it should be in the same subnet as well. Changing the server's subnet mask to 255.255.255.0 (option E) certainly would convince the server that it was on the same subnet as its router, but it also would affect its connectivity to the other Ethernet segment on the other side of the router, causing the server to attempt to communicate directly with those hosts without going through the router. Changing the router's local subnet mask to match that of the server (option F) and placing the server in the fourth-octet range 65 to 126 (option A) would get the server communicating to the rest of the internetwork, but doing so would break the router's connectivity with the other two hosts on the local subnet. Therefore, the best subnet mask for the server in this case is 255.255.255.128, which places all hosts with fourth-octet values from 1 to 126 on the same subnet. Because the other devices on the same LAN as the server already communicate with and through the router, after analyzing the diagram, you'll see that it is likely that they already have /25 masks as well as point to a default gateway of 10.89.155.65. All hosts on the same subnet should have the same subnet mask. Although bringing the router into line with the server's settings (options C and F) would solve the connectivity issues between the server and router, the other two hosts on the local LAN would need reconfiguration to point to the new default gateway address of 10.89.155.1. While it's possible to place both the server and the laptop within the fourth-octet range from 65 to 126 (options A and G), allowing them to remain in contact with one another as well as allowing the server access to the rest of the internetwork, doing so breaks the server's connectivity with the computer at address 10.89.155.16.

17. C. Because the hosts on the 172.16.45.0 subnet already have default gateways set for their local router, adding static routes to get to a remote network will not change their connectivity. Furthermore, you know that the default gateway configured on the two hosts on that subnet is already correct because each one can reach host 192.168.1.100 without being configured with any static routes. Because the router on the left is already configured to be able to reach the 172.16.45.0 subnet, the problem lies with the router on the right not being able to reach the 10.250.12.0 subnet. Establishing a static route for this purpose in the router on the right will establish full connectivity.

18. A, E. Both 255.255.255.224 and /27 represent the subnet mask that produces 8 subnets and 30 hosts per subnet for a Class C address.

19. B, E. Besides not being on the same subnet as the others, when a /28 mask is applied to all five addresses, 192.168.1.0 falls on a subnet boundary and cannot be used for host address assignment. Of the others, only 192.168.1.7 and 192.168.1.25 are valid host addresses on the same subnet when a /28 mask is applied. While 192.168.1.16 and 192.169.1.31 are both on the same subnet as the two correct answers, they represent the subnet boundary address and the subnet broadcast address, respectively, and are therefore illegal for use in host address assignment.

20. C, D, E. Remember, you can always use the 0 subnet, making option C a valid response. Because 32 – 29 = 3 and 2^3 = 8, the subnet boundaries in the fourth octet (32 is the next multiple of 8 higher than 29, and 32 ÷ 8 = 4) will be multiples of 8, making options D and E valid as well.