Chapter 6. Local Area Networks

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Introduction to Local Area Networks

Context

his unit follows on from the previous units and, in particular, from units 3 and 4.

Introduction

The comprehension of the Physical Layer and the Data Link Layer obtained after completing unit 5 provide the basis for understanding the operation of local-area networks. A local-area network provides a single channel, usually in the form of a cable, to be shared by the computers attached to it. They communicate by exchanging a formatted frame, which includes a field for dealing with any transmission errors that may occur. The issue that remains is how many computers can share a single channel in some fashion that avoids chaos by ensuring that no more than one computer is communicating over the channel at any time. This is achieved by what is called an access control method.

The topology of the single channel and the access control method are described for the most common local-area networks, including Ethernet and Token Ring local area networks. The impact of the mode of operation of a local-area network on its behaviour is assessed. The forms of behaviour of the common networks are compared with one another, particularly in the context of the typical usage required of and dictated by a local-area network.

With local-area networks, the Data Link Layer is conventionally divided into two parts with one, the Link Layer Control, responsible for assembling a frame, and the other, the Medium Access Control, responsible for gaining access to the transmission medium. Within this expanded view of the layers it is shown how a high-speed local-area network can be easily created with the aid of a so-called Conversion Layer.

Objectives

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

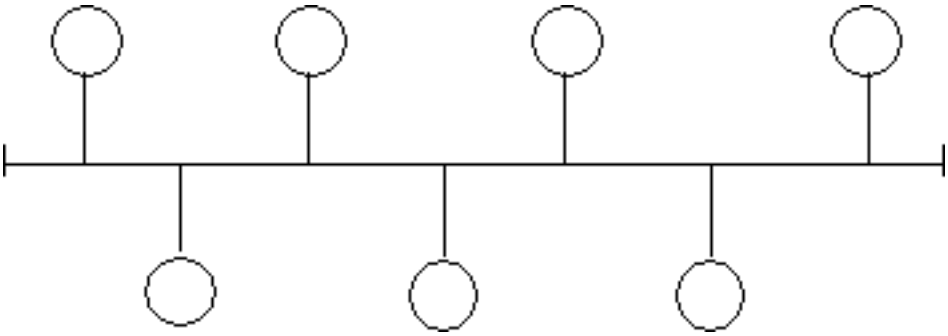
- understand the operation of local-area networks;
- explain the architecture of local-area networks;
- comprehend the operation of high-speed networks and metropolitan-area networks;
- appreciate the relationships between local-area networks and high-speed networks and metropolitan-area networks.

Content

In parallel with this unit, you should read the relevant parts of your textbooks.

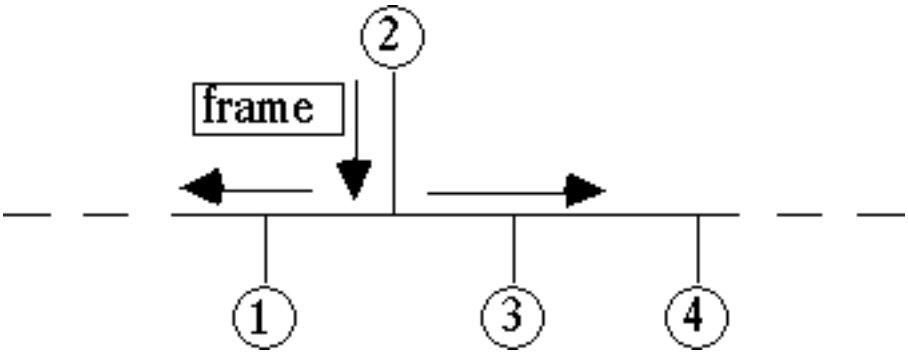
Local Area Networks

With a knowledge of signalling and error handling, we can explain the operation of local-area networks. A local-area network (LAN) provides a single channel (usually in the form of a cable) to link together a number of computers.

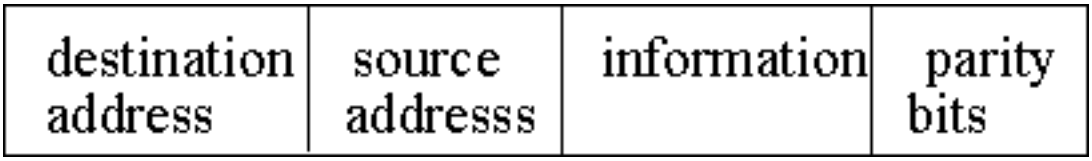


The length of the channel is typically around a hundreds metres, so that the computers attached to the network are to be found in a correspondingly small, local area. When the channel is a simple length of cable with two ends, as shown in the diagram, it is called a 'bus'.

Each computer is assigned an address. Communication between two computers on a LAN takes place by the exchange of a frame[1]. The frame is put onto the cable and, in effect, broadcast to all the other computers attached to the cable.



A frame is a formatted sequence of binary digits. The term 'formatted' implies that the digits in specific positions have particular meanings. A minimal format for a basic frame is:



The destination address is needed so that the frame carrying the information can be delivered to its destination. The source address is needed so that correct reception can be acknowledged or a retransmission requested. The parity bits are present to deal with any errors.

The issue that remains is how to prevent the chaos that would ensue if all the computers attached to the single channel tried to communicate at once. This is dealt with by controlling the access of the computers to the channel.

To Do

Carry out Activity 1.

In fact, a LAN can be completely described by giving the topology of its channel and its means of access control. For the Ethernet and Token Ring, the two most common types of LAN, these are:

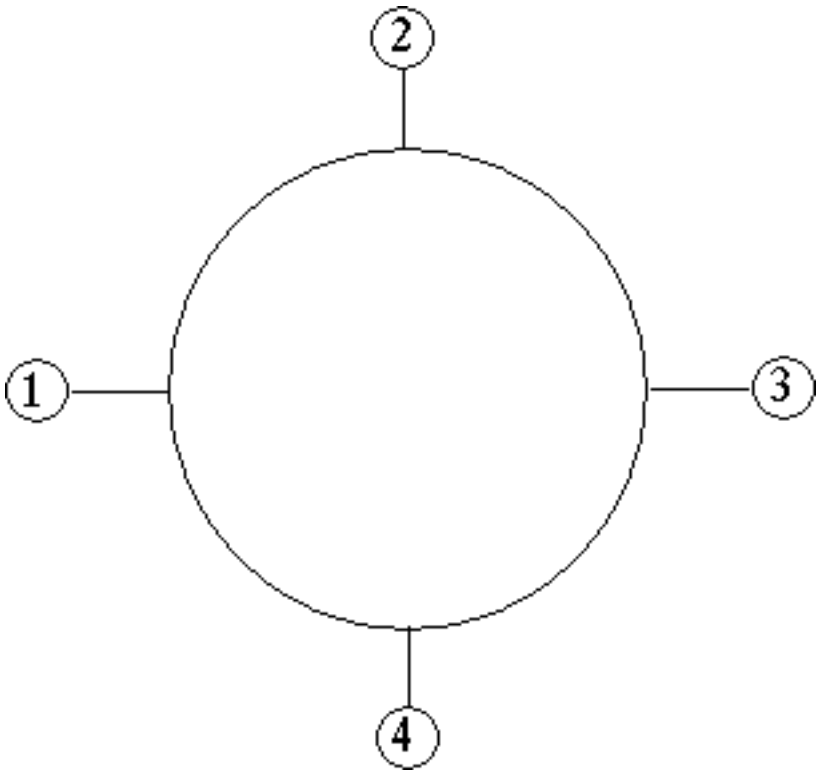
Type of LAN	**Topology**	**Access Control**
Ethernet	Bus	Contention
Token Ring	Ring	Token Holding

To Do

Do Review Question 1.

Token Ring

The channel of a Token Ring consists of a single cable formed into a ring, thus:



A special frame, known as the token, circulates around the ring. Access to the channel is controlled by possession of the token: a computer is permitted to send a frame only when it has acquired the token. When the computer holding the token sends a frame, the frame goes round the ring, passing the destination computer, which receives it by taking a copy. When the frame returns to the sending computer, it is removed. Having sent a frame and removed it, the computer must release the token to give the next computer with something to send its opportunity to do so. If it has more than one frame to send, it must wait while the token completes a lap and returns. The format of the token is:

SD	AC	ED

The format of a frame is:

SD	AC	FC	DA	SA	Info.	FCS	ED	FS

The fields of the token and the frame are:

SD Start delimiter

ED End Delimiter

AC Access Control

FC Frame Control

DA Destination Address

SA Source Address

FCS Frame Check Sequence (parity bits)

FS Frame Status

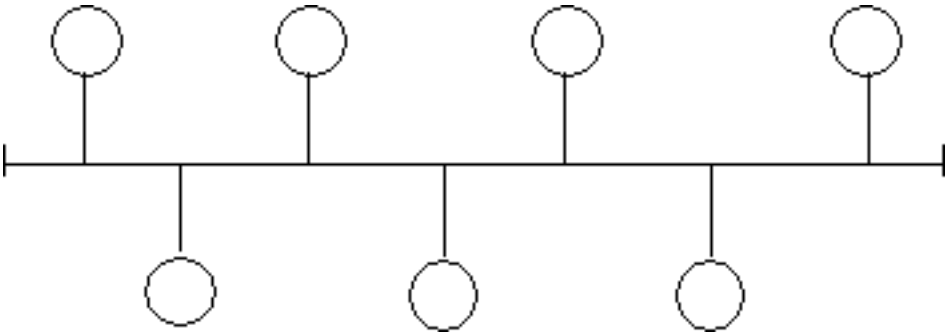
To Do

Do Review Questions 2, 3 and 4.

Carry out Activity 2.

Ethernet

The channel of an Ethernet is a single two-ended cable.



The access method allows a computer to send a frame at any time as long as the channel is free. To do this, each computer with something to send 'listens' to the channel, and as soon as it 'hears' that it is free, it sends its frame. If two computers should ever find the channel free and proceed to send their frames at the same time, their frames will collide. To detect any collision, a computer must continue to listen to the channel after sending a frame. When two computers both detect the collision of their frames, they are required to stop their transmissions and try again later. If they try again at the same time, there will be another collision, and so they wait for times with randomly selected durations, so that the one with the shortest wait 'wins' the chance to go first and, with it, the chance to transmit its frame again.

The format of an Ethernet frame is:

Here, Pre represents a preamble sequence to allow the receiving computer to synchronise with the frame transmission, L gives the length of the frame and, since there is a minimum length, Pad represents any padding that may be needed if the frame is not otherwise long enough.

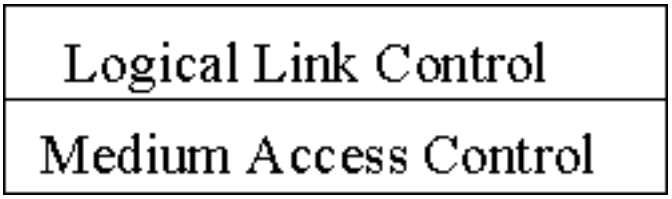
To Do

Do Review Questions 5, 6, 7 and 8.

Now read the relevant parts of your textbooks to fill in the details of the technical operation of an Ethernet.

Data Link Layer

The layer introduced in the previous chapter as an error-handling layer actually has rather broader responsibilities, and is generally referred to as the Data Link Layer. In the case of local-area networks, the responsibilities of the Data Link Layer clearly separate into two categories, and the layer is correspondingly divided into two parts



The upper part, the Logical Link Control, assembles the frame to be broadcast on the channel. This includes the assembly of its Frame Check Sequence to deal with any errors that may occur. The lower part, the Medium Access Control, is then responsible for gaining access to the Physical Layer. This division of responsibilities is clear in the operation of both the Token Ring and Ethernet local-area networks.

Typical usage of a LAN

A LAN is often used to support a group of people working at a common task or individually carrying out similar activities in neighbouring offices or on a small campus. It allows them to communicate with each other, to share the same resources and to store group work where it can be accessed with equal ease by all the members of the group. To facilitate this, one computer on the network (known as the server) is designated to hold the common resources and to store the group work. The items held by this computer are then freely and equally available to the user of any other computer on the network.

To Do

Do Review Question 9.

A comparison of Token Ring and Ethernet LANs

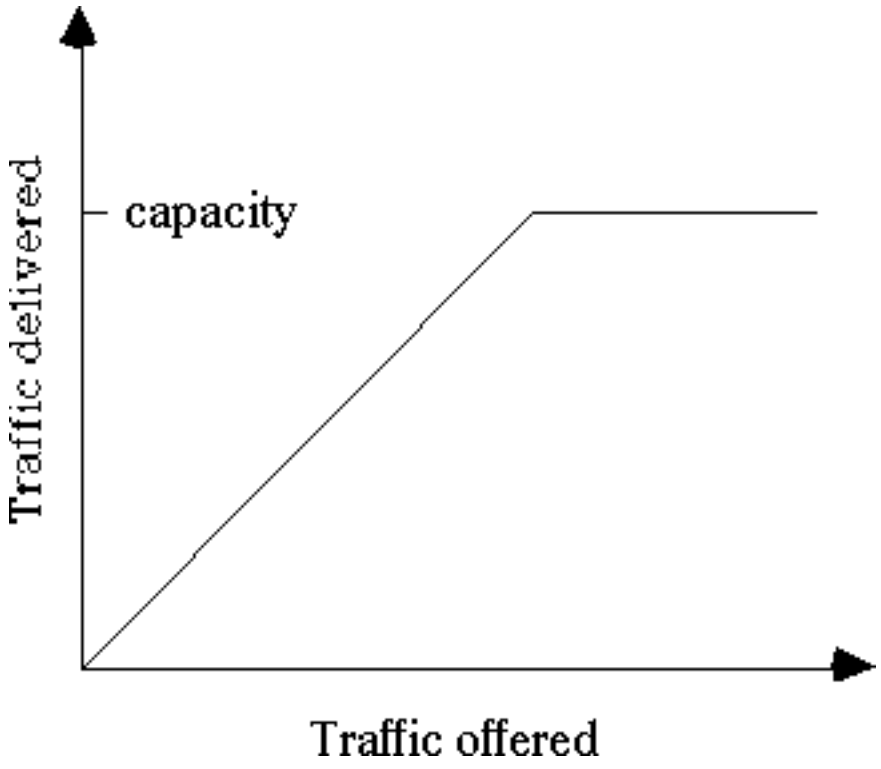
Because the Ethernet and Token Ring local-area networks operate differently, it might be expected that they behave differently. In particular, they might be expected to behave differently in the same circumstances. At this point, the difference in behaviour becomes apparent to the users of the network, and provides a way of deciding which network would better suit a small community of users in certain circumstances.

The following activity provides a way of comparing the performance of Ethernet and Token ring local-area networks in a qualitative manner.

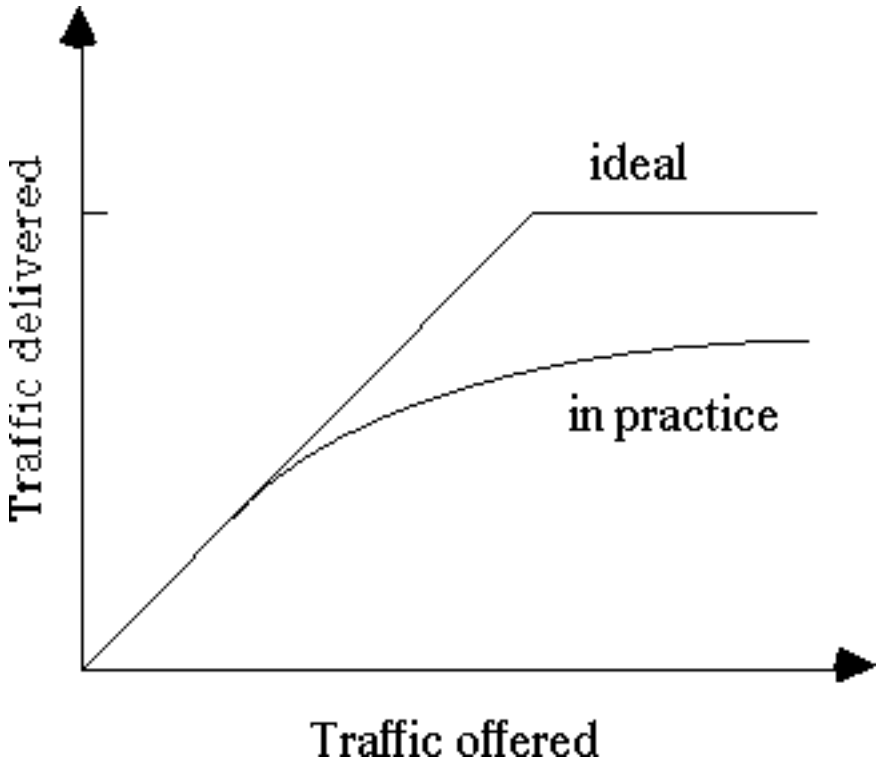
To Do

Carry out Activity 3.

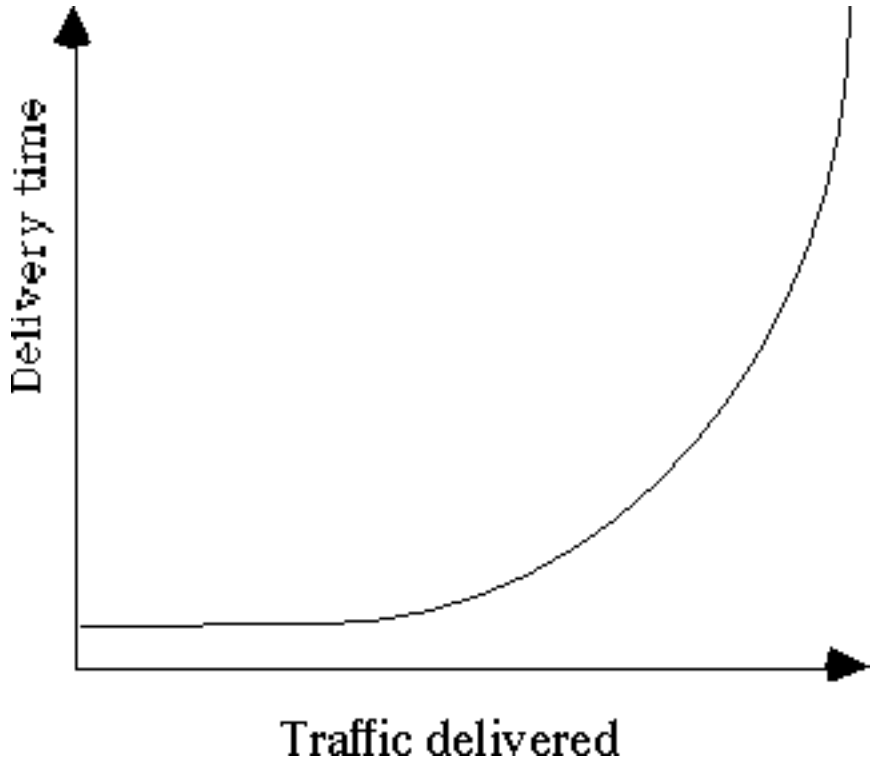
The performance of a local-area network may be captured by relating the amount of traffic offered to it to the traffic it actually delivers. Clearly, if the amount of traffic offered to the network is less than its capacity, it ought to deliver it, while if the amount of traffic offered exceeds its capacity, it cannot deliver it all. This line of thought shows that the ideal relationship between traffic offered and traffic delivered is:



In practice, the performance of a typical local-area network deviates from the ideal as shown:



An alternative way of representing the performance typical of a local-area network is captured by a curve such as that in the following diagram which emphasises a related but different aspect of performance by showing how the time taken to deliver a frame increases as the loading on the network increases.



To Do

Do Review Question 10.

Activities>

Activity 1 - Metaphors for Access Control

Imagine the situation in which a group of people in a small room are all talking at once, but no one can hear anyone else because of all the noise. Can you devise one or more ways of ensuring that only one person speaks at a time? Your systems of control should also be fair to everyone in ensuring that they all get an equal chance to speak sooner or later.

Having devised such a scheme, you have found a means of controlling the access of a number of computers to a single channel. The computers correspond to the people in the room, and the person that is allowed to speak corresponds to the computer that is allowed to use the single channel.

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

Activity 2 - Token Ring Details

Use your text books to find out the details of the fields in the format for a token ring frame. By putting these details together, you can build up a detailed account of the technical operation of a Token ring to any level that may suit you.

Activity 3 - Comparing Ethernet and Token Ring Performance

One station on a LAN has a large number of frames to send. All the other stations have only the occasional single frame to send. Describe the way in which the traffic at the station with a large number of frames to send is treated when the LAN is (a) a Token Ring, and (b) an Ethernet.

What are the consequences of this in terms of the applications for which the networks are suitable?

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

Activity 4 - Convergence Layer

Outline the type of service and activity that you would expect to find within a Convergence Layer.

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

Activity 5 - Metropolitan-Area Networks

How would you decide whether to use single attachment or double attachment to connect a station to a Metropolitan-Area Network? How do you deal with the problems arising from connecting a lower-speed LAN to a higher-speed MAN? What is the main function of the self-healing capability of a MAN and why is it provided?

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

Review Questions

Review Question 1

The channel of a LAN is 100 metres long and has a transmission rate of 10 Mbit/sec. The speed of propagation of signals on the cable can be taken as or 2*10 -7 m/sec, which is a significant fraction of the speed of light. How many bits would occupy half the channel?

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

Review Question 2

The channel of a LAN is 100 metres long and has a transmission rate of 10 Mbit/sec. The speed of propagation of signals on the cable can be taken as or 2*10 -7 m/sec, which is a significant fraction of the speed of light. How many bits would occupy half the channel?

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

Review Question 3

The early standard for the Token Ring insisted that a station may not release the token until it has removed its frame from the ring. Later versions permit the token to be released as soon as a frame has been transmitted. When is this 'early token release' helpful?

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

Review Question 4

What information would you need to determine the longest times that a station must wait for service on a Token Ring?

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

Review Question 5

Why are there a maximum and minimum sizes for an Ethernet frame?

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

Review Question 6

In a bus network is there any equivalent to the Token Ring's frame removal for cleaning up the channel after one transmission to make it ready for the next?

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

Review Question 7

If a bus is not properly terminated, signals are reflected from the termination. What is the consequence of improper termination for the operation of an Ethernet.

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

Review Question 8

What information would you need to determine the longest times that a station must wait for service on an Ethernet?

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

Review Question 9

What exactly is it about, say, an Ethernet that gives it the flexibility to support the needs of any small community located within a small area?

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

Review Question 10

Explain how the curves illustrating aspects of performance of a local-area network in terms of, respectively, Traffic offered and Traffic delivered, and Traffic delivered and Delivery delay, can be related to each other.

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

Discussion Topics

1. Discuss the extent to which local-area networks provide a suitable solution to the communication and resource-sharing needs of a small community sited in one location, and the extent to which local-area networks have been imposed on them as a way of communicating and sharing resources.

2. A virtual network is a network that is physically one thing but seems to its users to be another. How is this virtual status achieved? How could you create local-area networks that are:

   a) a physical bus but a virtual ring?

   b) a physical ring but a virtual bus?

Answers and Comments

Activity 1

The means of deciding who should speak that, in fact, correspond to the access control methods to be described here are:

1. There is a token (a baton, say) that the person who wants to speak must acquire before being allowed to do so. When the person with the token has finished speaking, the token is passed on to the next person.

2. Anyone wanting to speak must wait until the room is silent, and can then jump in. The first person to speak keeps talking the rest must remain silent. If two people should happen to start speaking at the same time, some arbitrary means of deciding who should continue can be adopted.

Activity 3

(a) On a Token ring, the traffic at the station with a long queue, one frame can be sent each time the token returns to the station. The queue will be dispersed after the time taken for a number of token rotations equal to the number of frames in the queue. The information needed to estimate the time taken for one rotation is all available - refer to Review Question 4.

(b) With an Ethernet, the station having the long queue must contend for access with any other station that has something to send. It will keep contending for access for as long as it has a frame to send. It may win round of contention each time it tries to send the frame at the head of the queue and disperse its queue quickly. It may lose the round of contention each time, and never even get its first frame away. All the possibilities between these extremes have a certain probability of occurrence.

The consequence of this is that the time taken by a Token ring for this activity, and correspondingly for any other, is finite and predictable. Some upper bound on the time can be given so that a performance guarantee may be made. With an Ethernet, the time needed is unpredictable. An average time needed may be computed, as may a likelihood that the task will be achieved within some time, but no guarantee can be given that the task will be completed within some time span.

Activity 4

There must be buffers (storage areas) where data can be entered at one rate and removed at another to provide the rate conversions that enable the high-speed channel to connect lower-speed devices at its end-points.

Activity 5

The principle is that single attachment extends one ring whereas double attachment allows for use of both rings and gives access to the self-healing capabilities.

A Convergence Layer can deal with rate differences.

Self-healing capabilities make the network fault tolerant, and are presumably provided because the network may well have to operate in an environment where the causes of the type of fault that can be tolerated are likely to be present.

Review Question 1

At the given transmission rate, it takes 10^(-7) seconds to transmit one bit. In that time, the signal travels 2*10^7 *10^(-7)metres = 2 metres. So 250 bits will take up half of the channel.

Review Question 2

To clean up the ring, leaving it ready for the next transmission.

The sending computer can check for transmission errors and to see that reception has been acknowledged.

Nothing could be done to check for transmission errors, or to deal with them. Reception could not be ensured. More importantly, the sending computer would not know when to release the token.

Review Question 3

When transmission is extremely reliable, so that errors and failure to receive are both highly unlikely.

Review Question 4

The length of the channel; the speed of signal transmission in the channel; frame size; token size; the number of stations attached to the channel; the degree to which each station is busy.

Review Question 5

If frames are too short, it is possible for two computers at opposite ends of the network to send their frames completely before they collide. This makes it impossible to stop a transmission as required by the collision detection procedure. If frames are too long, they become vulnerable to the occurrence of errors and let a transmitting station dominate the network.

Review Question 6

There must be! Actually, the ends of the bus must be properly terminated so as to absorb any signal reaching them. In this way, the broadcast signal is automatically removed from the bus when it reaches the natural ends of its transmission path.

Review Question 7

To a computer 'listening' to the channel prior to sending a frame, the channel will appear to be busy, so that the amount of traffic accessing the channel will drop, perhaps dramatically, from the level it should achieve.

Review Question 8

The length of the channel; the speed of signal transmission in the channel; the frame size; the number of stations attached to the channel; the degree to which each station is busy; the likelihood of a collision.

Review Question 9

A cable can be threaded through any small area to provide a community with connectivity. The server, which allows sharing and co-operation, can then be placed anywhere on the network and be accessible to all the members of the community for whatever they require of it.

Review Question 10

Redrawing one of the graphs so that, say, the Traffic delivered is on the horizontal axis of both graphs, and then overlaying the two shows that the Traffic offered and the Delivery delay are also related, and in fact, shows that the delay in delivery increases as the traffic offered increases.