71 However, data is not redundant and the impairments would result in a certain error rate in symbol reception. Although error control can be incorporated, this would reduce data throughput. Some errors will always arise.

72. Since data transmission over telephone type transmission lines is error prone to a degree depending on data signal speed, the data rate tends to be 'slow-speed' over such lines.

THE DATA COMMUNICATION SYSTEM

73. The data communication system in which terminals communicate with computers and computers with computers in order to achieve specific results comprises much more than transmission services.

74. It involves hardware components such as modems and multiplexors, such components being connected together in different configurations, networks and physical architectures. However the users view of the system, when he accesses files or application programs, will generally be different from the physical appearance. Hence the functional architecture must also be considered.

Types of Network

75. Networks consist of two or more locations (nodes) connected together using communication links. A node may contain any number of communication and computing devices. Networks may be of differing types.

76. Point to Point. The simplest type of network between two points. It may be transitory and exist only for the duration of a call on the switched network or exist permanently as a leased circuit. Commonly used where only a limited number of physically distinct routes are involved and distances are not excessive.

77. Multidrop. Where a large number of locations have to be connected and these can be broken down into geographical clusters, this form of configuration is generally more cost effective (Fig 9.12).

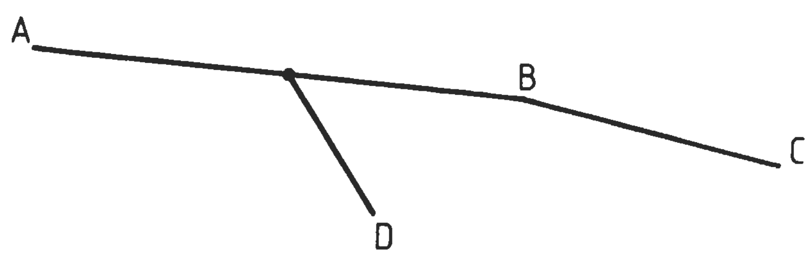

FIG 9.12 MULTIDROP DATA LINKS

78. All transmission from node A can be received by nodes B, C and D. Similarly only node A can receive data from nodes B, C and D only one of which may transmit at a time. Nodes B, C and D cannot communicate directly, only via node A.

79. Multidrop networks are used mainly to connect host computers to terminals or terminal clusters at remote locations and are only available on leased lines.

80. Point to point and multidrop circuits are the basic network components from which practical networks are constructed.

81. Star Configurations. Fig 9.13 depicts a star configuration employing point to point links. Node A represents a central computer site, the remaining letters represent remote terminals.

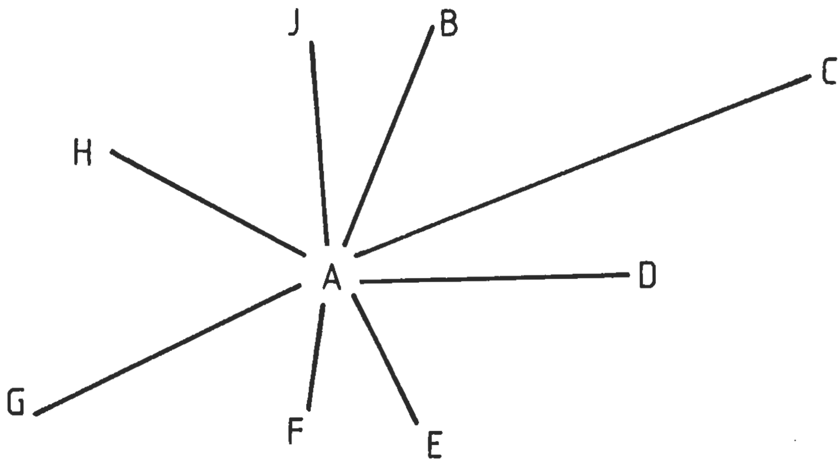

FIG 9.13 STAR NETWORK USING POINT TO POINT LINES

82. This has two major limitations:

(1) The remote devices can only communicate with each other via the central computer which functions as a switching exchange in addition to carrying out its primary processing function.

(2) The network is very vulnerable to failure, either of the central computer or the communication links.

83. Loop Network. There are several variations of loop networks (Fig 9.14):

(1) A closed loop with data links being provided by two-wire leased circuits. Messages are passed between the nodes in the network in one direction only, the host computer, A, controlling communication using 'list polling'. The failure of a single data link will halt all transmission on the loop.

(2) A closed loop capable of supporting transmission in both directions. In the event that a single data link is broken, the host computer, A, will be able to maintain contact with the two sectors of the network. Two data links will need to be broken before one or more nodes are isolated from the host.

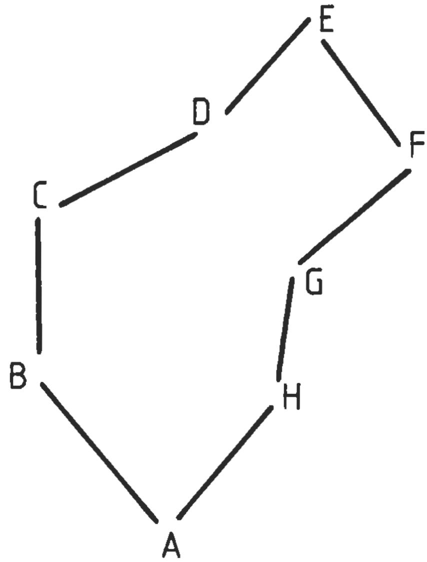

FIG 9.14 A CLOSED LOOP NETWORK

84. Mesh Networks. Mesh networks are mainly used where multiple hosts need connection to multiple slaves (Fig 9.15). In many cases the idea of host and slave is inappropriate as the nodes connected are of equal status.

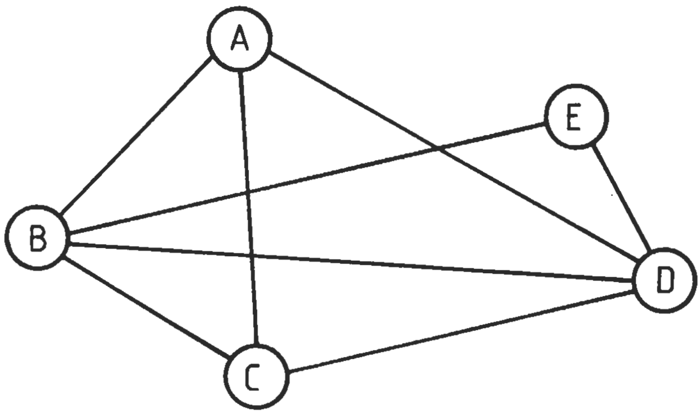

FIG 9.15 MESH NETWORK

85. Mesh networks are very resilient to failure, with alternative data routes being available when data link failure occurs. In many cases this resilience means that users are unaware that a network failure has occurred. Mesh networks are generally very expensive to implement and where circuit lengths are long or data volumes low, a public packet switched service may offer a cost advantage over a private mesh network.

Wide Area and Local Area Networks

86. Local area networks are specifically designed for the interconnection of computer systems and terminals within a single limited geographical area. The main difference between local and wide area networks lies in the technology employed.

87. Wide Area Networks (WAN). Include the PSTN, large private networks and the international network and are widely used for data communications. The quality

of circuit is often variable due to variety of lines used. Date rates are generally low, at Kbps rates, the rates being governed by the line quality. Packet switching is being introduced in the PSTN and will eventually become the normal method of communication.

88. Local Area Networks (LAN). LANs are characterised by:

(1) High data rate (1 Mbps to 50 Mbps).

(2) Low cost and ease of installation.

(3) Simple protocols, compared with those necessary over the longer distances of wide area networks.

(4) Uniform method of attachment for diverse types of equipment ie plug compatibility.

89. All the data traffic within the site can be carried on a single cable, which may be coaxial, twisted pair or optical fibre depending on the system.

90. Two basic data transport mechanisms are used on LANs though detailed implementation varies between equipment suppliers:

(1) Token Ring, specified as IEEE 802.5 standard, equivalent to ISO 8802/5 standard, operates at 4 Mbps on a twisted pair closed loop system. One or more data packets circle the ring, in one direction, being passed between nodes. Should a node need to send a message, it waits for an empty packet, inserts the message addressed to its destination and forwards it. The destination node reads the message and inserts a receipt in the packet. This is passed back to the source node, which empties the packet.

(2) Carrier Sense Multiple Access with Collision Detector (CSMA/CD) - known as Ethernet, specified as IEEE 802.3 standard equivalent to ISO 8802/3 standard operates using a bus structure on a coaxial cable to which all devices connect. It uses baseband communication (ie only one signal may travel on the cable at one time) at 10 Mbps. Any node wishing to transmit first checks to see if any other node is transmitting (carrier present on line). Once the network is free, the node will transmit, while continuing to listen to ensure that no other node is transmitting. In the event of a collision being detected, the node waits a random time before retransmitting.

91. A further network type being developed by industry is the Fibre Distributed Data Interface (FDDI) - a standard issued by ANSI - based on fibre optic cable, token passing methods and a ring topology. The network may be up to 100 km in length and can operate at 100 Mbps.

92. The specification gives dual counter-rotating optical rings giving increased fault tolerance. Use of optical techniques implies freedom from electrical interference, leading to fewer errors in transmission and thus, since less retransmissions are required, the bandwidth is effectively increased.

93. The second ring may be used for concurrent transmission to all nodes or it may be a standby ring connected to selected nodes only.

94. Nodes may be of two types: (Fig 9.16)

Type A - Connected to both rings.

Type B - Connects to one ring only. May be connected into the dual ring by means of wiring concentrators. Vulnerable to any fault in the part of the ring connecting the Type B unit to the wiring concentrator or in the wiring concentrator itself.

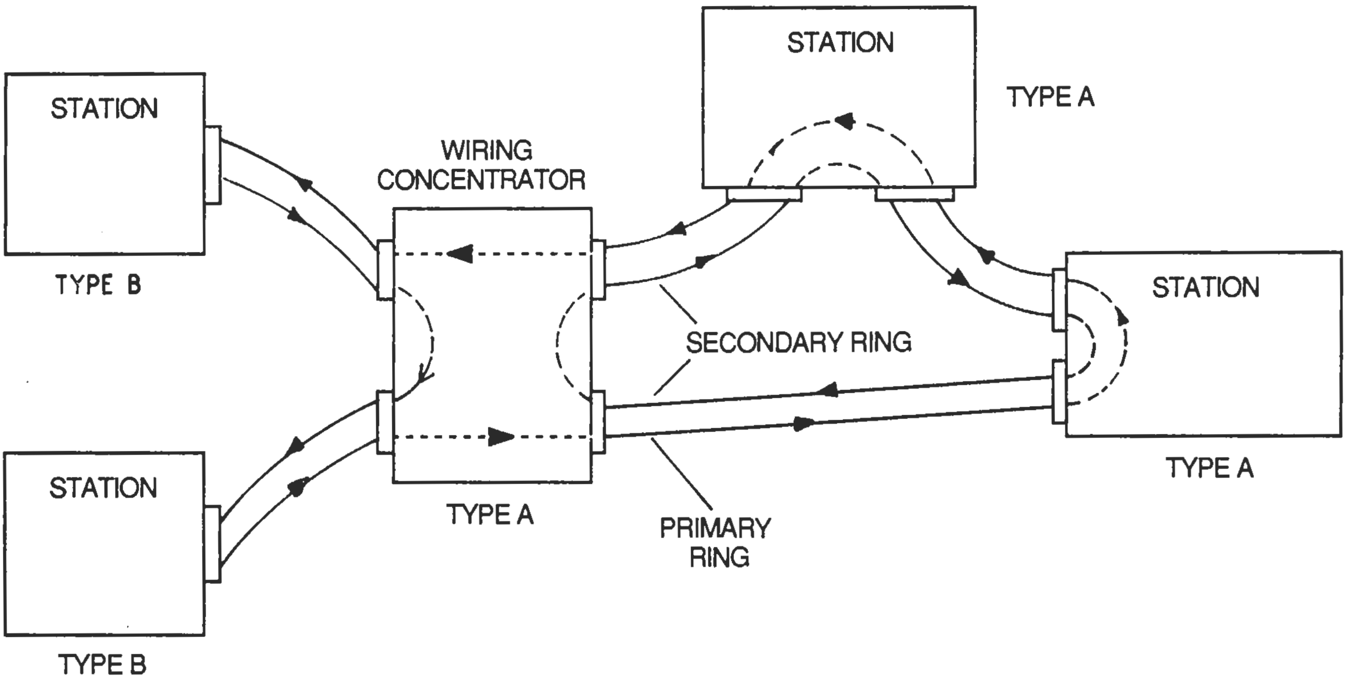

FIG 9.16 FDDI CONFIGURATION

95. The cost of FDDI is high, but it offers much more than the normal LAN particularly in its fault tolerance and maximum length of the network. Such a network may be considered as a Metropolitan Area Network (MAN).

96. Different manufacturers have produced their own local area networks. The international standards bodies are currently considering the area, but an accepted standard for industry is still some way off.

DATA TRANSFER

97. Data transfer regularly involves switching of messages between centres. Typically three well defined approaches may be employed, viz:

(1) Circuit Switching.

(2) Message Switching.

(3) Packet Switching.

98. Each method has its advantages and disadvantages depending on the usage. A summary of these is given in the following paragraphs. Packet switching is discussed in detail in Chapter 10.

99. Circuit Switching. A temporary sequence of fixed point-to-point circuits joined by switching exchanges is established. All links and switches must be available for the duration of the call.

100. Following a possible delay in establishing the circuit, interaction is then immediate, providing both calling and called parties are available.

101. The network is transparent to the users who need only be aware of the procedures for using the facilities.

102. As the load on the network increases, the delays in establishing calls correspondingly increase.

103. Message Switching. Does not require the presence of both calling and called parties. Messages may be transferred when most convenient.

104. The circuit consists of a number of point-to-point links connected by switching exchanges, each equipped with computer processors and memory. Each message must contain the addresses of both destination and origin together with the information.

105. Each exchange reads the destination address and forwards the message only if a suitable outgoing route is available. If not, the message is stored until a route is free. For this reason, the method is often known as 'store and forward'.

106. The method will offer no delay in accepting the message, but delays may result in the delivery time which includes:

(1) The time taken to travel between switches at the transmission speed of the links.

(2) The message handling time at each switching point.

(3) The time taken in store waiting for a suitable outgoing route.

107. An increase in load results in congestion, with the input exchange storing messages until they can be forwarded. Eventually no further messages can be accepted and there must be some restriction on input until output lines are available.

108. The method however, offers increased facilities including:

(1) Equipment speed matching.

(2) Retransmission on error.

(3) Alternative routeing.

109. A large variation in the length of message can be accommodated, the network taking full responsibility for maintaining the integrity of the message.

110. Because delays involved may be of the order of minutes, this method is not suitable for many computer applications.

111. Packet Switching. The main difference between packet switching and message switching is that the message (or data) is broken down into standard fixed maximum length packets.

112. Packet switching is designed primarily for computer to computer communications and has a response that matches the internal behaviour of computers.

113. Chapter 10 gives a breakdown of packet switching principles.

STANDARDISATION OF COMPUTER OPERATION

114. A basic consideration in data communications networks is the transmission of data from one point to another, often one computer system to another. The requirement for clear, unambiguously defined rules is fundamental, since although the systems can communicate with each other, in general they are autonomous and there is no necessary relationship between events at each end of the link. This must be controlled by externally imposed rules, with events at each end being coordinated through the exchanges of control messages and signals. No allowance can be made for discretion and intuition, everything must be clearly defined and rigidly adhered to.

Protocol

115. A set of rules agreed between two parties who wish to communicate so that a meaningful dialogue can take place.

116. Currently standardisation of protocols is some way off. Main frame computer manufacturers and some industries use their own, with the disadvantage that users may feel constrained by the computer suppliers equipment.

117. Because of their different purposes, protocols differ greatly in character. Some consist of little more than a vocabulary of messages for carrying out certain actions. Others may describe the interaction of complex mechanisms which obey mathematical rules.

118. Work on standards is being progressed by the International Standards Organisation (ISO) and CCITT. The ISO in an attempt to provide a framework for

standards proposed the ISO Open Systems Interconnection (OSI) Model. This defines seven protocol levels in an attempt to clarity the scope of the task each level is assumed to undertake.

119. The ISO Open Systems Interconnection Model. The model identifies seven levels arranged as a hierarchy of principal functions:

Level 7 - Application Support	-	Provides user interface to lower levels.
Level 6 - Presentation Control	-	Provides data formatting and code conversion.
Level 5 - Session Control	-	Handles co-ordination between processes.
Level 4 - Transport Functions	-	Provides control of quality of service.
Level 3 - Network Level	-	Sets up and maintains connections.
Level 2 - Link Level	-	Provides reliable data transfer between terminal and network.
Level 1 - Physical Level	-	Passes bit stream between terminal and network.

120. Layered Protocol Hierarchy. In Fig 9.17 the protocol layers are numbered serially starting with the physical circuit.

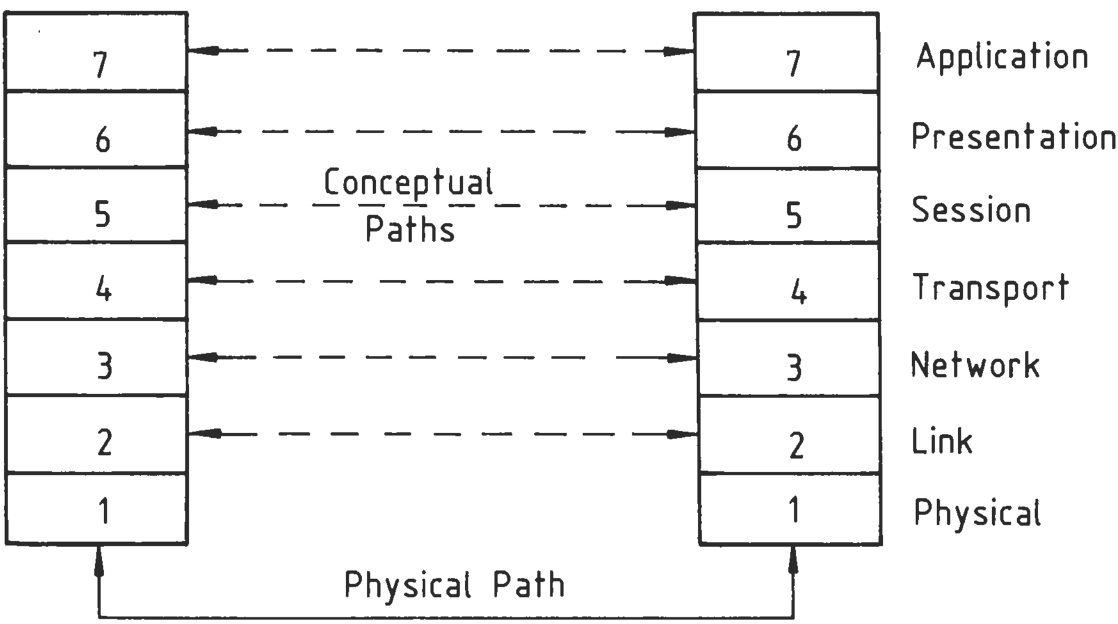

FIG 9.17 LAYERED PROTOCOL HIERARCHY

121. A layered model has several interesting properties. Firstly, no one function or module in a particular layer needs to know how the services it requests from lower layers are actually implemented or is concerned how its functions are used by the higher layers. However the way one layer requests services from a lower layer and the form of the response must be clearly defined.

122. This allows separation of functions, eases design and debugging, allows separate groups of people to write separate parts, ensures clear interfaces between layers and allows each layer to be modified independently. Modification of a layer to keep in line with hardware changes, additional peripheral devices or technology changes is thus relatively simple.

123. A user communicates with an equivalent user at the same level within another part of the network. The data is passed to the next lowest layer in the communication hierarchy, this layer, after processing it, will pass it to the next lowest layer. This passing through the layers will continue until the data has reached the receiving user in the same form that it left the sender. To the users, it appears that they are communicating directly with each other, ie the layers below the users are transparent. Because corresponding users in the same layer appear to communicate meaningfully at that level although there is no direct physical path, we can regard this as a conceptual path. These are indicated on Fig 9.17.

124. At present little has been achieved towards standards at the higher levels (5-7). Implementation of levels 1-3 already exists with X25 recommendations being structured according to levels 1-3.

THE ELECTRICAL INTERFACE

125. CCITT have devised the following nomenclature for use in the context of public data networks:

(1) DTE - Data Terminal Equipment, which could be a computer, a communications processor, terminal controller or terminal.

(2) DCE - Data Circuit - terminating Equipment which provides the interface between DTE and the physical transmission circuit or network.

126. The physical interconnection of data communication equipment lends itself to precise definition and international standarisation has long been in existence.

127. The main standardisation authority for telecommunications is the CCITT which issues recommendations. Adoption of these is not mandatory, but the PTTs generally adopt them to ease interworking with other authorities.

128. The DTE-DCE Interface. The boundary between the DTE and DCE is at the connector by which they are linked. A complete description of this boundary goes beyond the physical attributes of the connector and includes protocol governing the interchange of electrical signals. These signals fall into two categories:

(1) Those which control functions such as switching or seeking or communicating status information.

(2) Those which transport data.

129. As far as the DCE and the communication link is concerned, the meaning and content of data are irrelevant.

130. The majority of DCEs in current use are modems, but as analogue transmission circuits are replaced by digital transmission, many of the modems functions will no longer be required and they can be replaced by some simpler Network Terminating device.

131. The interface specifications of a modem are listed in Table 9.1

Physical Attributes	Logical Attributes
Dimensions and construction of connector.	Meaning of electrical signals on each pin.
Number of pins in connector.	Interrelationship between signals.
Electrical signals on pins.	Procedures for exchanging information between DTE and DCE.

INTERFACE SPECIFICATIONS

Table 9.1

132. These features have all been standardised internationally, the standards being known generally as V24 and RS232 for data transmission over analogue circuits.

133. RS232C is a recommended standard of the US Electronic Industries Association. This standard is in widespread use in America and formed the basis of CCITT recommendation V24 which is common in Europe. RS232C defines all the features listed in Table 9.1. Recommendations V24, V28 and the international standard ISO2110, are jointly referred to as the "V24 interface'. Generally V24 and RS232 can be regarded as synonomous.

134. <u>Interchange Circuits</u>. On a V24 interface, interchange circuits are provided for each signal between terminal and modem. Two sets of interchange circuits exist:

(1) The 100 series used for data, timing and control circuits.

(2) The 200 series used for automatic calling.

135. Of the 100 series circuits, there exists a core of 8 circuits common to many applications. These are listed in Table 9.2.

Circuit V24	Designation	Direction To Modem	Direction To Terminal
102	Signal Ground or common Earth		
103	Transmitted data	X	
104	Received data		X
105	Request to send	X	
106	Ready for sending (Clear to send)		X
107	Data Set ready		X
108/1	Connect data set to line	X	
or	or		
108/2	Data terminal ready	X	
109	Data channel received line signal (ie carrier) detector		X

<u>V24 INTERCHANGE CIRCUITS</u>

Table 9.2

136. A summary of the more common CCITT recommendations are given in Annex A to this chapter.

137. <u>Digital Data Networks</u>. Although analogue transmission circuits and associated modems are scheduled to be around for a long time, most of the world's PTTs are committed to eventually converting their networks to digital transmission.

138. This will be a gradual change with both types of network in use.

139. To this end, CCITT are engaged in preparing recommendations governing the attachment of equipment to digital networks (Annex A gives a summary of the current recommendations).

140. At the level of DTE-DCE interchange circuits the interface is the same for all types of service, including digital leased lines, circuit switched services and packet switched services and is somewhat simpler than a V24 interface.

141. In a digital network, the DCE is not a modem, but rather a form of coder/decoder to put data into the correct form for digital transmission.

142. There are two basic interface specifications defined in CCITT recommendations X20 and X21. X20 is designed for asynchronous terminals giving full duplex transmission up to 300 bps. X21 is designed for synchronous terminals giving full duplex operation up to 48 Kbps.

143. Within these interfaces, the DTE is responsible for all aspects of call establishment and disconnection. A handshake protocol is defined in which DTE inputs the number (address) of the party to be called together with any special requirements. The data exchange responds with instructions and call progress signals, call establishment time being typically less than one second.

Network Components

144. The availability of low-cost microprocessors has resulted in a wide range of network components, ranging from modems and multiplexors which have become very sophisticated to 'black box' devices which can be programmed to perform specialist tasks such as protocol conversion.

145. Modems. The word is derived from the two words MOdulator and DEModulator. The modem is the interface between the data terminal and the transmission channel, which channel may be in the PSTN or a leased telephone-type circuit. Because the PSTN was designed for analogue speech, it is generally incompatible with data because the frequency spectrum of the digital data signals extends from dc to hundreds of kHz. This requires that the spectrum of the data signals be band limited and translated into the passband of the analogue channel.

146. Modem Generations. Since modems are connected to transmission lines, compatibility is essential between modems supplied by different manufacturers. At present, any modem connected to a BT-owned line has to be BT-approved.

147. Modems in current use are of the 4th generation, using LSI microprocessors and associated components to give a complete family of modems each using common chassis size and case.

148. Modems are coded using a 4-digit number to identify functions as follows:

(1) First figure is 4 to indicate generation.

(2) Second and third figures indicate maximum speed of operation.

(3) Fourth figure indicates the facilities/CCITT recommendations to which the modem conforms.

eg: 4th figure = 1 half duplex operation on 2-wire circuits

2 full duplex operation on 2-wire circuits

3 combined V21/V23 asymetrical duplex operation 300/1200 bits half duplex

4 combined V21/V23 full duplex at 1200 bbs on 2 wire circuit

0 non BT specification modem

149. Modem facilities. A number of facilities are available in modems, the particular modem required depending on the facilities required and the circuit to be terminated.

150. Modems may be synchronous or asynchronous, duplex or half duplex, of bit rates from 300-72000 bit/sec. Additional facilities include:

(1) Auto dial - allows the computer or terminal equipment to 'dial' a given telephone number.

(2) Auto answer - allows a dial-up connection to be made without human intervention at the called site.

(3) Auto bit rate selection - during initial handshake procedure the modem samples the data from the remote modem and automatically adjusts the speed.

(4) Multiport options - many higher speed synchronous modems incorporate this option which allows the capacity of the modem to be divided between several ports with the sum of the port data rates being equivalent to the modems rated speed.

(5) Auto standby switching - where a PSTN back up has been provided, the modem is capable of switching automatically from a private circuit link to the standby PSTN line when 'carrier fail' is detected.

151. Multiplexers and Concentrators. When a data network connects a large number of terminals to one or more computers, cost is incurred both in the hardware involved (terminals, modems etc) and in leasing BT or other circuits to carry the data. The second cost is a recurring one and is likely to be substantial over the life of the network.

152. Using multiplexers and concentrators, such costs may be minimised if the network topology allows, by combining the data traffic from a number of terminals, usually at relatively low speed, into a continuous high speed stream which may be transported to the computer by a single data circuit.

153. Multiplexers form a 'transparent' route for the data on a channel ie to the remote terminal, its connection appears directly to the computer. Concentrators on the other hand manage the connected terminals and communicate on their behalf with the computer using their inbuilt buffering capacity to queue inputs to match the capacity of the output line. With the advent of more intelligent multiplexers, the distinction between the two is being eroded.

154 Multiplexing. Two basic methods of multiplexing are used, FDM and TDM. The use of FDM is limited generally to the use of relatively low speed channels over an analogue aggregate link.

155. With the advent of high speed digital links the use of TDM is preferable with each source being allocated the full bandwidth of the channel on a time shared basis. Since the output of data terminals is already digital, the use of TDM greatly simplified the procedure. TDM may be bit-interleaved ie one bit from each channel or character-interleaved ie one character from each channel.

156. Statistical Multiplexers. With basic character-interleaved TDM, each channel is allocated its share of the aggregate output link capacity, whether or not any data needs to be transmitted. Statistical multiplexers extend this concept in that each low speed channel is monitored at the rated speed of that channel, but the aggregate output is only utilised if there is data to be transmitted.

157. The maximum throughput of a statistical multiplexer is the same as that of a basic TDM multiplexer, but whereas the basic TDM multiplexer only reaches its maximum throughput when each low speed channel is operating at maximum capacity, a statistical multiplexer on the other hand serves more less heavily utilised channels to achieve a higher average throughput across the aggregate link.

158. As the combined speeds of the input channels probably exceed that of the aggregate output channel, it is possible that the data flow from the combined channels will exceed the capacity of the aggregate channel. To cope with this eventuality large buffers capable of absorbing short term peaks in demand are provided in statistical multiplexers. The data flow into the statistical multiplexer must be accurately controlled to prevent any chance of buffer overflow.

159. Using statistical multiplexer techniques, it is possible to combine both synchronous and asynchronous input lines at various speeds to give one or more synchronous outputs to the computer.

SUMMARY OF CCITT RECOMMENDATIONS

V Series recommendations, covering data transmission over telephone circuits.

V1	-	Equivalence between binary notation symbols and the significant conditions of a two condition code.
V2	-	Power levels for data transmission over telephone lines.
V3	-	International Alphabet No 5.
V4	-	General structure of signals of International Alphabet No 5 code for data transmission over public telephone networks.
V5	-	Standardisation of modulation rates and data signalling rates for synchronous data transmission in general switched networks.
V6	-	Ditto, on leased telephone-type circuits.
V10	-	Electrical characteristics for unbalanced double-current interchange circuits for general use with integrated circuit equipment in the field of data communications.
V11	-	Ditto, but for balanced double-current interchange circuits.
V13	-	Answerback unit simulator.
V15	-	Use of acoustic coupling for data transmission.
V16	-	Recommendation for modems for transmission of medical analogue data.
V19	-	Modems for parallel data transmission using telephone signalling frequencies.
V20	-	Parallel data transmission modems standardised for universal use in the general switched network.
V21	-	200 Baud modem standardised for use in the switched telephone network.
V22	-	1200 bps full-duplex 2 wire modem standardised for use in the general switched telephone network.
V22 bis	-	2400 bps full-duplex 2 wire modem standardised for use in the general switched telephone network.

V23	-	600/1200 bps modem standardised for use in the general switched telephone network.
V24	-	List of definitions for interchange circuits between data terminal equipment and data circuit-terminating equipment (ie modem).
V25	-	Automatic calling and/or answering equipment on the general switched telephone network.
V26	-	2400 bps modem for use on 4 wire leased point-to-point circuits.
V26 bis	-	2400/1200 bps modem standardised for use in the general switched telephone network.
V27	-	4800 bps modem for leased circuits.
V27 bis	-	4800/2400 bps modem with automatic adaptive equaliser standardised for use on leased circuits.
V27 ter	-	4800/2400 bps modem standardised for use in the general switched telephone network.
V28	-	Electrical characteristics for unbalanced double-current interchange circuits.
V29	-	9600 bps modem for use on leased circuits.
V31	-	Electrical characteristics for single-current interchange circuits controlled by contact closure.
V32	-	9600 bps modem on 2 wire CCTs.
V33	-	14400 bps modem on 4 wire leased circuits.
V35	-	Data transmission at 48 kilobits per second using 60-108 kHz group band circuits.
V36	-	Modems for synchronous data transmission using 60-108 kHz group band circuits.
V40	-	Error indication with electromechanical equipment.
V41	-	Code-independent error control system.
V50	-	Standard limits for transmission quality of data transmission.
V51	-	Organisation of the maintenance of international telephone-type circuits used for data transmission.