Chapter 3. Communication and Data Communications

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Introduction to Communication and Data Communications

Context

Following the introduction provided by units 1 and 2, this unit establishes some general ideas regarding the principles, practice and usage of communications.

Introduction

This unit uses the general model of the communication process, due to Shannon, to provide a context for data communications. The model is described, and the way in which it is embedded in direct human communication and in established communication networks such as the telephone network is demonstrated.

It is then shown how the process may be implemented in any number of ways to provide a simple point-to-point data communication system. This provides the opportunity to introduce within a coherent framework concepts such as signalling and representation; communication media, including cables and optical fibre; and devices such as modems and cable modems. The ever-present nature of noise is also introduced: its description and its effects are dealt with in the next unit.

The unit concludes by using the Physical Layer as a way of collecting and summarising much of what has been covered in the unit, of linking it to the idea of computer interface, and bringing in the idea of layering for the first time.

Objectives

At the end of this module, you should be able to:

- describe a general model of the communication process;
- show how this model is embedded in a variety of communication systems, including data communication systems;
- show how this model is embedded in a variety of communication systems, including data communication systems;
- understand the role of signalling in communication systems;
- describe the functions of, and give examples of, the following: physical layer, modem and communications medium.

Content

In parallel with this unit, you should read, or re-read, the relevant parts of Chapters 1- 4 of W Stallings, "Data and Computer Communications".

The Communication Process

The general communication process implemented by all communication systems can be seen as a solution to the problem:

- How can the information at one place (where it is stored or created) be moved to another place (where it is needed)?

In general, there will be a communication channel between the place where the information is and the place where it is needed. Just thinking, for the sake of an example, of the situation in which one person is speaking to (communicating with) another, it might seem that the communication process can be represented as follows:

- Information source - channel - destination

But this form of representation hides a problem, the basic cause of which is that the form of the information to be sent rarely matches the form in which the channel can convey it. To stay with the example of one person talking to another, the real purpose of communicating is to convey some idea, information or instruction that exists in one person's head to the other person with the aim of getting it into their head. But, as telepathy is not something that most people would claim to be able to do, the idea or information to be conveyed is spoken. The reason it is spoken, rather than anything else, is that, in the form of the air around us, we have a channel that can convey sounds from one person to another. (There are other channels available to us. It is possible to communicate with visible signs that take advantage of the fact that light signals can also be conveyed from one place to another in our everyday environment.) The point is that the information to be conveyed can actually be conveyed only if it is first converted to a form in which it can be carried by the communications medium that is available.

For this reason, a stage is needed between the source and the channel to convert the information from its current form to a form suitable for transmission over the channel. This stage (which is referred to as the transmitter) can be seen as a signal generator that generates signals suitable both for transmission and to represent the information. A corresponding inverse stage (called the receiver) is needed between the channel and the destination to convert the transmitted signals to give back the information in its original form for consumption at the destination. This gives the chain of events in the course of communication as:

- source - transmitter - channel - receiver - destination

There is a second issue, though, in that channels act to distort signals by contaminating them in various ways. Sources of contamination include interference, electrical noise, imperfections in the channel, and so on. These sources can be lumped together and referred to as 'noise'. This gives the overall model for the general communication process as:

- source - transmitter - channel - receiver - destination
- |
- noise

This general model catches the communication process at a high level of abstraction. This process is embedded in just about any communication system one can find. The model captures and links the component parts of the process and also shows why information is not necessarily received in perfect condition after transmission by a communication system.

Example: The Telephone System

The purpose of the telephone system is to allow a person in one place to speak to someone else, no matter how far away they may be. To do this, it has to communicate voiced sounds from one place to another when those places are joined by a telephone line. Now, sounds will not pass directly down a telephone wire (!), and so they must be converted to a signal that will, that is to say, to an electrical signal. This gives rise to the following assignments:

Source: caller's voice.

Transmitter: Microphone in telephone hand set that converts voiced sounds to corresponding electrical signals.

Channel: telephone wire that can conduct electrical signals.

Receiver: 'Loudspeaker' in telephone hand set that converts electrical signals to the corresponding sounds.

Destination: Caller's voice delivered to called party.

Noise can be introduced during transmission in various ways to cause the received signal to differ from that which was sent. The channel can act to distort the signal and electrical noise signals can be added to the transmitted signal. Since the received signal is different from the signal that was sent, the sounds that are communicated will differ correspondingly from the original spoken sounds. The end result is that, as everyone who uses the telephone knows, no one sounds the same on the telephone as they do when speaking directly.

To Do

Now do Review Question 1.

Noise and its Effects

Noise affects the fidelity of communication. By distorting the transmitted signal it also distorts what the signal represents, that is, it distorts what is being communicated. When the receiver converts the received signal to its original form, the effect of the distortion will be apparent at the destination. As we have just seen, when the transmitted signal represents voiced sounds, the effect of noise is an audible difference between what is sent and what is received.

The effect of noise, then, will depend on what the transmitted signal are being used to convey. When visible signals are being communicated, as they are in a television transmission, the effect will be visible.

Often, the message being communicated consists of a string of symbols each of which is drawn from a fixed alphabet. E-mail, for example, requires the communication of a string of alphanumeric symbols. With this kind of message, the effect of noise will be the intermittent presentation at the destination of an erroneous symbol.

The simplest situation of all is data communication, where messages consist of strings of data symbols each of which is drawn from a vocabulary of size two. The two symbols are usually denoted by 0 and 1. This means that a data transmission system has to transmit only two different signals. At any time, then, a data transmission channel is carrying one of two possible signals. The only effect of noise on the transmitted signals that matters in this context is whether it can cause one of the signals to be mistaken for the other. The corresponding effect on data communication is that when a data stream, that is, a sequence of data symbols, is communicated, it is possible that some of the data items presented to the destination will be erroneous.

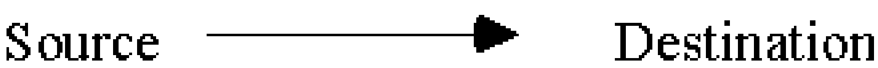
To Do

Now do Review Questions 2, 3, 4 and 5.

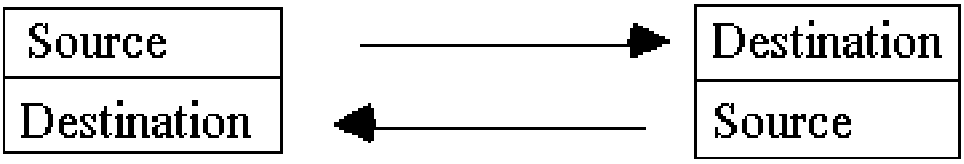
We set aside the issue of noise for the moment to concentrate on signalling. We shall return to the noise problem in the next unit.

The Model as a Building Block

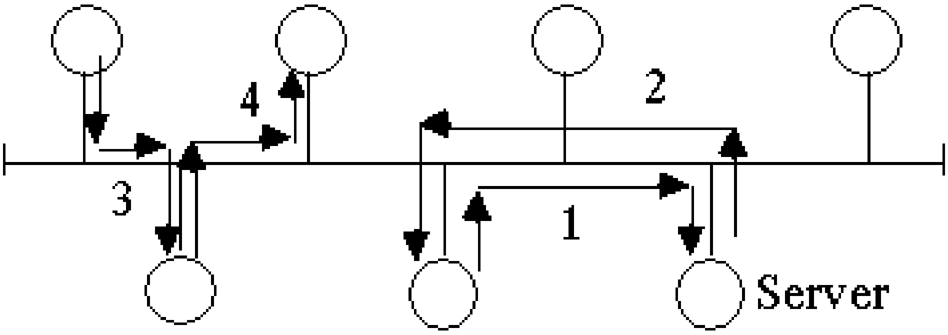
The model presented above actually represents the communication process involved in one-way, point-to-point, communication.



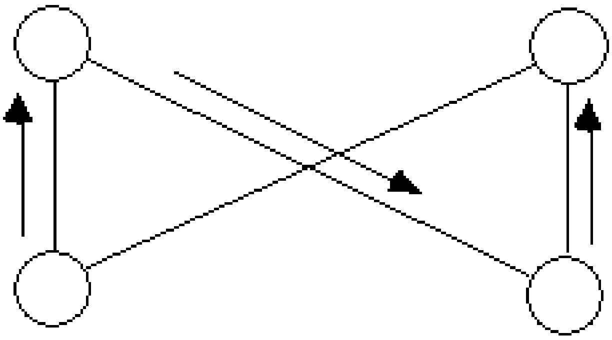
At first, this may seem to be a considerable limitation, but it is not hard to see that the modelled process can be used as a building block with which more complicated communication sessions may be constructed. For example, two-way communication can be constructed like this:



The pattern of communication on a local network becomes sequence of one-way communication activities, such as:



The pattern of communication on a mesh network can be:



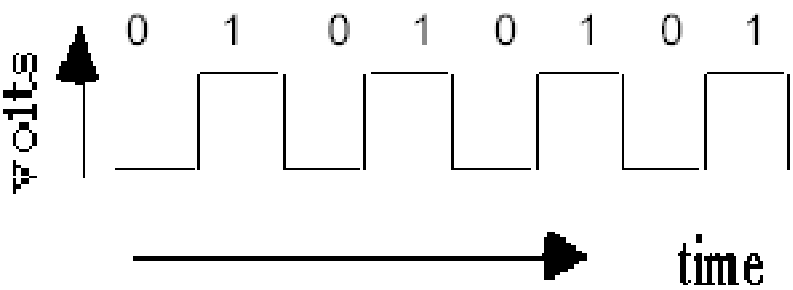
To Do

Now do Review Question 6.

Data Communication

Now consider the situation where data at one place, stored in a computer, is needed at another place, by another computer. Data communication, following the general model of communication, can take place as follows:

1. The data held by the source computer must be passed to its communications interface, from where it can be signalled in a standard form. This involves the use of specific signalling levels (in volts) to represent the data, with one level representing a 1 and the other a 0, and a specific signalling rate (in bits per second). A typical signal emerging from an interface represents the data in the following way:



2. A cable connecting the interface of the sending computer to the interface of the receiving computer can serve as a channel capable of conveying signals between the two computers.

3. At the destination computer, the signals received at the communications interface need only to be interpreted in the light of the standard to recover the data so that it is held by the receiving computer.

To Do

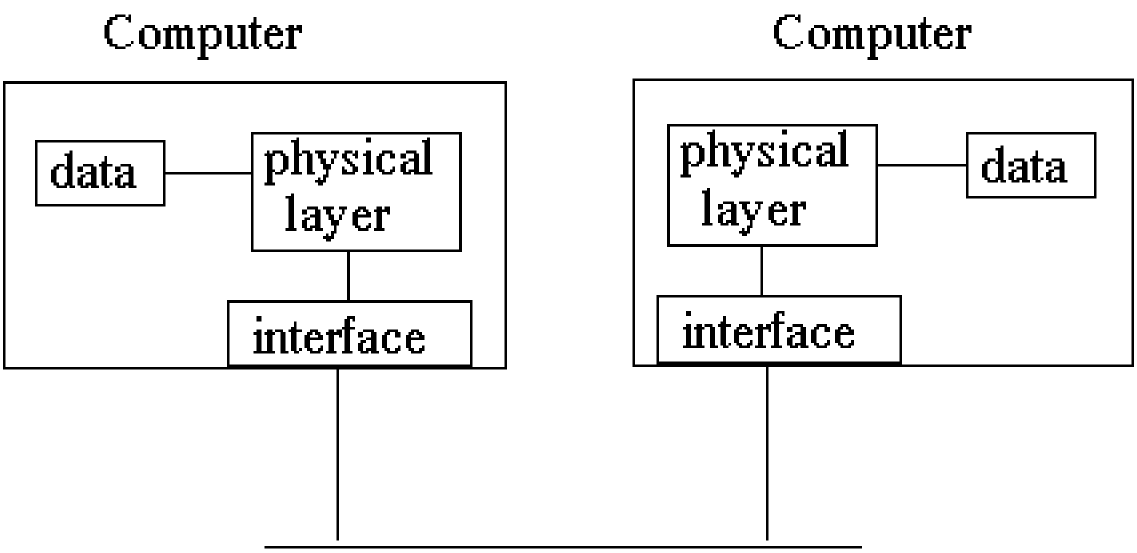
Now do Review Question 7 and Activity 1.

This way of communicating data between computers has certain definite limitations. The effects of noise have deliberately been omitted. More importantly, it has a very limited range of operation. The signals emitted by computer interfaces are usually too weak and of the wrong type to be transmitted to a distant destination over any long-distance communications channel.

The Physical Layer

This section re-describes the method of data communication presented in the previous section as a way of introducing some terminology.

The communications capabilities of a computer are provided by communications software. This software is organised in terms of 'layers'. (A layer fulfils essentially the same purpose as a procedure or object in that it is an abstraction used for structuring software.) The layer responsible for converting data to signals is referred to in the jargon as a 'physical layer'. Its relation to the other entities involved in computer communication and referred to in the previous section, including the data source and the communications interface, is indicated below.



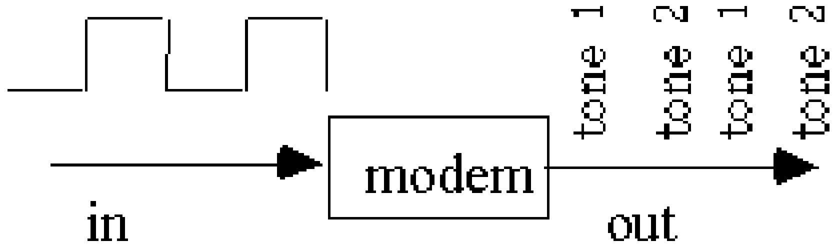
To Do

Now do Review Question 8.

Extending the Range

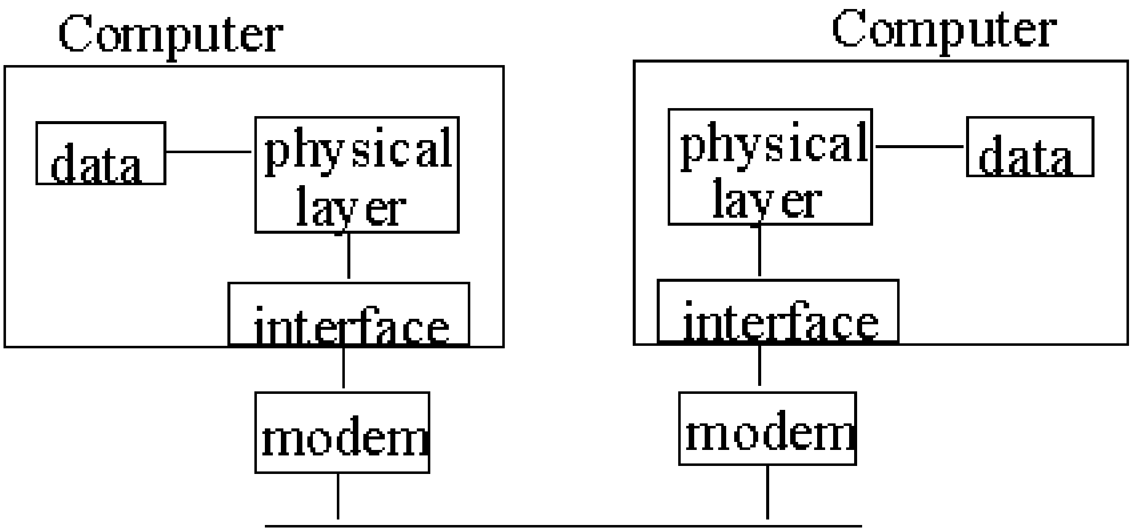
To increase the distance over which data may be communicated between computers, the standard signals from a computer interface can be used as the input to a communications device that can convert them to signals suitable for transmission over a long-distance communication channel. At the receiving end, a corresponding device will be needed to convert the transmitted signals to the standard signal expected by a computer interface.

A typical device of this kind is a modem. It is designed to allow data to be communicated over a telephone line. To do this, in its transmitter role, it accept signals from the computer interface and emits the same kind of signal that a telephone hand set produces in response to spoken input. In fact, the output that most modems produce in response to data input is the same as a telephone would produce if someone sang a 'melody' composed of only two separate notes. (The correspondence is that one note is used to represent a 1 and another for a 0.) In this sense, a modem can be said to 'sing' data down a telephone line. (Although if you have ever picked up a telephone that is delivering data sent by a modem you might object that the effect is not particularly musical.) The relationship between the input and output of a modem can be illustrated in the following way:



At the receiving end, a second modem receives the signals from the telephone network and converts them to signals suitable for the interface of the destination computer, which can accept them and convert them to data.

The overall process is indicated below:



Expressing this process in terms of the general model gives a description of the situation at each stage, and defines the role of each stage in the process required to move the data from one computer to another as:

Source:	The sending computer moves data from where it is held to its physical layer.
Transmitter:	The physical layer generates the corresponding signals and passes them to the interface. From there, they pass to the modem which, in a second conversion, changes the signals to make them suitable for the communications medium.
Channel:	The channel conveys the signals produced b the modem. In general, they will be affected by noise during transmission.
Receiver:	The receiving modem, in the absence of noise, correctly converts the received signals to the corresponding signals for the interface. From

	the interface, they pass to the physical layer of the receiving computer which reconstructs the communicated data.
Destination:	The receiving computer accepts and holds the data.

You should note that, in general, the way that the designers of communication systems cope with the demands of increasingly complex communication processes is to increase the complexity of the transmitter (and receiver).

To Do

Now carry out Activity 2 and Review Questions 9, 10 and 11.

Communications Media and Signalling

The following table lists some typical communication media and the type of signals they carry. Note that the problem of determining which signals to use is a representation problem. One signal is needed to represent a 0 and another to represent a 1.

Medium	**Signal**
Telephone cable	Two electrical signals representing audible tones.
Co-axial cable	Two electrical signals within the range supported by the cable.
Optical fibre	Two light signals, perhaps of different colours.
Air	Two radio signals.

Signal Design

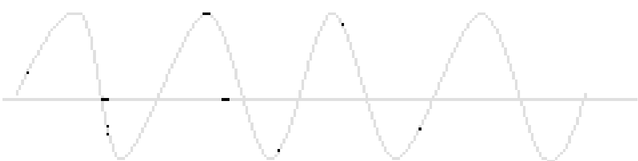
The context for this section is that designing a data signalling system is, on the face of it, a rather simple matter of assigning one signal to represent a 1 and another to represent a 0. And yet this simple task can be done well or badly. A good choice will result in a data communication system that performs much better than one for which a bad choice has been made. A bad design decision will handicap the resulting system forever. Considerations such as this make it important to understand the issues involved in distinguishing good ways of signalling data from bad ones.

As long as noise is not a problem, data can be signalled by using any two signals. One pair of signals is as good as any other. When noise and distortion become important, though, it becomes important to choose the signals with care. In the interests of not confusing one signal with the other, it is a good idea to make the two signals as different is as possible in the circumstances.

Most modems, as we have seen, transmit a signal with one frequency for a 0 and a signal with another frequency for a 1.

Question: How can these two signals be made as different from each other as possible? Answer: A certain range of frequencies is always made available for a transmission and so, within this constraint, the signals can be made as different as possible by separating them in frequency by as much as is possible.

Much of the remainder of this discussion relates to tones. The waveform of a pure tone is a sine wave:



A sine wave has three basic characteristics: its frequency, amplitude and phase. With an audible tone, the frequency determines its pitch and the amplitude its volume. Just as tones in the audible frequency range can be heard because they are sound waves, so tones in the visible frequency range are light waves, and tones in the radio frequency range are radio waves. In this way, the tone gives a way of talking about signals in general regardless of the transmission medium over which they are to be sent.

The signals usually transmitted by a modem have different frequencies, but the same amplitudes and phases. It is possible to produce pairs of signals to represent data by varying any one characteristic while keeping the other two fixed.

Question: What other signal pairs can be obtained in this way?

Answer: A pair of signals with different amplitudes but the same frequency and phase. A pair of signals with different phases but the same frequency and amplitude.

This, at least, indicates that there are various ways to signal data. The different possibilities are needed because techniques that are appropriate for signalling over a telephone wire may not be at all suitable for transmission over, for instance, a radio link.

To Do

Now do Review Question 12.

We can require that the signals in any of these pairs be as different as possible.

Question: How can two signals that differ only in amplitude be made as different from each other as possible?

Answer: One is assigned the maximum possible amplitude and the other zero amplitude.

Question: How can two signals that differ only in phase be made as different from each other as possible?

Answer: The phase of one differs from that of the other by the maximum possible amount, that is, by half a cycle.

To Do

Now do Review Question 13.

The final question in this treatment of data signals is: Which of the pairs of signals you have discussed and drawn is the most different? The answer to this gives the signalling scheme that is most resistant to noise and interference, and so the one that is most likely to deliver data correctly to its destination. The matter is left for Discussion.

At the end of this, you have explored the issues involved in the design of data signals so as to be able to assess or even design a signalling system. It may not always be possible to use the best method, as pragmatic issues such as ease of implementation may intervene. Even so, the trade-off involved in a compromise design can be assessed.

Activities

Activity 1 - Communications Interface

Study the details of a standard interface such as RS232C to ensure that you understand the details of its operation. The details can be found in the recommended texts. If your computer uses another type of standard interface, you can, instead, study it if you want to.

Activity 2 - Modems

There is a whole range of standards for modems. These standards range from those, such as V.21, for modems that are more or less obsolete because their transmission rates are, by current reckoning, slow such as V.90 for modems that operate at speeds up to 56 kbits/sec to broadband speed such as ADSL, ADSL2+ etc. You should familiarise yourself with the nature of these standards and the uses envisaged for various types of modem.

Review Questions

Review Question 1

Map the communication process as it is implemented by the following systems onto the general model.

1. f.m. radio;
2. fax;
3. Semaphore;
4. file transfer.

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

Review Question 2

What are the effects of noise when the following are being communicated, and how important are these effects?

1. television;
2. a computer program;
3. a black-and-white image;
4. a financial transaction.

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

Review Question 3

What is the essential difference between the signals used for the type of transmission required to transmit voice messages using directly corresponding electrical signals, and the signals used for the type of transmission needed when messages consist of strings of symbols?

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

Review Question 4

What is the essential difference between the ways in which fidelity of communication can be assessed in the two situations distinguished in Review Question 3?

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

Review Question 5

Complete the following input/output table. The key words needed in doing this are 'message' and 'signal'.

Component	Input	Output
Source	None	Message
Transmitter	Message	Signal
Channel	Signal	Signal + Noise Signal
Receiver	Signal + Noise signal	(Distorted?) Message
Destination	(Distorted?) Message	None
Noise	None	Noise signal

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

Review Question 6

Explain why the one-way communication events that occur on a local network such as the one illustrated must occur sequentially. Does this restriction apply to communication in mesh networks such as the one shown?

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

Review Question 7

With reference to the components of the general model of the communication process, the cable has been allocated the role of the Channel, but how have the other roles been allocated and where are they located?

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

Review Question 8

With reference to the components of the general model of the communication process, the cable has been allocated the role of the Channel, but how, in the diagram above, have the other roles been allocated and where are they located?

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

Review Question 9

Describe the basic operation of a 'cable modem', that is a device that allows computers to exchange data over a high-capacity cable.

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

Review Question 10

Describe the basic operation of what might be called an 'optical modem', that is a device that allows computers to exchange data over an optical fibre.

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

Review Question 11

Describe in broad terms the operation of a generic device, of which modems, cable modems and wireless modems are instances, that allows computers to exchange data over a channel.

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

Review Question 12

Sketch the waveforms for pairs of signals with:

1. different frequencies only;
2. different amplitudes only.
3. different phases only.

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

Review Question 13

Sketch the waveforms for pairs of signals that are as different as possible from each other and have:

1. different frequencies only;
2. different amplitudes only.
3. different phases only.

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

Discussion Topics

1. Discuss the reasons why a model of communication that applies to the way that human beings communicate directly with each other a good one to adopt when designing the communication systems that we use.
2. One reason for talking about the communication process is that this form of language allows communication to be talked about in the same terms as computing. Any activity that is distributed across a network will have to involve both communication and computing, and will have to integrate them. Discuss the ways in which the use of the term 'process' helps in this integration, and consider whether the use of the term represents a recognition of commonality or an artificial imposition of commonality.
3. Which pair of signals, from all those obtained during the study of data signals in this unit, consists of the two signals that are the most different from each other? What makes some signal pairs more different than others?

Answers and Comments

Review Quetion 1

1. Source: Source of programme material; Transmitter: radio transmitter, including frequency modulation device; Channel: the air; Receiver: radio receiver, including frequency demodulator; Destination: listener. Noise: Radio interference, electronic noise, etc.
2. Source: Source document; Transmitter: fax scanner and transmitter; Channel: telephone line; Receiver: fax receiver and printer; Destination: document destination. Noise: Telephone interference, electronic noise, etc.

Review Quetion 2

1. Impairment to viewed pictures;
2. One error is usually enough to cause the program to fail in some way when it is run.

3. Parts of the image will be black instead of white and vice versa.

4. Could invalidate the transaction, or cause a transaction different from that intended to take place.

Review Quetion 3

Direct transmission of speech requires the transmission of a waveform, that is a continuously varying signal, whereas transmissions representing symbol strings consist of the successive transmission of the pre-selected signals corresponding to the symbols.

Review Quetion 4

With a waveform, fidelity is assessed by the accuracy of the received waveform in replicating the transmitted waveform, whereas with symbols, accuracy is assessed by the rate with which the received symbols successfully replicate the transmitted symbols.

Review Quetion 5

Component	**Input**	**Output**
Source	None	
Transmitter		
Channel		
Receiver		
Destination		None
Noise	None	

Review Quetion 6

On the single channel of a local network, simultaneous transmissions will collide with each other and prevent successful communication. To avoid this, they must take place sequentially. On a mesh network, transmissions can take place in different parts of the mesh at the same time.

Review Quetion 7

The sending computer acts as both the Source and the Transmitter. The receiving computer acts as both the Receiver and the Destination.

Review Quetion 8

The Source and the Transmitter are still located at the sending computer, but the Source is 'data' and the transmitter the 'physical layer'. The Receiver and the Destination are still located at the receiving computer, but the Receiver is the 'physical layer' and the Destination 'data'.

Review Quetion 9

A 'cable modem' accepts signals from a computer interface and produces signals suitable for transmission over a high-capacity cable. (And vice versa.)

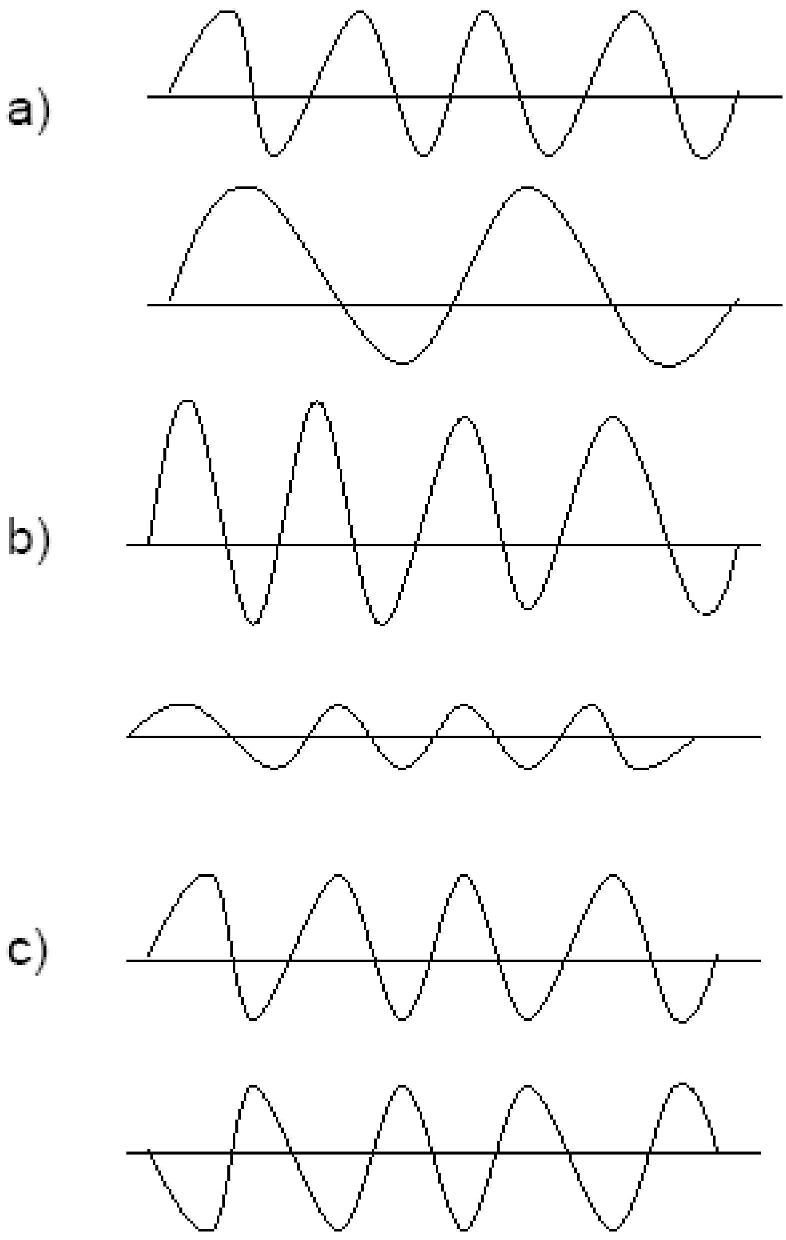
Review Quetion 10

An 'optical modem' accepts signals from a computer interface and produces signals suitable for transmission over an optical fibre, that is light signals. (And vice versa.)

Review Quetion 11

The generic device accepts signals from a computer interface and produces signals suitable for transmission over the available transmission medium. (And vice versa.)

Review Quetion 12



Review Quetion 13