Data Transmission and the New Outlook for the Computer Field

By M. V. Wilkes

This paper, which is based on a talk given to The British Computer Society in London on 14 November 1960, describes some of the developments now taking place in data transmission. These are likely to be of immense importance to users of data-processing equipment, especially in the business field.

Data transmission is not new in itself since all forms of telegraphy are, in a sense, data transmission. What is new is the amount of attention now being given to the subject by the telegraph administrations of the world and by the large telegraph companies. Data links are already being used in connection with computers and their number may be expected to grow rapidly.

A conference on Data Transmission was organized by the Benelux Branch of the I.R.E. and held at Delft in September 1960; this conference was concerned with the transmission of data by telegraph channels, by telephone channels, and by radio. It was well attended by telegraph engineers and there were also a number of people from the computer field although perhaps not quite as many as one would have wished.

There are a number of technical questions concerning the transmission of binary signals along a communication channel which fall specifically within the province of the telegraph engineer. These relate to the type of modulation to be used—amplitude, frequency, and phase modulation are all possible—and the way in which the received signals should be demodulated; it is, for example, possible to treat each digit in isolation or, in cases when the received digit is on the borderline between a 0 and a 1, to have regard to the previous digit received. Telegraph engineers are also studying the nature and statistical distribution of errors introduced during transmission. Given this information it is possible to determine the sources of some of the errors and to examine possible measures that might be taken for their reduction.

However, it is agreed on all sides that, whatever success may be had with these measures, telegraph and telephone lines are unlikely to be good enough in their raw state for data transmission. It will be necessary to incorporate them into systems which provide for the detection and correction of the greater part of the errors. This can be done by transmitting redundant information, and using it at the receiving end to detect errors and cause them to be corrected by repeated transmission or otherwise.

Fig. 1 is taken from a paper presented at Delft by Dr. R. G. Enticknap of the Lincoln Laboratory, M.I.T., and gives a good idea of the performance that can be expected from a telephone channel. It shows the results of 23 days' continuous monitored transmission at 1,000 bits per second; the vertical black lines show the observed error rate for each of 23 periods of 24 hours, together with the mean for the whole period. Errors occur either individually or in short bursts and are scattered throughout the day. However, an idea of the meaning of the vertical scale may be obtained from the statement that an error rate of one part in 10^5 is equivalent to the loss of an aggregate time of one second in 24 hours. An examination of the way errors are distributed over the day leads to the conclusion that many of them are due, in one way or another, to the activities of the main-
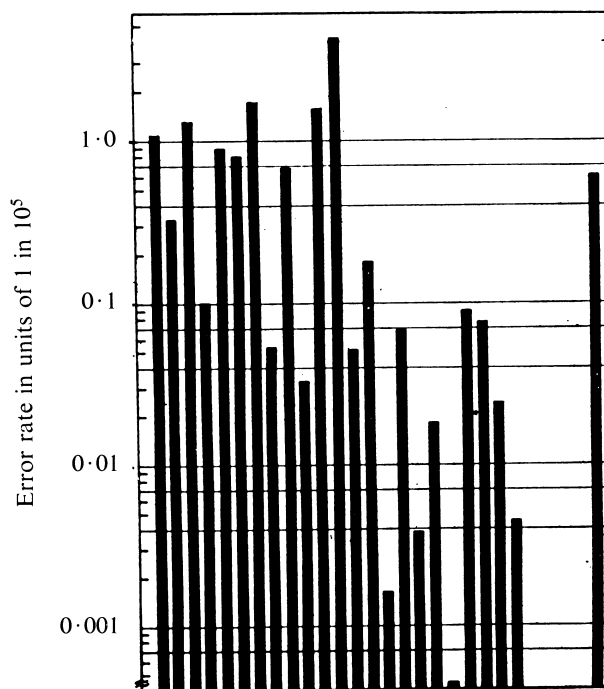

Fig. 1.—Error rate observed on a telephone channel during 23 separate periods of 24 hours, together with the average

(Reproduced, with permission, from "Errors in Data Transmission Systems," by R. G. Enticknap, *I.R.E. Transactions on Communications Systems*, Vol. CS-9, No. 1, March 1961.)

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tenance staff; for example, when working on an adjacent channel a maintenance man might cause vibration to be transmitted to the circuit carrying the data, and this could well give rise to a disturbance if there were a joint or contact not in perfect condition. This diagnosis of the source of errors is confirmed by some results also given by Enticknap for the Hawaian submarine cable, which was found to be approximately 100 times as good as regards error rate. It was remarked by another speaker at the conference that a circuit between London and Glasgow, set up in the ordinary way on the telephone network, may contain as many as 7,000 soldered joints and 6,000 pressure contacts. Perhaps the main conclusion to be drawn from Fig. 1 is that it is very dangerous to base conclusions on error measurements over a period of 24 hours or less. In fact an average over a period of at least a month is required in order to obtain figures having any degree of statistical reliability.

There has been some discussion as to what is the minimum guaranteed overall error rate that can be accepted for data transmission. One error in 10^6 bits is sometimes mentioned as a minimum. Certainly this would give the programmer something to work on, and he could introduce such further checks as he thought necessary. Such checks will undoubtedly be applied, and this fact should be taken into account by computer people when specifying to the designers of data transmission systems what performance they require. For example, the accountant will still want to balance his books, however good the guaranteed performance of a data link.

Control of Errors

Fig. 2 shows ways in which redundancy may be added to binary data in order to permit errors to be detected after transmission. These will be well known to workers in the computer field. The last digit of each row is a redundant digit and is chosen to give odd parity, that is to make the total number of ones in the row odd. This will be referred to as *row parity*. It is also possible, alternatively or additionally, to use *column parity*, that is, to transmit the extra row, shown at the bottom of the figure, in which the digits are chosen so as to make the total number of ones in each column odd. If both row parity and column parity are used we have an example of *two co-ordinate parity*. In practice, blocks may contain anything between 50 and several hundred digits instead of the few digits shown for illustrative purposes in the diagram.

When a block of information has reached the receiving end of a data link, the parity digits are recomputed and the results compared with the digits received; any discrepancy indicates that an error has taken place during transmission or reception. If the parity is correct it does not, however, follow that no error has occurred, since it is perfectly possible for a group of errors to have a self-compensating effect on the parity digits. Row parity is particularly vulnerable, since errors effecting groups of consecutive digits are very common. For this reason,

0	0	0	1	0
0	0	1	0	0
0	0	1	1	1
0	1	0	0	0
0	1	0	1	1
1	1	1	0	1

Fig. 2.—Data coding: row and column parity

in two co-ordinate parity systems, it is better to avoid the use of row parity digits and instead to make use of parity checks applied to digits chosen in some other systematic manner, for example to digits lying along the diagonals. If sufficiently good error detection cannot be obtained with two co-ordinate parity, then it is possible to use three or even four co-ordinate parity.

Another form of error detection is provided by the use of fixed-ratio codes, either by themselves or combined with parity checks. In a fixed-ratio code the ratio of the number of ones to zeros in a row is always the same. An error in transmission can be detected if it leads to an alteration in this ratio. There is, in quite widespread operation on radio links, a telegraph system based on the use of a fixed-ratio code and associated with the name of Dr. van Duuren, head of the Dutch P.T.T. Research Organization. In this system each character of the teleprinter alphabet is represented by seven binary digits of which three are ones. Two channels, one go and one return, are used, and normally each channel carries independent traffic. When a character arrives at a receiver it is tested to see whether it contains three ones and four zeros, and it is printed only if it passes the test. If the character does not pass the test, traffic on the reverse channel is interrupted and a signal demanding a repetition of the incorrectly received character is interpolated. The system is carefully designed so as to take account of the fact that the signal demanding repetition is itself subject to error in transmission. The van Duuren system has been very successful within the limitations imposed by the relatively simple system of redundancy which it uses.

In addition to providing error detection, the two co-ordinate parity system illustrated in Fig. 2 is also capable of providing error correction under certain circumstances. For example, a single error will cause two parity failures, one in a row and one in a column. If it is assumed that there is no other error, the digit affected can be located and corrected. A more efficient form of error-correcting code is that due to Hamming (Hamming, 1950) and illustrated in Fig. 3. All the digits

1	1	1	1	1	1	1
	*	*	*			*
*		*	*		*	
*	*		*	*		

Fig. 3.—Hamming code

are shown as ones although in practice they would be a mixture of ones and zeros. The first four digits are the information digits and the remaining three digits are the parity check digits (this is not the order in which the digits were originally given by Hamming). Each parity digit is chosen so that the four digits identified by the corresponding row of stars shall have even parity. On reception it may be found that the three parity checks are still satisfied; alternatively, it may be found that there are one, two, or three failures, there being seven possible ways in which this can happen. The reader will easily satisfy himself that each of these possibilities corresponds to an error in a particular digit, it being assumed that not more than one error can have occurred. The addition of an extra bit to the Hamming code (a parity bit covering all digits) enables the occurrence of two errors to be detected (but not corrected) provided that it is assumed that the occurrence of three or more errors is impossible.

When multiple errors occur they frequently occur in groups or *bursts*. A burst-correcting code may be constructed by interleaving a number of Hamming codes as follows: A B C D A B C D A B C D . . . Here the letters A represent successive digits of one Hamming code group, the letters B represent successive digits of a second Hamming group, and so on. It will be seen that this code enables a burst of up to four consecutive errors to be corrected provided that it is followed by a sufficiently long period of error-free transmission. Descriptions will be found in the literature of more sophisticated burst-correcting codes (for a survey of the subject see Wier, 1961.)

Codes of the type just described are sometimes called *forward-acting* error-correcting codes and in theory enable accurate transmission to take place over a noisy channel without making use of transmission facilities in a reverse direction. Much effort has gone into their development (this is partly, no doubt, on account of the mathematical interest attaching to the subject), but it is now generally agreed that there is little future in their use for ordinary data transmission purposes. In order to be able to deal with the worst conditions that are likely to be encountered it is necessary to use a code with a high degree of redundancy (50–100% or even more); under normal conditions this degree of redundancy is not required and it unnecessarily reduces the transmission speed.

More satisfactory systems are those which, like the van Duuren system, use redundancy for error detection only and which rely on automatic repetition to ensure accuracy. For data transmission, as distinct from ordinary telegraph traffic, error detection based on a character containing only 7 bits as in the van Duuren system is hardly good enough, and it is necessary to divide the digits into blocks of a substantial size and to use at least two co-ordinate parity.

Fig. 4 shows the block diagram of a system based on error-detection and repetition. Data are fed from the data source (which may be a reader for punched cards
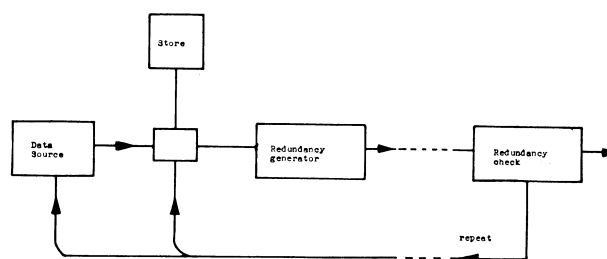

Fig. 4.—Block diagram of system using repetition

or for punched tape, or a magnetic-tape deck) and pass through a redundancy generator where the redundant digits are added. The data are also passed into the store (which may, for example, be a magnetic drum) in which a complete block can be held against the possible need for a retransmission. From the redundancy generator the data are passed along the communication channel to the receiving end. Here the parity digits are checked and if no discrepancy appears the data are passed out to a storage device or possibly direct to a computer. If an error is revealed a signal is sent along the return channel to the receiving end. This signal causes the emission of data from the source to be interrupted, and the store to be connected to the redundancy generator in order that the incorrectly received block may be transmitted afresh. The arrangement illustrated in Fig. 4 is one of a number of variants that are possible; in some of these the redundant information is transmitted in the reverse direction.

Apart from the data source and store, the system just described requires something like 300 transistors at each end. The store could be omitted if the data source were capable of retransmitting a given block of information; this would be possible, for example, with a magnetic-tape unit or with a reversible punched paper tape reader.

The factor of improvement obtained over the raw error rate on a telephone channel depends on the system used for adding redundancy to the data. Enough statistical information about the performance of telephone channels is not yet available for the most satisfactory system to be determined, but it may be said very roughly that row-parity will give an improvement by a factor of ten, column-parity by a factor of 100, and a good system of two co-ordinate redundancy by a factor of 1,000. In all these cases it is assumed that the total amount of redundancy is of the order of 10%. Even on a noisy channel with a raw error rate of 1 in 10^3, the experiments of E. P. G. Wright and T. A. Maguire (Wright, 1961; Maguire and Wright, 1961) have shown that, provided the block size is well chosen, repetitions do not increase the total transmission time by more than 1 or 2%. If the errors were truly random and did not have a tendency to occur in bursts, a two co-ordinate parity system would give a very much greater improvement in error rate, the factor being more like 10^7 than 10^3. This shows how important it is to have adequate

statistical information about the errors that are likely to be generated during transmission through data links.

In order to facilitate re-assembly of the blocks of data when they arrive at the receiving end, it may be found desirable for the redundancy generator to add not only parity digits but also a block serial number. It will probably be found sufficient to use four or five digits for this purpose, the numbers repeating cyclically.

Application to Magnetic-Tape Storage

It may be mentioned in passing that the principles just described have an application to magnetic-tape storage. The statistical characteristics of noise from magnetic tape are quite similar to those of noise from a telephone channel. Most of the tape is extremely good, as the possibility of recording speech and music with a range of more than 40 db shows. Here and there, however, there are slight irregularities which give rise to peaks of impulsive noise of all sorts of amplitudes. There are, in addition, bad blemishes which cause what are usually known as "drop-outs." The latter have been brought under control partly by greater attention to manu-facturing procedure and partly by not using sections of tape containing them. Impulsive noise of smaller amplitude, however, remains, and the signal/noise ratio is in consequence rather poor, even when high class tape is used.

If a read-back head is mounted close to the writing head and used to read back the signals that have been written, then the magnetic tape can be regarded as a data transmission medium, and the "check and repeat" system shown in Fig. 4 can be applied to it. The resulting arrangement is shown in Fig. 5. If a block of data fails to be read back correctly, a signal is passed to the computer which repeats the writing of the block in question. This may be done under the control of a program making use of an interrupt facility. The erroneous information is allowed to remain on the tape and, in this respect, the system differs from others in common use in which the tape is reversed when an error is detected and the erroneous block over-written. Systems of the latter type must be designed so that repeats are very rare, since stopping and reversing the tape is time-consuming. I suggest that if the system advocated here is adopted, and the circuits designed on the assumption that under normal operation 1 or 2% of repetitions will take place, then it should be possible, with a given band width and quality of tape, to obtain a higher performance as regards information transfer rate and effective packing density.

Types of Channel Available

The British Post Office has issued a small brochure (G.P.O., 1958) giving details of channels which can be made available for data transmission.* The cheapest is the telegraph channel with a band width of 120 kc/sec

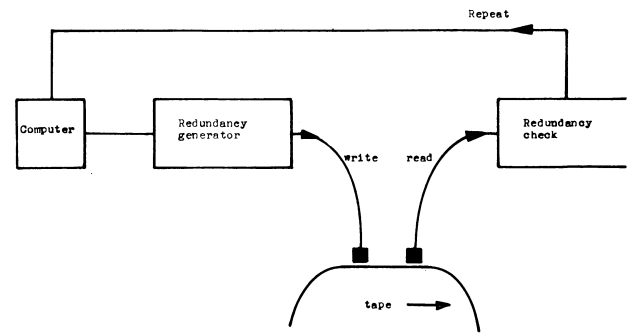* See also the paper by Long and Truslove on p. 34 of this issue.—ED.

Fig. 5.—Application to magnetic tape

and capable of transmitting about 50 bits/sec. Such channels can be hired for continuous private use or can be set up as required through the Telex system. Some organizations have obtained quite successful results using telegraph channels and ordinary teleprinters, but, apart from these being slow, the absence of any error-detection facilities when using the international tele-printer alphabet is a severe disadvantage.

Telephone channels have an unspecified band width and are capable of transmitting about 1,000 bits/sec. Use may be made of such channels obtained through the public telephone network, or, alternatively, a private wire may be rented. The charge quoted for a private wire is £12 per radial mile, and for a distance of 100 miles this breaks even with trunk call charges on the present tariff, if the line is used for slightly more than one hour per day for 300 days a year. For a somewhat higher rental a high-quality telephone channel with a band width of 3 kc/s can be obtained. Private wires, especially if they are of any length, are subject to the development of faults, and from the reliability point of view there is something to be said for using switched circuits since, if a connection fails, another can be immediately obtained by dialling.

The Post Office are prepared to supply channels with a wider band width on request. For example, a carrier group such as is normally used to carry 12 telephone channels and which has a band width of 48 kc/sec could be provided. I have no information as to the rate at which data could be sent along such a channel, but it might be something of the order of 15,000 bits/sec.

Operational Use of Data Transmission

One can get an idea of what a data rate of 1,000 bits/sec means by observing that a photoelectric tape reader reading five-channel paper tape at 200 rows per second produces data at this rate. Similarly an 80-column alphanumeric line printer running at 120 lines per minute absorbs data at the same rate.

The safest way to operate a data transmission system is to run it off-line, and under normal circumstances this would certainly be the most sensible thing to do in the first instance. However, I think there is a future in the direct connection of data links to computers. There

seems to be no reason why a small computer without magnetic tape should not be completely controlled through a telephone channel; it would be necessary to provide means whereby the principal machine controls, such as the start button, could be remotely operated. Similarly, time-shared operation of a large computer might be effected along a data link. Dr. R. W. Bemer made some remarks on this subject in a lecture given to the British Computer Society on 29 September 1960 (Bemer, 1961). He pointed to the development of self-operating systems, in which the machine is controlled not by an operator but by a supervisory program, as making possible developments in remote operation.

There are difficulties about the remote handling of magnetic-tape files, and it seems likely that the remote user (who will naturally be a minority user since otherwise it would be better to remove the machine to the remote location) will either be restricted to problems which do not involve the use of permanent files on magnetic tape or, alternatively, that the files will be stored near the computer and handled as required by local staff. It would no doubt be possible to provide data links of sufficient capacity to enable remote magnetic-tape units to be connected to the computer, but this does not strike me as a reasonable proposition. Magnetic-tape units form part of the machine, and to put them in one place and the rest of the machine in another would be nearly as foolish as having the high-speed store at one end of the country and the arithmetic unit at the other.

The New Outlook

It is difficult to look into the future, but there can be little doubt that data transmission will come to influence more and more the development of computer applications, since it affects so directly the economics of computer application. We all know of computers that are under-loaded despite the fact that the organizations owning them have plenty of work that computers could do, if means could be found of bringing the work and the computers together. We also know that large fast computers are more economical than small slow ones, provided that they can be fully loaded. This suggests that a large centralized computer would be more economical than a number of small computers at scattered locations.

I am, however, very far from wishing to advocate a Utopian scheme in which all the computing of the country is done on a very few super-speed machines. Even if the necessary dictatorial powers were forthcoming, any attempt to establish such a system would fail, as all schemes for the over-centralization of services are bound to fail. I am more concerned with the consequences of the introduction of cheap, accurate, and fast data transmission in an expanding computer field, particularly on the business side. On the scientific side data transmission will undoubtedly be useful in giving research workers access to machines of moderate power when these are not available locally. Scientific research

workers who wish to make serious use of digital computers, however, will always require easy access on an informal basis to very powerful machines. Some apparent inefficiency must, I think, be accepted here. Scientific research, like warfare, is not an operation to which ordinary standards of efficiency apply; the only thing that matters is that the objectives should be attained, and in many scientific fields in the future they will not be attained if the workers concerned are restricted in the computing facilities available to them.

Data transmission will bring data processing to the smaller firms who at present find it beyond their reach. They cannot afford a machine of their own, but they may be able to afford the necessary data-transmission equipment to enable them to have work done at a data-processing centre. Hopes are sometimes expressed that as time goes on digital computers will be produced at prices to suit all pockets, however small. I cannot myself foresee this happening. Apart from the main store and the arithmetic unit, which are essential parts of any computer, a computer intended to handle more than part of the business problem must have magnetic tape or some form of file memory. These are expensive, and small firms do not necessarily have small files.

One very reliable form of data transmission is the postal service. This and similar methods, such as carriage by passenger train, have been used by a number of organizations to provide a link with a data-processing centre. An extreme case was described to the British Computer Society by R. L. Sutton (Sutton, 1960), who described a system in use by an insurance company which had a data-processing centre at its headquarters in Canada; data were regularly sent to this centre for processing from many distant places, including this country. I do not wish by any means to disparage these pioneering efforts which, I am sure, will lead to further developments on a large scale. But in many circumstances the mismatch in speed between the computer and the postal service is really too great. It may be all right when all goes well, but little margin is left for dealing with emergencies. In our private lives we all make use of the postal service for the conduct of our ordinary affairs, but as soon as anything goes wrong we pick up the telephone.

While the bringing of small firms into the electronic data-processing fold will, I am sure, be the most significant result of the coming into general use of data transmission, important possibilities may also be foreseen for large firms whose operations are conducted in many different places. Here much depends on the cost of the terminal equipment and whether it could, for example, be provided on a co-operative basis to serve a number of establishments in the same town.

What I have said will give some idea of the possibilities of data transmission. Anyone who uses computers would do well to investigate the facilities for data transmission now becoming available, and to consider whether he could advantageously avail himself of any of them.

5

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Summary of Discussion

The following points were made during the discussion which followed the presentation of the above paper to The British Computer Society in London on 14 November 1960.

Mr. H. W. Gearing (*The Metal Box Company Ltd.*): For many commercial data-processing operations, the letter post will remain the most efficient method of data collection. Daily batches of data can be assembled and sent in from branches: all the transactions of the day for one branch are received together at head office and processed together. This facilitates the building up of control totals. Teleprinted data would have to be stored at the centre before it could be processed.

Mr. R. G. Dowse (*Dolcis Ltd.*): A great deal of information is transmitted from the branches of a multiple retail trader to its head office. Broadly speaking, information can be divided into two types, financial details and stock information.

Although financial information is obviously of great value, speed is not necessarily vital, and the postal services are usually quite adequate.

In many cases, however, information about stock positions is required in considerable detail, and the quicker it is sent the better. One of the problems affecting the organization of a central warehouse with its connected transport system is the uneven pattern of trade throughout the week. In many types of retail business it is quite common to take 50% of the sales on Saturdays. The effect of this is that on Monday morning in the warehouse there is a big load of information to be digested before branch replenishment can start. If it were possible to transmit stock information during the week-ends which could be received by the central point in a form ready for immediate processing, it would be possible to start the replenishment cycle early on Monday, and thus avoid waste of warehouse labour and transport time.

In cases where deliveries to branches take place only once or twice a week, it is important that the goods despatched should be selected having regard to the latest sales information. Rapid transmission of stock data would assist in merchandizing the branches.

Multiple traders may well have common problems in this field. It is, however, important to remember that shops are comparatively small units and that the capital cost of equipping them with transmitting equipment could be very considerable. There are probably about 250 major shopping centres in the country, and something of the order of 1,000 secondary shopping centres. There would appear to be a case for collective examination of this problem to consider whether it would be worth while to establish shared transmission facilities in each shopping centre. This would cut down the capital cost very considerably, and provided that the transmission centre was established under the aegis of a neutral agency, such as a bank, post office, or railway station, it should be possible to protect the confidential nature of the messages.

Reference has been made to the transmission of information in the form of punched cards, each punched card relating to the sale of one item of stock. Similar techniques are available, of course, in the form of Kimball tags. Although these are valuable, there is a good deal of sorting, gang punching, mark-sense reproducing, and such like operations to accomplish before they can be assimilated into a system. It would seem that in present circumstances the best approach is along the lines of the punched card, until more rapid data transmission methods become available.

Mr. K. G. Brown (*Midland Bank Ltd.*): In the example which Mr. Dowse has quoted, if each box of shoes contained two punched cards, both bearing the stock number of the shoe, then, when a pair of shoes was sold, one of those cards could be despatched by rail parcel service to London the same night. This card could be used during the week-end to prepare lists for the warehouses for commencement of re-stocking the branches on the Monday morning.

The other card could be sent in later by post, with details of the sales staff, so that commission and full branch records could be kept. The first card would act as a check against the second and permit the computing centre to spread their loads. With such a system, I would see no point in the use of line transmission, with its inevitable cost. Line transmission only appears to be

suitable where the data had a high perishable rating, such as bank data, or, possibly, data relating to perishable foods, etc.

(Mr. Dowse stated that they were handling the problem in substantially the manner Mr. Brown had outlined.)

Mr. ————* (*I.C.T. Ltd.*) referred to the use of Kimball tags for recording details of retail sales in footwear and clothing stores, and to experiments which were being made (by certain banking companies) to use closed-circuit television channels for transmission of document facsimiles from a suburban records centre to the counter of branches in the central area of the City. His Company had developed apparatus for recording a London hotel's sales on a number of keyboard devices, which transmitted information to a central automatic key punch, where a 40-column punched card was created for each transaction: this device had been exhibited at the London Business Efficiency Exhibition a few weeks earlier.

Mr. J. W. Mitchell (*Circuits Management Association Ltd.*): At present there are between 200 and 300 main centres of commerce and industry in the British Isles. Most retail stores and large organizations, who would require data-communication systems or networks, have around 250 branches; 250 centres would seem to be a good average. (I am indebted to Mr. R. G. Dowse for this information.)

It would seem that one requirement is a network of communication channels, linking these 250 main centres. With a basic network covering the country, each organization could have a local feeder-link, connecting it to the nearest terminal point. In the majority of cases, this would only be a comparatively short distance. What is then required is a system of switching and timing which would enable the data channels to be available to each of the users in turn.

Whilst I was in the United States of America in 1958, I spent a considerable amount of time studying airline reservation systems and I worked on the Eastern Airlines computer equipment. This equipment included automatic scanners, which searched a number of subsidiary locations, such as desk units, to discover if any of them had a message to transmit to a central computer. When a unit with a message to transmit was discovered, the scanner locked on to that unit and transferred the information via the public telephone network to the central computer. The data was then processed in the computer, and the reply message sent back along the communications channel to the originating source. The scanner then proceeded to search other sources to find the next message to be transmitted.

This equipment has been in operation for several years now, and it would seem that this could easily be adapted for the purpose of scanning various locations and transmitting messages over the data highways. A unit could probably be developed to read from each message the

* It is regretted that this speaker's identity could not be established by the Honorary Editor.

code of the destination to which the message was intended to be passed, and to transmit that message to the final destination when received at the terminal sorting station. This equipment could apparently be developed, using existing techniques.

The most advanced system which was being planned, whilst I was in America (I do not know if it was ever completed) was for United Airlines. They were planning for a network of eight computers, two to be in their head office and the other six located at other positions throughout the United States. These computers were to be linked by a communications network with each other, and with all originating sources, so that, in the event of a breakdown of one computer, the data could be processed elsewhere.

This equipment naturally operates on a fixed message length, but it would seem to be feasible to develop equipment capable of using a message of variable length.

One other installation of which I have heard, whilst in the United States, was for a mining company. In this case punched cards were produced at the mine, to record movement of ore. When the ore-wagon trains left the mine, the cards (punched with quantities and destinations) were transcribed over a telephone circuit to the nearest television station. At the television studio the pulses received over the telephone network were used to modulate a transmission on a television wavelength. At the head office of the mining company, the transmissions were received, and from the modulations recording the data, magnetic tapes were prepared for input to the computer. I did not discover how accurate these transmissions were, but it is possible that the data was transcribed twice over the network in order to provide a comparison at the receiving end.

Mr. T. Fuller (*British Petroleum*): In dispersed organizations a central office continuously receives information on teleprinter lines. Some of the messages may be data for possible computer jobs, but most will not be. If the jobs are to be run on a conventional computer, an operator must collect paper tape from the teleprinters, cut out irrelevant parts, join pieces to form a tape for each computer job, and feed each tape into a computer when the latter is obeying the program for the corresponding job.

It is desirable to eliminate such extensive operator intervention, and one of the more advanced computers under design today would offer a neat solution to the problem. The computer would be capable of holding several programs in a queue with interruption facilities, and all the teleprinter lines would be directly connected to the computer. When information arrived the current program would be interrupted and a supervisory program would be called in, to decide what to do with the information. As a result, irrelevant messages could be sent to teleprinters and printed immediately, while relevant data could be accumulated in a storage area for the appropriate program to use at some subsequent time.

Formerly it would have been prohibitively expensive

to use a computer to perform such a switching function on teleprinter lines; but a computer with suitable interruption facilities would be held up for a negligible time while disposing of the incoming information, so there are now grounds for hoping that the expense would not be great.

Mr. C. C. Dilloway (*Ford Motor Company Ltd.*): We have a rudimentary form of data transmission in operation. Every week for over three years punched cards, mark-sensed with the payroll data for our employees at Doncaster and Southampton, have been sent by passenger train to Dagenham for calculation on our ICT 555 Computers. British Railways, to their credit, have never let us down. The cards are received at Dagenham by Tuesday morning and the payrolls are back at their destination on Wednesday morning.

There is a particular branch of data transmission that is of great interest at the present time and that is data collection. Our studies have shown a real need for an instrument to collect data over our existing internal telephone system. A telephone instrument is inexpensive and there does not appear to be any reason why a data collection device should be more than about the £5 that a telephone costs.

Mr. D. E. Cooper (*The Marley Tile Company Ltd.*): Our Company has been using teleprinters and the Telex system for the past five years for the transmission of data from a number of branches to our head office. The perforated tape is then converted automatically to punched cards, which are then processed in our large central punched-card installation.

As the majority of our work is based on a monthly cycle, for the first three weeks of the month the perforated tape and page copy produced on the teleprinters are sent through the normal post in suitable containers. During the last week of the month it is transmitted via the Telex service using auto transmission. This enables us to take advantage of rapid input to our punched-card installation at the most important time, yet keeps our costs to a minimum.

With reference to accuracy of transmission over Telex circuits, we have found it to be thoroughly practicable. In our experience transmission is 100% correct or 100% incorrect. In the latter case it is immediately apparent to the operators concerned, because it is completely incomprehensible, and is inevitably corrected by clearing that line and reconnecting to the branch concerned.

Mr. I. V. Idelson (*Mullard Ltd.*): Progress in the U.S.A. has been very fast in the last year and, for example, over two thousand Dataphones have been installed, nearly all for commercial applications. However, the nearest approach to the kind of large interruptible computer installation that Dr. Wilkes foresees is, I believe, the installation projected for scientific purposes by the Massachusetts Institute of Technology. They are hoping to finish the TX2 successor by the end of 1961 or early 1962 and this machine, the FX1, will be a very big, fast machine—internally 70 megapulse. They are hoping to connect it up to perhaps 500 input/output mechanisms

so that any scientist at M.I.T. can have instantaneous access to the machine. These scientists will probably be divided between two locations some 20 miles apart. M.I.T. say that their greatest difficulty is the high cost of available input/output equipment (e.g. electric typewriters) and its unsuitability for the kind of work they want to do, which really demands a larger set of symbols than they can obtain.

Mr. J. Rhodes (*G.P.O. Engineering Dept.*): Firstly, I should like to congratulate Dr. Wilkes on giving a very fair summary of the Transmission Engineers' problems in Data Transmission.

I should like to comment on Dr. Wilkes's remark that the error rate on the private (leased) circuit was not likely to be so good as that of a connection over the switched public network. We should expect that the error rate on a private circuit would be definitely better than on a switched connection since the elimination of the switching equipment, which may produce spurious noise pulses, would reduce the error rate. However, circuits do become faulty at times, and in the case of a private circuit it would be out of service until a repair could be effected. If the data transmission is over the switched public network, however, all a subscriber has to do is to re-dial the call. He is almost sure to select another circuit and he can immediately repeat the transmission.

With regard to error rates on the Telex network, the Post Office Engineering Department have carried out intensive and prolonged error rate tests embracing the whole network of the United Kingdom, and the results show that the average error rate is somewhere between 1 in 20,000 and 1 in 40,000 characters.

As regards the use of the switched public telephone network for medium-speed data transmission, the Post Office at the moment propose only to provide the terminal modulator and demodulator, leaving freedom for manufacturers of data-processing equipment to provide the necessary equipment for the error control, i.e. the equipment for the error coding, detection, and correction of errors. In this respect, the Post Office is willing to provide the manufacturers of such equipment with information on tests that have been made, over the switched public telephone network, concerning the error rate and the incidence and distribution of errors.

We foresee that the problem of data transmission will have international repercussions, and the International Telephone Consultative Committee (C.C.I.T.T.) has formed a special study group on Data Transmission which it is hoped will lay down some basic standardization for world-wide application. This study group held its first meeting in March of this year, when it was able to make two recommendations, one concerning the power levels that may be used on telephone-type circuits, and the other concerning the equivalence between binary notation symbols and the significant conditions of a two-condition code.

Mr. E. P. G. Wright (*Standard Telecommunication Laboratories Ltd.*): The diagram showing the variation in error rate from day to day illustrates very well the

difficulty which exists in defining the amount of disturbance one may expect. I think it is the general experience to find that the error rate during the afternoon is about an order better than it is in the morning, and about an order worse than it is during the lunch hour.

It is a complication for the designers of error-detection systems that the errors tend to arrive in bursts rather than as a random distribution. However, it is also wrong to consider that most of the errors are grouped together because evidence shows that the majority are independent, but the minority tend to occur in bursts.

Dr. Wilkes has explained the simple process of transmitting redundancy with the data in the forward direction in order to allow the receiving station to check whether any error can be detected. It is interesting in some applications to send the redundancy from the receiving to the sending station for checking there; if this is done, without interrupting the forward transmission of data, the effective bit rate is greater than with "forward" redundancy.

A considerable interest has been indicated in data collection and data distribution systems. It is rightly claimed that the out-station equipment must be relatively cheap. The design of a system of this type does not appear to introduce any serious technical difficulties,

but I regret to say that our own efforts have taken much longer than we expected.

Mr. A. C. Croisdale (*G.P.O. Engineering Dept.*): The van Duuren A.R.Q. system is extensively used on Commonwealth h.f. radio links and we have a large number of equipments working in London. However, for data transmission on land-lines it is unnecessarily complicated and expensive; a two-channel terminal equipment costs about £4,000.

The Post Office is developing a cheaper device, suitable for the transmission of data over the U.K. Telex system; this equipment will either detect errors for manual re-transmission, or at more cost, detect and correct errors automatically. It is intended that, for transmission of data, a Telex call shall be established using the normal Telex equipment; and then the data equipment will be switched on to the circuit, permitting the use of any type of code providing only that the code does not produce "false clearing" of the automatic Telex call; this could occur with a continuous period of "start" polarity exceeding about 200 msec.

The Post Office has carried out extensive tests to determine the error rate likely to be met on all types of telegraph circuit and statistics of error rates will be supplied to anyone who is interested.

British Productivity Council

The One-Day Conference on Integrated Data Processing, which was held in London in February, is to be repeated on Wednesday 24 May in the Assembly Hall of Church House, Great Smith Street, Westminster. Tickets are £6 6s. 0d. for the day and include luncheon with wine at St. Ermin's Hotel, also a copy of the EPA Mission Report, with which the Conference is principally concerned.

The speakers will be:

Mr. Brian A. Maynard, President, E.P.A. Mission on IDP to U.S.A. (1960).
Mr. John A. Goldsmith, Editor of Mission Report.
Mr. W. F. Brackman, Gillette Industries Ltd.
Mr. Denis S. Greensmith, Boots Pure Drug Co. Ltd.
Mr. K. F. Turner, Rolls-Royce Ltd.

The chair will be taken by Sir Walter Puckey.

Applications for tickets, enclosing a remittance of £6 6s. 0d. per ticket and giving the name and position in the organization being represented (for each delegate), should be sent to:

IDP CONFERENCE,

BRITISH PRODUCTIVITY COUNCIL,

VINTRY HOUSE,

QUEEN STREET PLACE,

LONDON, E.C.4.

The Conference is being organized in conjunction with BCAC, BIM, and ICWA. (The EPA Mission Report was reviewed in *The Computer Journal*, Vol. 3, p. 236.)