Chapter 1. Networks and Network Operation

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Introduction to Network Operation

Context

The purpose of this unit is to provide an introduction to the technology and to the business use of computer networks. It introduces some of the concepts fundamental to the operation of computer

networks. These concepts are essential to an understanding of the workings of computer networks, and form the foundation on which a more complete understanding may be built. The unit also describes in general terms the basic uses of computer networks. When specialised and combined, these generic uses can be used to create any number of business services and applications.

Introduction

The module begins with an introduction to network technology. This unit starts by considering the reasons for attaching a computer to a network, and underlines them by comparing and contrasting the capabilities of a stand-alone computer and a networked computer. Various ways in which a computer may be attached to a network are described before going on to consider, in an introductory fashion, some of the different types of computer networks. The networks described range from small, local-area, networks to the Internet with its global coverage. The roles of hardware and software in the creation of a computer network are described, and their interaction and interdependence are stressed. In view of the fact that computers of any kind may be attached to a network, the need to establish some kind of uniformity of network operation is explained, and the way in which this is imposed by means of standard ways of operating is described.

In addition, this unit introduces, or revisits as the case may be, some basic ideas on binary representation, data, coding and files.

Why have Computer Networks?

In parallel with this topic, you should look up in relevant sections in your textbook.

The reason for attaching a computer to a network is to connect it to the other computers that are already attached to the network. At the same time, the user of the computer is, in effect, connected to the users of other computers. The benefits that stem from this connectivity are that a computer can:

- communicate with other computers, and
- share resources with other computers

These capabilities are made available in the form of services. Computer networks can offer a range of communication services, of which the best known is probably electronic mail, which provides the users of computers with a fast mail-like service. There are also services for resource sharing. Before continuing, you could pause to consider what kind of resources might be shared by the computers on a computer network.

The resources that can be shared include:

- information
- advice
- software
- computing facilities
- storage
- printers

These items can be broadly classified as software and hardware. The software category includes information, expertise, software and, broadly, anything that can be stored in digital form in a file. The hardware category includes the computer hardware, probably to be used for computing, and computer peripherals, including storage devices to be used for storage. A service is usually provided for sharing software and another for sharing hardware. Since most software items can be stored in a file, the service for sharing them usually takes the form of a file transfer service.

To Do

Now do Review Questions 1, 2 and 3.

The Stand-alone Computer and the Networked Computer

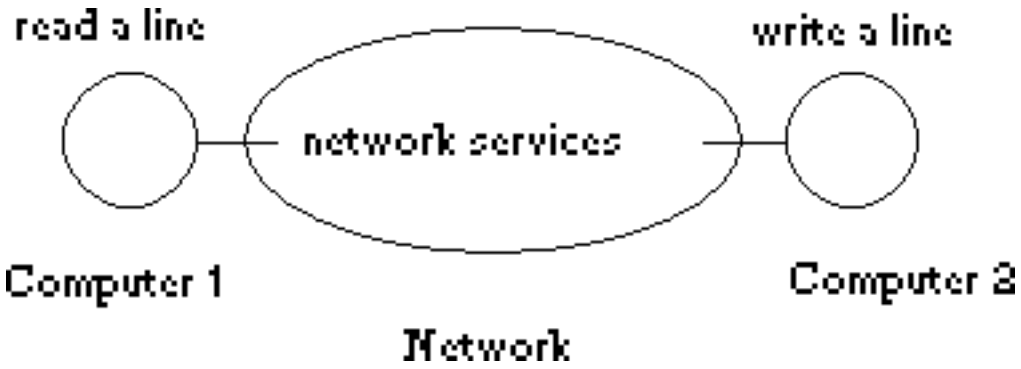
In parallel with this topic, you should look up in relevant sections in your textbook.

A stand-alone computer is, by it very nature, a personal computer in the sense that it is likely to be used by a single owner. The files stored on it are likely to be the creation of that person and to be unavailable to anyone else. This is precisely what the networked computer is not. While a stand-alone computer, by definition, cannot communicate and share, a networked computer can. This makes it easy to see that a networked computer can, and is intended to, support communal activities in which a group of people co-operate and collaborate in some task, whether within an organisation or in the community at large. `while (true) {echo}`

Here 'echo' means something like echo (or copy) the input to the output. A simple elaboration of this gives, for example, the routine at the core of a word processing program: `while (true) { read a line; process a line; write a line }`

By contrast, a typical program for networked computers is: `while (true) { read a line at one computer; process a line; write a line at another computer }`

The environment in which this program would be run can be represented as in the following diagram.



The program for the networked computers has essentially the same structure as that for the stand-alone computer, but differs in that it involves more than one computer. This allows it to provide the ability to communicate. Clearly, the 'network services' indicated in the diagram must do something to make possible the intended operation of the program. What they do is the concern of much of this module, and will be explained as it proceeds.

The program for networked computers given above can be elaborated to indicate the basis of a program for group communication and also for collaboration.

To Do

Now do Review Questions 4, 5 and 6.

Converting a Stand-alone Computer to a Networked Computer

The essential difference between a stand-alone computer and a networked computer is that the former is not connected to a network while the latter is. When put like this, it is not hard to see how to convert a

stand-alone computer to a networked computer - just connect it to a network! As a physical matter, this may involve no more than attaching a cable to one of the computers sockets or inserting a network card in one of the computer's slots and then attaching a cable to the socket on the card. As an operational matter, though, it may be rather more complicated than this: it is one thing to connect a computer, but another to connect it in such a way that it will work with the computers that have already been connected and are working together. Or, to put it another way, the fact that a computer can send signals is no guarantee that they are suitable for reception by another computer.

To Do

Now carry out Activity 1.

Using a Networked Computer

Once a computer has been connected to a network it should ideally be used in the same way as a stand-alone computer, and should be just as easy to use.

The ability to communicate should be made available as an application that works in the same way as the computer's other applications.

The extra resources should be made available in the same way as the computer's own resources.

In this way, putting a computer on a network should make it seem to be a more capable computer: apart from this, it should be used in the same way. In fact, to the user of the computer, the network should be invisible!

To Do

Now carry out Activity 2.

The Technology

Given the aims for a computer network and, from the point of view of the users, a style for the achievement of these aims, the question that remains is how to realise such a network.The technology required to implement such a solution consists of hardware and software.Hardware is needed to create the physical network: to connect the computers, and to provide the links of the network.

Network software is needed to provide the necessary network services to make this hardware:

- usable,
- usable in a certain style, and
- transparent.

Application software is needed to support different types of communication and resource sharing. The hardware consists of the computers, communication interfaces, connectors and transmission facilities such as cables. The network software enables communication over the hardware in a way that is standardised, robust and reliable. It also provides a user interface.

The application software provides the services that will be available over this communication network. Application software in this environment is different from that for a stand-alone application in that it is distributed. Communication is from one computer to another. Resource sharing involves one computer sharing the resources of another. In both cases two computers are involved, and a part of the software must run on each computer.

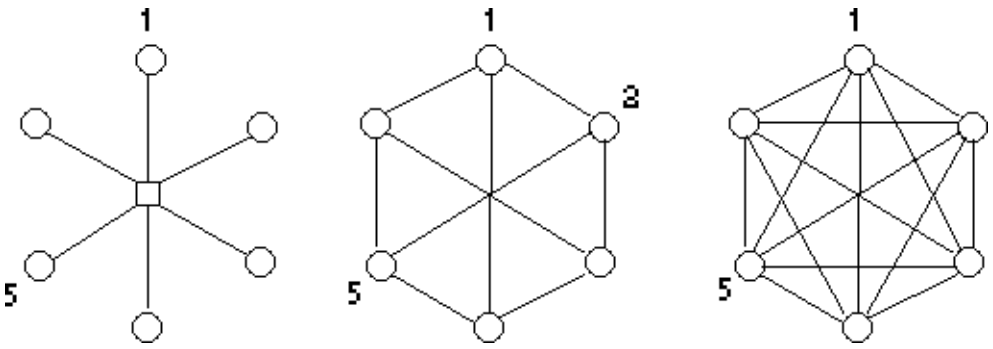
To Do

Now do Review Questions 7, 8 and 9.

Network Architecture

A network's architecture is essentially the combination of its hardware and its network software. In a good architecture, the two aspects will be well matched to each other. The rest of this section shows how the structure of the hardware and the operation of the software of a network are inextricably related to each other, so that they cannot sensibly be selected individually and without regard for each other.

Consider these ways of linking six computers:



The first, star, network has the minimum number of connections (6). The last has the maximum number of connections (15), and is fully connected in that every computer is connected directly to all the others. The connectivity of the second, partially connected, network lies between these two extremes.

Now consider what has to happen when computer 1 needs to send a message to computer 5. In the star network, computer 1 sends its message to the central node, which then forwards it to computer 5. In fact, this is the procedure that any two computers must follow to exchange a message. In the fully connected network, the sending computer selects that connection linking it to the destination computer, and sends its message directly to its destination. In the partially connected network, computer 1 is not connected directly to computer 5, but it can forward its message to computer 2, which is connected to the computer 5 and can, in turn, forward the message to it. The general procedure is that if the sending computer is connected directly to the destination computer it sends its message directly to it, otherwise, it forwards it to a computer that is nearer to the destination computer which, in turn, does the same thing.

The discussion illustrates how the software that determines how a network is to operate, in this case the rules for routing messages across a network, depends on the topology of the network. The two components of the network architecture must be matched to each other. The consequences of their not matching can be disastrous (imagine the routing protocol for the star network used on the fully connected network).

To Do

Now do Review Questions 10, 11 and 12.

The Networked Computer and the Network Computer

A fully capable computer can be given the ability to communicate. This enables it to take advantage of what a network has to offer and turns it into a networked computer. But this is not the only way to approach the creation of a computer network. Since a computer network possesses information and computing resources, it can be used by attaching a simple communication device. As long as this device can gain access to these resources it is in a position to take advantage of what the network has to offer. This is the idea of the Network Computer.

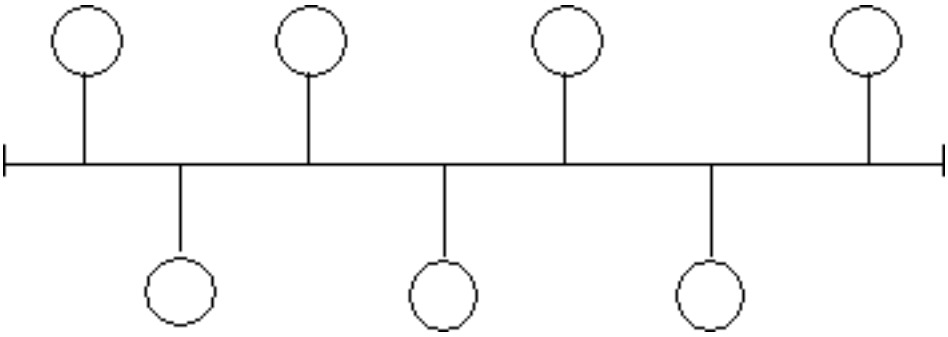
We can see the networked computer as a computing device to which a communication capability has been added, and the Network Computer as a communication device that can gain access to computing capabilities. The approaches are equally valid in that they are both ways of combining communication and computing so that each helps the other. The former might well be called 'communication-enhanced computing' and the latter 'computer-enhanced communication'.

To Do

Now carry out Activity 3.

Patterns of Connectivity

Networks giving different patterns of connectivity have been devised to meet different needs. For example, one network devised to meet the needs of a small group of people in the same location consists of a cable to which all the computers in one room or a few adjacent rooms can be attached. This can be represented as shown below:



Of course, in practice the cable will snake between the computers in the room, but the network will be topologically equivalent to that represented in the diagram. When all the computers on the network are carrying out similar tasks or are used by the members of the group to achieve some overall task, it is useful to have a computer on the network to hold the shared resources or to store the results of co-operative efforts. Such a computer is called a server and, for the moment, we can think of a server simply as a computer that holds resources needed by other computers. There is also the issue of how a number of computers can share one cable, but that is a topic for a subsequent unit.

The Internet, of course, provides global connectivity. It does this by linking together other networks such as networks belonging to organisations, national data networks and so on.

The intermediate networks can range from an organisation's network built up by connecting the small networks that exist on its different sites to provide connectivity across the organisation, to data networks providing national coverage with some partially connected mesh such as that discussed above.

To Do

Now do Review Questions 13 and 14.

Uniformity and Standards

In parallel with this topic, you should also read the relevant sections from your textbooks

Usually, there is a requirement to connect computers of any kind to a network. This raises a problem in that different types of computer work in different ways, so that it is not at all clear that, for example, messages produced by one computer and sent to another mean the same thing, or indeed anything, to the receiving computer. To allow computers of different kinds to exchange information meaningfully (that is, in such a way that the information means the same thing to all the computers involved in the

exchange) there is a need to enforce some kind of uniformity. This may be achieved by agreeing on a standard way of working to which all computers attached to the same network must conform.

At the application level, uniformity may be achieved by requiring that all the programs for a specific purpose, such as, for example, e-mail, produce their output in a standard format. This means that everything conveyed across the network will conform to this standard so that any receiving computer can be assured that anything it receives is in this standard format. At the communication level, standard forms of assembling and signalling are needed so that all the items communicated across the network are assembled in a standard form and signalled in a standard way so that each receiving computer knows exactly how to interpret the signals it receives. The basic division is that the semantics of communicated items is standardised across the application software while their syntax is standardised across the network communication software.

On the Internet, for example, the communications software (known as Transmission Control Protocol / Internet Protocol - TCP/IP) is standardised, and must run on each Internet computer so that it can communicate in a standard fashion with any other Internet computer. The Internet's distributed applications, such as e-mail, also conform to a standard so that an e-mail sent by any Internet computer, regardless of its type and the type of the e-mail software it is running, can be not only received but also read at any other Internet computer, regardless of its type and the type of its e-mail software.

To Do

Now do Review Question 15.

Data, Codes and Styles

In parallel with this topic, you should also read the relevant sections from your textbooks

Computers process data and communication networks transmit data, so we need to be clear about what data is. We can regard it as sequences of 0's and 1's but with the proviso that the sequences represent something. For example, they can represent numbers:

decimal number	**4-digit binary number**			
0	0000			
1	0001			
2	0010			
3	0011			
4	0100			

(You should be sure that you can cope with decimal-to-binary and binary-to-decimal conversions). They can represent alphanumeric characters. The American Standard Code for Information Exchange (ASCII) is one such representation. Part of this code is:

character	**8-digit code**			
A	01000001			
B	01000010			
C	01000011			
D	01000100			
E	01000101			

By using this code, a text, such as that of an e-mail, can be converted to data. (You should also find a complete table for thfe ASCII code in a textbook and familiarise yourself with it. Note that it provides data representations not only for alphabetic characters but also for communication symbols such as ACK and NAK.)

Strings of 0's and 1's can also represent colours (to see this just replace the capital letters in the table above by the names of colours), objects in a drawing program, for example (replace the capitals by Line, Rectangle, Oval, etc.). Thus, a coloured image can be converted to data by listing in some defined order the codes for the colours of its pixels. A graphic can be converted to data by listing the codes for the objects that it consists of.

We know that computers store the results of their computations in files. Because just about everything can be represented by a sequence of 0's and 1's, files tend to look much the same whatever their intended meaning. The content of a text file is just a list of the ASCII codes for text symbols, while an image file contains a list of codes for colours. For this reason, it is essential to know what the contents of a file represent before the file can be (properly) used.

To Do

Now do Review Question 16 and carry out Activity 4.

Activities>

Activity 1 - How are Computers Physically Attached to a Network?

If you have access to a computer that is attached to a local-area network, examine the computer to see how it is actually attached to the network. Find the connector. Has the computer had a card inserted in one of its slots or does it have a built-in network card?

You can find a discussion of this activity at the end of the chapter.

Activity 2 - Computer or Network Operating System?

On a computer that is attached to a network, the network operating system is usually a seamless extension of the computer's own operating system. On a networked computer to which you have access, check to see if you can find, say, two aspects of the operating system that relate to its use in stand-alone mode and two that relate to its use as a networked machine. Check whether all these aspects are made available in a uniform fashion.

You can find a discussion of this activity at the end of the chapter.

Activity 3 - The Players in the Network Computer Arena

The companies most prominent in Network Computer activity have included Microsoft and Oracle. Their attitudes to it have changed quite a lot in a relatively short time. Visit their Web sites (at www.microsoft.com and www.oracle.com) and see if you can find how they see the role of the Network Computer currently.

You can find a discussion of this activity at the end of the chapter.

Activity 4 - The ASCII Code

Find a table giving the complete ASCII code. Be sure that you can interpret the table correctly - it is often presented in a confusing way. Identify the characters that are intended for communications use only, and compile a precise description of their meanings.

You can find a discussion of this activity at the end of the chapter.

Review Questions>

Review Question 1

You could share the computing facilities on a network by, for example, making use of another computer on the network. Why might you want to do this?

You can find an answer/comment for this review question at the end of the chapter.

Review Question 2

Why would the members of a group want to share information with each other?

You can find an answer/comment for this review question at the end of the chapter.

Review Question 3

How can expertise be shared?

You can find an answer/comment for this review question at the end of the chapter.

Review Question 4

What kind of things are the responsibility of the 'network services' mentioned in the diagram?

You can find an answer/comment for this review question at the end of the chapter.

Review Question 5

Network services are implemented in software. Where does this software reside?

You can find an answer/comment for this review question at the end of the chapter.

Review Question 6

How can the programs given in this section be interpreted so that the program for a stand-alone computer describes a way of storing a file, and the program for a networked computer describes a way of transferring a file from one computer to another?

You can find an answer/comment for this review question at the end of the chapter.

Review Question 7

Is it true that all network applications are distributed?

You can find an answer/comment for this review question at the end of the chapter.

Review Question 8

What does it mean to say that the communication supported by a network is 'robust'?

You can find an answer/comment for this review question at the end of the chapter.

Review Question 9

What does it mean to say that a network is 'transparent' to it users?

You can find an answer/comment for this review question at the end of the chapter.

Review Question 10

Describe in broad terms the architecture of the University network and of the Internet.

You can find an answer/comment for this review question at the end of the chapter.

Review Question 11

How many links are there in a network with N computers when they are:

1. fully connected
2. connected in a star arrangement
3. partially connected, with each computer connected to three others

You can find an answer/comment for this review question at the end of the chapter.

Review Question 12

How is the answer to part 3 of the previous question to be interpreted?

You can find an answer/comment for this review question at the end of the chapter.

Review Question 13

What do the acronyms LAN, MAN and WAN stand for?

You can find an answer/comment for this review question at the end of the chapter.

Review Question 14

More importantly, what are LANs, MANs and WANs?

You can find an answer/comment for this review question at the end of the chapter.

Review Question 15

Uniformity of operation at the application level can be achieved by what is called 'cross-platform development', that is, by developing application software (software to create a browser, say) in such a way that the result is a number of different version of the same program that will run on many different types of computer (platforms). What are the problems of 'cross-platform development' that do not occur with single-platform development'? What is the alternative to 'cross-platform development'?

You can find an answer/comment for this review question at the end of the chapter.

Review Question 16

Using their word processor, someone types the four-letter sequence 'ABCD' twenty-five times and stores the result as a text file. The letters are coded using the ASCII code in which the codes for A, B, C, D are, respectively, by the 8-binary digit representations of the decimal numbers 65, 66, 67 and 68.

1. Give the first sixteen binary digits of the data segment of the file.
2. How many binary digits does the data segment of the file contain?

3. How long will it take to transmit the data segment of the file across a link operating at 64 kbit/sec?

4. How long will it take to transmit the contents of the file across a store-and-forward network via two intermediate nodes when the storage time at the intermediate nodes is negligible?

5. The most significant digit of each code word is transmitted first. In a particular transmission errors occur to the data in positions 7, 16, 22, 23 and 24. What are the first four characters displayed when the received text file is loaded into a word processor at the receiving computer?

6. After a second transmission, the file is received correctly, but opened by an image processing program. This program manages a screen with an 8 by 8 resolution and its colour code includes: 65 - red, 66 - blue, 67 - green, 68 - violet. What does the displayed image look like?

You can find an answer/comment for this review question at the end of the chapter.

Discussion Topics

1. The early part of this module deals with the way in which computer networks are used to provide a 'data communications fabric' that is computer supported and appropriate to the needs of all kinds of groups. Discuss the kinds of activity needed by groups that can be supported by taking advantage of this communication capability.

2. It is well known that, by enabling communication and sharing, the Internet encourages the formation of communities. These have been called virtual communities, although there are communities that meet in the real world as well as by using the network. Why does the Internet encourage the formation of communities? What is the consequence of this in a business context?

3. From the points of view of the various interested parties, including users, manufacturers, service providers, etc., what are the relative merits of the networked computer and the Network Computer? Would users be better off with one than the other? Could service providers and network operators give users free Network Computers on the basis that they could find other ways of making money from them? How would they do this? Is it possible that there is a win-win situation for users and providers based on the use of the Network Computer?

4. The data segment of a file contains nothing but data, and that data will have been assigned a meaning by its originator (it will represent something, whether text or an image or something else). How is it possible to ensure that after a file transfer, the content of the file is interpreted in the way intended by its originator (so that, for example, the contents of a text file are not treated as an image)? Can something be done so that correct interpretation is made automatically?

Answers and Comments

Answers and Comments for Activities

Activity 1

If you set up your own computer and, for example, attached or installed a modem, you will know how your computer is attached to its network. If you are using a computer that has already been set up by someone else, look at the sockets at the back or side to see where the cables leading from it are connected. If you have difficulty in locating or identifying the connectors, sockets, cards and so on, then you can seek help from the local technical support staff.

Activity 2

On a stand-alone computer, the operating system provides commands, for example, for examining the contents of a disc and for running a program that is stored on a disc. When a computer is attached to a local-area network, the contents of the shared disc drive on the server can be examined in the same way

as the contents of a local disc. The network operating system will also allow, for example, examination of the network configuration and identification of other currently active computers on the network.

Activity 3

Generally speaking, Microsoft's approach has been nearer to the extreme of attaching an already capable stand-alone computer to a network. Microsoft's operating systems have, over the years, evolved from systems for stand-alone computers to systems for networked computers. Oracle, at least when it first became interested in this area, favoured something much nearer to the minimal Network Computer. The situation is, however, extremely fluid. An examination of the Web sites of these companies should provide a picture of the current situation.

Activity 4

Both Stallings and Halsall use the same potentially confusing presentation of the ASCII code. It may help in checking that you can read the table correctly to know that the code word for Z is 1011010.

Stallings and Halsall both identify the 'control characters', that is, the non-printing characters. Those intended specifically for communication purposes include ACK, NAK and SYN. The meanings of these characters are given in the texts.

Answers and Comments for Review Questions

Review Question 1

Perhaps because it's a better computer than yours. Another computer may be able to run a program faster than your computer. It may be able to run a program that your computer cannot run at all because, to give one possible reason, it doesn't have enough memory.

Review Question 2

They could be investigating the same topic, in which case sharing the information they have found will prevent them from duplicating each others' efforts. They could be compiling a joint report, in which case each member of the group needs to see what the others have done.

Review Question 3

One way is to communicate with an expert. Another is to access a knowledge base containing expertise that has been elicited from an expert.

Review Question 4

They have to accept an item from a computer with something to send, convey it across the network so that it can be presented to the computer for which it is intended.

Review Question 5

Software is, of course, run by computers and, although people speak of the 'software installed on the network', the software is actually installed on the computers on the network.

Review Question 6

If 'echo' is replaced in the program for a stand-alone computer by 'read a line from an input device and copy it to a storage device', we have the essence of a program to store a file. If, in the program for a networked computer, 'read a line' is taken to mean 'read a line from a storage device' and 'write a line' is taken to mean 'write a line to a storage device', then we have the essence of a program that can, line by line, transfer a file.

Review Question 7

Yes. If they were not distributed, but ran on one computer, you could run them on a stand-alone computer and there would be no need for a network connection.

Review Question 8

Essentially, that successful communication will continue even when difficulties are experienced by the network.

Review Question 9

That users can, metaphorically, 'see through it'. That is to say that it operates so effectively that they are unaware of its presence in performing any part in an activity they are carrying out.

Review Question 10

The hardware is, in effect one large global network constructed by linking together existing networks with a system of routers. (You can find out what a router is from the glossary or the texts for the module). The software is the Internet's communications software, TCP/IP. (Again, you can look this up in the same places as you did for a router.)

Review Question 11

1. N*(N-1)/2
2. N
3. 3*N/2

Review Question 12

If N is an even number, it can be divided by 2 and the formula gives the number of links in the network. If N is odd, the formula gives the number of links as something-and-a-half. As it makes no sense to have half a link, a network of this connectivity cannot be constructed for an odd number of computers.

Review Question 13

Local-area network, metropolitan-area network and wide-area network, respectively.

Review Question 14

Essentially, they are small-, medium- and large-sized networks, respectively. You should refer to the texts for this module to elaborate on this answer.

Review Question 15

While creating software intended to run on a number of different types of computer, the main difficulty is to ensure that it runs reasonably efficiently on each type of computer. It is hard to use general techniques and at the same time take advantage of the particular distinguishing features of each type of computer. The alternative is to develop the program separately for each type of computer. This makes it easier to take advantage of the features specific to each type of computer, but harder to ensure that the programs developed for each type of computer all behave in the same way.

Review Question 16

1. 0100000101000010

2. 25*4*8 = 800 bits
3. 800/64,000 = 1/80 seconds
4. 3*1/80 = 3/80 seconds
5. CCDD
6. Repeated vertical stripes of red, blue, green, and violet.