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DATA SWITCHING IN AN EXPERIMENTAL PCM SWITCHING SYSTEM

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ABSTRACT

This paper proposes a new structure of a partially integrated digital switching network for data and telephone traffic (PINDATE). A hierarchical network is considered as an example. The structure regards the fact that even in the 1980's the number of data subscribers will be only some percent of the number of telephone subscribers. This communications network is based on the CCITT 30/32 PCM-system.

Data subscribers with different bit rates (all classes according to CCITT recommendations and high speed data subscribers) and different transmission modes (asynchronous with start-stop as well as synchronous) can be connected via this switching network.

The paper shows in detail the principles for the multiplexing of asynchronous or synchronous data signals, respectively into one speech channel (64 kbps) of a PCM-system.

The main aim of this paper is to present a new solution for an economic and traffic flexible, partially integrated switching network which avoids the deficiencies of both, fully integrated or fully separated telephone and data networks, respectively.

1. INTRODUCTION

The demand for telephone and data communication has been growing rapidly during the last years. Investigations show an increase of 10 up to 20 percent per year /1,2/. However, the number of data subscribers will be even in the 1980's only some percent of the number of telephone subscribers /3,4/. Therefore it is worthwhile to investigate a solution which integrates the different types of data traffic at least to a certain economic extent in one integrated communications network for telephone and data.

Today the main technical reasons for the operation of separate data networks are the following features of the public telephone networks:

- the relatively high error rate ($\approx 10^{-5}$ per bit) /5,6/
- the limited data rate in dialled data connections (less than 4.8 kbps)
- the set-up time which may exceed the holding time of a short data connection.

These three objections could be eliminated if the analogous telephone network is replaced by a network with digital transmission and fully electronic digital switching. Then it seems to be possible to use this integrated communications network economically for all types of traffic, i.e. telephone and data.

In /12/ an experimental local PCM-switching system was presented based on the CCITT 30/32 channel system. This paper now deals with the extension of this telephone PCM-system to the additional use for data traffic.

In Section 2 a survey of the different data rates is presented, covering the field of

- slow asynchronous data rates from 50 bps up to 200 bps
- medium speed isochronous data rates from 600 bps up to 48 kbps
- fast isochronous data rates with > 48 kbps.

Section 3 deals with principles for multiplexing the different types of data rates to a synchronous 30/32 PCM-system. Section 4 describes the concept of the experimental PCM-telephone switching system. The structure of the partially integrated switching network for data and telephone traffic PINDATE is presented in Section 5. Hereby the emphasis is put on concentrating and switching of data connections with a bit rate of ≤ 48 kbps. The signalling necessary for call establishment and disconnection is described in Section 6. The paper is concluded with a brief consideration of switching high speed data rates with > 48 kbps.

2. TYPES OF TRAFFIC

Whereas PCM-telephone traffic is characterized by a uniform bit rate of 64 kbps, there exists a great variety of different bit rates originated by a great number of different data terminals. Some typical bit rates are shown in Table 1.

traffic type	bit rate kbps	transm. mode	remarks
telephone	64	isochronous	
videophone	$16 \cdot 10^3$	isochronous	bit rate with source encod. prob. ≈2Mbps
user class *)			
1	0.05	asynchronous	TELEX, I.A. No.2
2	0.2	"	} I.A. No.5
3	0.05...0.2	"	
4	0.6	isochronous	
5	2.4	"	
6	9.6	"	
7	48	"	
fast data transmission	> 48	isochronous	e.g. computer communication
image service	$1 \ldots 10^3$	isochronous asynchronous	e.g. facsimile, computer graphics /7/

*) according to CCITT recommendations /8,9/

Table 1: The most important types of traffic in an integrated communications network.

Data connections with a bit rate less than 48 kbps need only a fraction of one PCM-channel with 64 kbps of the 30/32 PCM-system. Therefore some of these slower data connections can be multiplexed to one PCM-channel.

Because of the use of an envelope structure (cf. Section 3) data subscribers with a bit rate of 48 kbps require a full PCM-channel with 64 kbps. In so far they can be switched like one telephone connection.

Connections between data subscribers with a bit rate higher than 48 kbps need more than one channel of a 30/32 PCM-system. In the near future bit rates of up to 1.44 Mbps are of interest; these connections will occupy up to a whole frame.

Digital videophone transmission will have a bit rate of up to 16 Mbps, which may be probably reduced to 2 Mbps, if source encoding will be applied. These connections require therefore at least one frame. In this paper videophones are not regarded in detail, because today a widespread application cannot be foreseen and the problems of source encoding are not yet solved sufficiently.

3. MULTIPLEXING AND SYNCHRONISATION OF DATA SIGNALS

One PCM-channel has a bit rate of 64 kbps and each word within this channel consists of 8 bits. Therefore an envelope structure with 6 data bits and 2 additional bits for synchronisation and signalling (6+2 envelope) will be applicable /10/. Thus a maximum bit rate of 48 kbps is available for data transmission within one PCM-channel. Data connections with bit rates less than 48 kbps (user classes 1 to 6 of Table 1) need only a part of one PCM-channel. As it will be shown later the slowest bit rate which has to be multiplexed is 600 bps. This bit rate requires only every 80th word of one 48 kbps channel ($\frac{48}{0.6}=80$). Therefore 80 frames of the considered 30/32 PCM-system are composed to one s u p e r - f r a m e (cf. Section 3.1) with a period of $125\ \mu s \cdot 80 = 10 ms$ /16/. Analogously for data connections with bit rates greater than 48 kbps (cf. Table 1) a s u b f r a m e structure (cf. Section 3.2) is obtained.

3.1 Superframe Structure for Data Signals with ≤ 48 kbps

3.1.1 Isochronous Data Signals

A data channel with 600 bps within the superframe will be defined as a s u b c h a n n e l. Thus the isochronous data signals need the following number of subchannels (Table 2):

user class	synchronous bit rate	number of subchannels
4	600 bps	1
5	2.4 kbps	4
6	9.6 kbps	16
7	48 kbps	80

Table 2: Number of subchannels for isochronous data signals

3.1.2 Asynchronous Data Signals

Asynchronous data signals according to user classes 1 to 3 (Table 1) have to be converted to synchronous signals to be transmitted via a PCM-system. A principle for asynchronous to synchronous conversion will be presented in Section 3.5. Applying this principle the following corresponding synchronous bit rates are necessary for the transmission in the PCM-system (Table 3).

user class	asynchronous bit rate	synchronous bit rate	number of subchannels
1	50 bps	600 bps	1
2	200 bps	2.4 kbps	4
3	50...200 bps	2.4 kbps	4

Table 3: Number of subchannels for asynchronous data signals

3.2 Subframe Structure for Signals with > 48 kbps

Regarding signals with >48 kbps different user classes of data rates are possible. Up to now these bit rates are not specified by CCITT. Therefore a new switching system should be able to switch different high speed bit rates. Corresponding to the highest bit rate the 125 µs frame of the PCM-system has to be subdivided into the corresponding number of subframes. One example is shown in Fig.1, where the PCM-frame is split into 4 subframes, i.e. 4 channels of the 30/32 PCM-system are combined to one channel of the subframe.

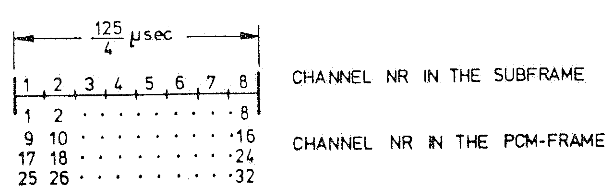


Fig.1: Example of a subframe structure for 192 kbps

One channel within this subframe is able to transmit the bit rate of a connection with 4·48 kbps=192 kbps or of two connections with 96 kbps or of four connections with 48 kbps, respectively. Combinations of 96 kbps and 48 kbps are also possible.

3.3 Multiplexer for Isochronous Bit Rates with < 48 kbps

In Fig. 2 the multiplexer (MUX) for the s u p e r f r a m e structure is shown. This MUX combines a certain number of connections with different bit rates to o n e 48 kbps data stream.

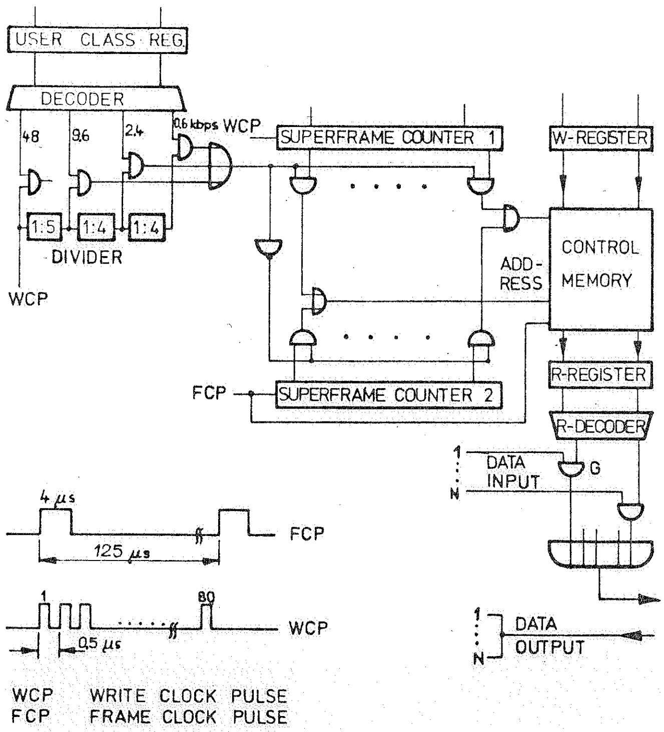


Fig.2: Multiplexing of isochronous data with different bit rates into one PCM-channel

To establish one 600 bps connection, the position number of the subscriber which is to be connected to the MUX is placed into one of the 80 cells of the control memory. The address of each memory cell corresponds to the subchannel number to be occupied. In case of a 2.4 kbps or 9.6 kbps connection this subscriber address is entered in the memory 4 or 16 times, respectively.

The connecting to the PCM-channel via the MUX is done in the following way:

- the subscriber position number is placed in the write register (W-REGISTER)
- the superframe counter 1 is set to the selected subchannel number. In case of data connections with more than one subchannel it is the lowest subchannel number
- the user class number is entered in the user class register
- by means of the divider the subscriber number is stored in the control memory as often as subchannels are necessary for the corresponding bit rate (user class).

These subscriber position numbers are read out of the control memory cyclically every 125 µs by the superframe counter 2. Then via the R-decoder the corresponding gate G is opened to shift 8 data bits into the PCM-system.

This shift operation is done by the frame clock pulse FCP during the time interval of one PCM-channel (125/32) µs ≈ 4 µs. Thus (125-4) µs=121 µs remain for the MUX control to enter or to clear subscriber position numbers for connection or disconnection. This is done by the aid of the write clock pulse WCP.

The timing of the clock pulses of the two superframe counters are shown in the lower part of Fig.2.

The number of data subscribers N may be greater than the number of 80 subchannels in which one PCM-channel is divided. So the MUX performs also the function of traffic concentrating.

3.4 Subchannel Hunting Strategies for Data Traffic with Different Bit Rates Offered to One PCM-Channel

In order to explain the strategy concerning the hunting of the 80 subchannels within the superframe, the subchannels are arranged as shown in Fig. 3. The numbers in this figure represent the 80 subchannels in consecutive order. For example, one 9.6 kbps connection needs every fifth subchannel in the superframe, e.g. the subchannels 5, 10, 15 ... 80.

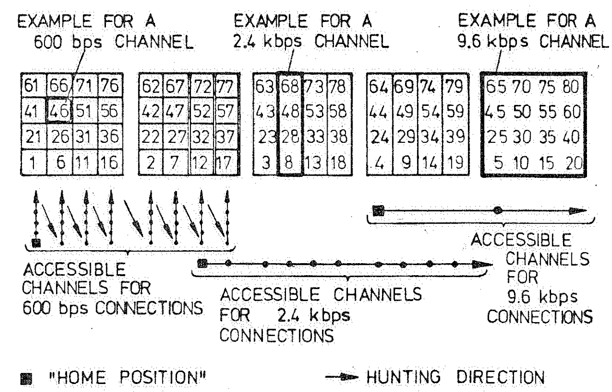


Fig.3: Accessible channels and hunting strategies for the different data rates offered to one PCM-channel

To achieve a good efficiency of the PCM-channel a suitable hunting strategy is necessary. If the subchannels were selected at random, already five 600 bps connections (e.g. in the subchannels 1, 2, 3, 4 and 5) could block the considered PCM-channel for any 9.6 kbps connection even if the remaining 75 subchannels were idle. By means of the hunting strategy shown in Fig. 3 this can be avoided. This holds also for the case that all the three different data rates start hunting at channel No. 1 in the first block of the left hand side.

On the other hand, five 9.6 kbps connections occupy all subchannels and no other connections can be established. Therefore for reason of service protection /11/ not all subchannels should be accessible for all data rates. For each data rate one has to prescribe a certain part of accessible subschannels depending on its offered traffic.

In Fig. 3 the 600 bps connections have access to 32 subchannels with a hunting order as shown in the figure; 8 out of these 32 subchannels are accessible for 2.4 kbps connections. The 2.4 kbps connections have access to further 32 subchannels, i.e. ten simultaneous connections of this traffic type are possible at most. The 9.6 kbps connections have access to 32 subchannels, 16 out of these 32 subchannels are commonly accessible for the 2.4 kbps connections. Therefore, a maximum of 2 simultaneous 9.6 kbps connections is possible.

The individual "home position" for the hunting of the subchannels can be chosen fixed or can vary as a function of the offered traffics.

Moreover, subchannels may be allocated permanently to a subscriber (leased circuits).

The efficiency of a PCM-channel with data traffic could be further increased, if the 2.4 and 9.6 kbps connections would not require equally spaced subchannels within each superframe as shown in Fig. 3. But the allocation of randomly spaced subchannels to one data connection would be only possible, if the MUX has buffer memories for storing all bits, arriving at each data input during one superframe. Furthermore, the control information transfer between exchange to MUX (often located in a remote concentrator) will increase considerably, as the number of all subchannels, allocated to one connection, must be transmitted for the set-up of this connection.

3.5 Multiplexing and Demultiplexing of Asynchronous Bit Rates

Asynchronous data, transmitted in the start-stop mode, cannot be multiplexed directly to a subchannel. Polarity reversals occur at any instant and the bit rate can vary within tolerated limits.

One possibility to synchronize asynchronous bit rates is the sampling method. But in order to obtain a small signal distortion, a high sampling frequency and more subchannels are necessary.

Considering a 50 bps data rate, a sampling rate of 2.5 kbps would be necessary to get a signal distortion less than 2 percent. For the transmission of the corresponding 2500 sampling values five subchannels with 600 bps each would be required for one 50 bps asynchronous data connection.

More efficient are principles with "time encoding". Every polarity reversal is encoded with one polarity bit and the number of that time interval during which the reversal occurred.

These time encoded reversals are multiplexed into a subchannel of one PCM-channel with such a rate that at least every reversal is transmitted.

The following method for time encoding is suggested which is also useful for transmission as well as for the switching of data connections in PCM-exchanges.

As within an 8 bit envelope six information bits are available one of them will be used for the polarity bit and the remaining five bits for time encoding. Fig. 4 shows this method applied to a 50 bps asynchronous data flow.

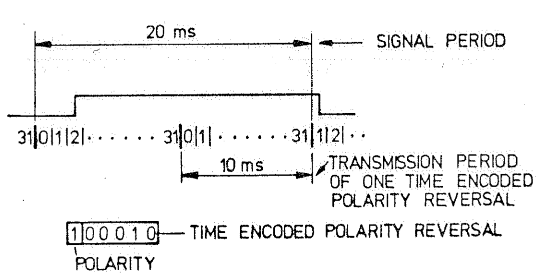


Fig.4: Time encoding shown for the example of a 50 bps asynchronous data rate

As these envelopes are transmitted every 10 ms, the resulting bit rate is 6 bit/10 ms = 600 bps. This corresponds to the bit rate of user class 4. The signal distortion amounts to 10 ms/(20 ms$\cdot 2^5$) = 1.6 per cent.

This small signal distortion is tolerable, even more because transmission per se does not affect the signals any longer.

A block diagram of the synchronization/desynchronization equipment is shown in Fig.5.

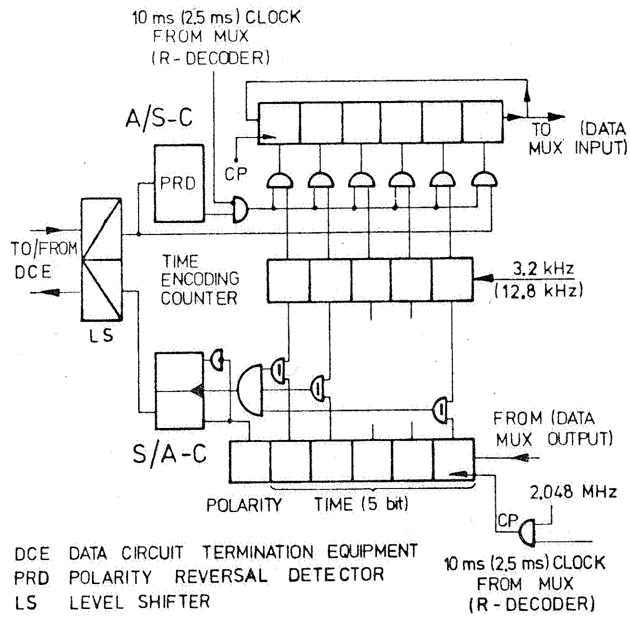


Fig.5: Asynchronous to synchronous (A/S-C) and synchronous to asynchronous converter (S/A-C) for a data rate of 50(200) bps

In the upper part the asynchronous to synchronous converter (A/S-C) is depicted. The polarity reversal detector causes the new polarity together with the time interval to be entered in a shift register. Every 10 ms this register is read out by the MUX with the 2.048 MHz clock pulse. The enregistration is delayed during the 4µs shift period of the register.

If no reversal occurs within one period of 10 ms the preceding envelope is given once more to the MUX. Since this envelope contains the same polarity as the preceding envelope, a time evaluation is not required.

The counting clock pulse is 3.2 kHz for 50 bps and 12.8 kHz for $\leq$ 200 bps.

The synchronous to asynchronous converter (S/A-C, lower part of Fig. 5) regenerates the polarity reversals. The polarity bit and the time interval number are shifted in a register by the MUX. If there is a match between the time counter and the time enregistrated, a flip-flop is set according to the polarity.

3.6 Multiplexing and Demultiplexing of Isochronous and Quasiisochronous Bit Rates

Isochronous data terminals need additional interchange circuits between MUX and terminal. Signal element timing is transmitted continuously by the MUX. The character alignment will be performed by a frame timing interchange circuit. This circuit defines continous 24 bit sequences, i.e. three characters of No. 5 Int. Alphabet. However, fixed or variable delay time equalizers are necessary for data connections with higher bit rates.

Quasiisochronous terminals can be connected to the network by the aid of pulse stuffing circuits. Control information can be exchanged by a preceding mutual transmission of synchronization ("SYN") characters. As these terminals, however, should be replaced by isochronous terminals according to the CCITT recommendations /9/, they are not regarded in the following.

4. THE EXPERIMENTAL PCM-TELEPHONE SWITCHING SYSTEM

In /12/ an experimental PCM-switching system was presented. The structure of this system is the basis for the integrated communications system for speech and data to be discussed in the next section.

The block diagram of this switching system is shown in Fig. 6.

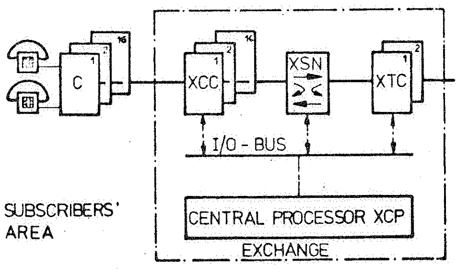


Fig.6: The local PCM telephone exchange TLE

The subscribers are connected with the central switching network XSN exclusively via concentrators C. To each concentrator a maximum of 512 telephone subscribers can be connected.

Each concentrator is linked to an individual concentrator control circuit XCC within the exchange via two 30/32 PCM-systems.

This XCC controls the concentrator; it is a peripheral device of the central processor XCP.

The trunk control circuit XTC, individual for each outgoing PCM-system, performs a similar function with regard to the outgoing/incoming PCM-systems to/from other exchanges.

Both control circuits, XCC and XTC, are microprogrammed.

The main advantages of the use of XCCs and XTCs are:

- to relieve the central processor XCP from many routine switching functions
- to reduce the number of control informations of the XCP to and from the concentrators
- to increase the reliability of the exchange by this partial decentralization. (Because of smaller and simpler control processors, one gets a smaller MTBF).

4.1 The Concentrator C

The concentrator has the following tasks:

- to scan the telephone subscribers (off-hook and on-hook e v e n t s)
- to concentrate the subscriber lines by means of a space division link system to 60 channels. (This link system is controlled by the XCC).
- to convert the audio frequency signals to PCM signals and vice versa
- to receive the dialled digits (MFC), to convert them to binary digits and to transmit them to the exchange
- to perform auxiliary functions such as synchronizing, transmission-error-detection, etc.

4.2 The Concentrator Control Circuit XCC

For the establishment of a call the XCC of the calling subscriber performs the following tasks :

- to occupy an idle channel between the XCC in the exchange and a digit receiver of the C
- to switch the connection from the subscriber to this idle channel through the concentrator link system
- to mark the calling subscriber busy by means of an individual state flip flop in the C (now the calling subscriber is disregarded by the subscriber scanner in the C until he goes on-hook)
- to send the dial-tone to the calling subscriber
- to hand over control to the XCP as soon as the subscriber starts dialling.

The XCC of the called subscriber performs the following functions:

- to connect the called subscriber to an idle channel
- to send the ringing-tone and to disconnect it when the called subscriber goes off-hook.

Similar functions are performed in the XCCs if a connection terminates.

4.3 The Trunk Control Circuit XTC

The main tasks of an XTC are :

- to occupy an idle channel to another exchange
- to handle signalling informations to and from the neighbour exchange

4.4 The PCM Switching Network XSN

The switching network XSN carries the internal traffic (to and from the Cs) as well as the external traffic (to and from other exchanges).

4.5 The Central Processor XCP

The main tasks of the XCP are:

- to process the dialled digits
- to hunt a path through the XSN
- to perform special facilities (e.g. abbreviated dialling)
- to supervise the XCCs and XTCs.

5. THE INTEGRATION OF DATA TRAFFIC IN THE PCM-SWITCHING SYSTEM

5.1 Forecast of Data Terminals Requirement in an Integrated Communications Network

To integrate the data traffic in the considered PCM-telephone system it is necessary to know the quantity of data terminals to be connected with the communications network. Of special interest are figures of

- the data subscribers within the area of a telephone exchange with 10,000 subscribers and
- the data subscribers within the area of a telephone concentrator with 500 subscribers

In Table 4 these expected figures for the year 1985 are presented for the FRG with reference to /1/. In this table the user class No.1 includes also the large number of the TELEX stations, using Alphabet No. 2, although this type of service is no longer recommended by CCITT. As in the FRG about 90,000 TELEX stations exist, this service has still to be regarded also for the long run. (The suggested time encoding of Section 3.5 is applicable to any type of digital alphabet and not restricted to International Alphabet No. 5).

traffic type	average number of data subscr related to 10,000 telephone subscribers	average number of data subscribers in the connection area of a concentrator
telephone	10, 000	500
videophone	100	5
user class		
1*) 50 bps	82	≈ 4
2 200 bps	18	≈ 1
3 50...200 bps	6	<1
4 600 bps	42	≈ 2
5 2.4 kbps	36	≈ 2
6 9.6 kbps	2	<<1
7 48 kbps	1	<<1
fast data transmission > 48 kbps	1	<<1

*) user class 1 includes the TELEX stations

Table 4: Estimated mean number of data subscribers related to 10,000 telephone subscribers (capacity of one exchange) and to 500 telephone subscribers (capacity of one concentrator).

The table shows that the number of data subscribers within the area of one concentrator is only about 10 in the year 1985! Taking into consideration the mean number of subscribers per each user class, a maximum of about 18 subchannels (of 80 available subchannels per superframe) are sufficient.

Therefore, in many cases a concentration cannot be performed in the concentrator. But in many city areas with a high density of terminals it will be economic to provide the data facilities for some concentrators only. Now, all data terminals of this area are connected with these data and telephone concentrators. In these cases a concentration can be performed which leads to a more efficient utilisation of the available PCM-channels for data traffic.

5.2 Concentration and Switching of Data Traffic

In Fig. 7 the structure of the suggested national integrated communications network PINDATE is shown /13/. The topology of the telephone network is assumed to be organized hierarchically like the telephone networks in many countries of the world; e.g. /14/.

All telephone and data subscribers are connected via concentrators DC-TC with the network.

The traffic from the data concentrator DC to the DLC requires 1 or 2 channels of the two PCM-systems connecting the concentrator DC-TC with the local exchange DLC-TLE.

Assuming that up to 16 concentrators are connected with one local exchange; then 16 up to 32 PCM channels with data traffic can be concentrated in the DLC concentrator. Assuming the average number of data subscribers as listed in Table 4, one needs 3 up to 6 PCM-channels outgoing from this concentrator DLC. These channels form a part of the telephone PCM-systems which lead to the junction exchange DMUX-TJE.

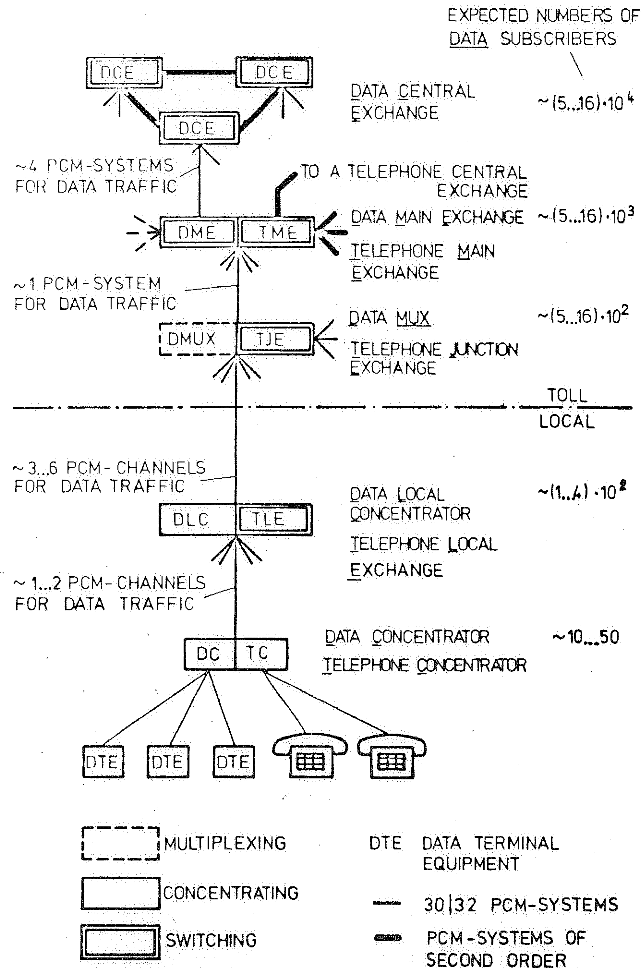


Fig.7: Structure of the partially integrated digital switching network for data and telephone traffic (PINDATE) with regard to data traffic. This structure is based on the expected number of data subscribers and the expected amount of data traffic

This DMUX handles about 2400 subchannels, i.e. the capacity of 30 PCM-channels. For safety reasons it will, however, be useful to divide up these subchannels to several telephone PCM-systems from DMUX to main exchange DME-TME.

Within the main exchange data and telephone traffic are fully separated. Separate telephone PCM-systems lead to a superior telephone central exchange as well as to other telephone main exchanges. Similarly the data main exchange DME is connected via data PCM-systems with a data central exchange DCE as well as with other data main exchanges.

Thus, the first data switching is done on the main exchange level. This implies that all connections between data subscribers must be connected via data main exchanges. This connecting strategy is economic, because the costs for switching on the junction or local level would be higher than the transmission costs for a detour switching (for the small amount of internal traffic) via the data main exchange.

The data central exchanges DCE represent the highest switching level and they are fully meshed like the central telephone exchanges. High usage routes can also be provided between DMEs or between DCEs, respectively.

In the following a description of the concentrating, multiplexing and switching nodes will be given. Hereby the considerations are focused upon the data traffic.

5.2.1 The Data and Telephone Concentrator DC-TC

The first concentration is performed in the concentrator DC-TC. But a concentration is only possible, if the sum of the isochronous data rates of all subscribers is greater than 48 kbps, i.e. it exceeds the capacity of one PCM-channel. The MUX, presented in Section 3.3, allows this concentration by the aid of its address memory. The subscriber address is entered during the establishment of a connection.

5.2.2 Data Concentrator and Telephone Exchange DLC-TLE

The data traffic flows from each concentrator DC-TC via one or two PCM-channels within a 30/32 PCM-system between concentrator and exchange. At first these PCM-channels with data traffic, incoming from all concentrators DC-TC at the TLE, are switched through the central switching array of the exchange (XSN) to a separate 2.048 Mbps outlet. This collects the total incoming data traffic (Fig. 8). As the number of available PCM-channels of this 2.048 Mbps data outlet is greater or equal to the number of incoming PCM-channels this switching through the XSN has a multiplexing function only. This 2.048 Mbps outlet for data traffic has the same (mostly low) mean occupancy with data connections as the incoming PCM-channels from the concentrators DC.

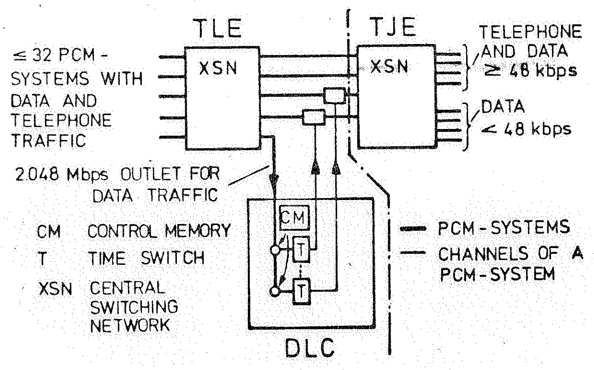


Fig.8: Data concentrator and telephone exchange DLC-TLE

Therefore in a next step the total data traffic of the DLC-TLE area is now concentrated by means of the data concentrator DLC of this exchange. As a rule 3 to 6 PCM-channels (carrying a total data rate of 48 kbps each) will be sufficient. Between the DC and the corresponding DLC, the data connections even with different bit rates are transmitted on the same PCM-channels. Now, in the DLC the data traffics are separated according to their bit rate (i.e. (0.6; 2.4; 9.6) kbps). For each bit rate at least one i n d i v i d u a l PCM-channel is provided.

This separation of data traffic according to the bit rate reduces slightly the efficiency of the concentration. However, the data switching arrays in all network nodes upwards the hierarchy can be adapted to the concerning bit rate and require a smaller amount of equipment. The reason for the equipment saving is that in case of mixed bit rates e.g. one 9.6 kbps connection is handled as 16 simultaneously occupied subchannels. Therefore 16 locations in each memory (control as well as time shift) are required, instead of one location in each memory in a separate 9.6 kbps switching array.

Furthermore, this bit rate separation saves the service protection hunting method as shown in Section 3.4.

These PCM-channels each carrying data traffic with a certain bit rate are distributed to the outgoing PCM-systems with telephone traffic to the corresponding DMUX-TJE. Thus a breakdown of an entire 30/32 PCM-system involves, if at all, only a smaller part of the data traffic.

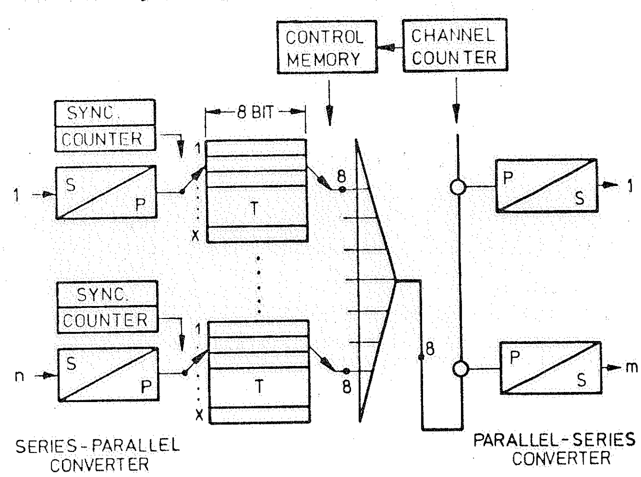
5.2.3 Data MUX and Telephone Junction Exchange DMUX-TJE

For each type of data traffic the concerning incoming PCM-channels from all DLCs of the area have to be multiplexed. A further concentration seems not to be economic. These incoming PCM-channels are multiplexed to the outgoing telephone PCM-systems leading to the data main exchange DME.

5.2.4 Data Main Exchange DME

The data main exchange DME is the first data switching node in the network. This data exchange controls all connections between data subscribers within this DME area as well as connections with subscribers outside of this area.

For each bit rate a separate switching array is provided. It consists of switching arrays (SA) similar to /16,17/, see Fig. 9. This switching array operates internal with 8 bit parallel. According to the number m of outgoing PCM-systems the clock pulse gets (2.048/8)·m Mbps.



DATA RATE/kbps	0.6	2.4	9.6	48
X	2560	640	160	32

Fig.9: Nonblocking switching array SA

Furthermore, above the DC-TLE level, data PCM-systems are one-directional and have therefore separate switching arrays for each direction of establishment. This separation into two parts of half size reduces the internal clock by the factor 2.

The incoming PCM-channels carrying the three bit rate types of data traffic will be taken out of the telephone PCM-system before entering the switching array for telephone traffic in the TME. If one has e.g. 100 incoming data PCM-channels per bit rate type, they can be multiplexed to 100/30 ≈ 4 PCM-systems per bit rate type which form the inlets of the DME. Time shifting by the aid of memories is not necessary as long as the data PCM-channels in lower levels are suitably allocated to the channel within the telephone PCM-system.

From the DMEs to the corresponding (highest) DCE level one has PCM-systems with data traffic only. Assuming as an example the number of subscribers as in Table 4 one needs approximately one data PCM-system between each DME and the corresponding DCE for each bit rate.

As to the switching array for the fourth and not yet discussed bit rate of 48 kbps some additional remarks are necessary. A 48 kbps data channel needs a full 64 kbps PCM-channel. Because of the comparatively small number of 48 kbps data subscribers in the considered communications network (cf. Table 4) it makes no sense to provide fixed data channels for this bit rate to the DME level. Therefore, it seems to be economic to handle such data subscribers from their terminal to the outlets of the TME switching array like a telephone connection. They will be transmitted on any idle PCM-channel. Only after being switched through the TME one enters in the separate 48 kbps data switching array of the DME.

The basic structure of the resulting switching arrays is shown in Fig. 10.

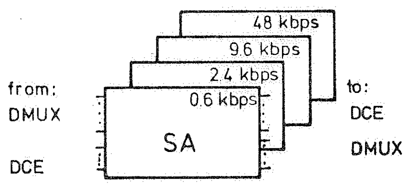


Fig.10: Basic structure of the switching arrays in the data main exchange DME

5.2.5 Data Exchange DCE

The DCE is a separate data switching exchange. Similar to the switching array of the DME exchange the switching arrays of the DCE provides individual switching arrays for each bit rate. These switching arrays are also non-blocking, however, with higher internal clock rate.

6. CALL ESTABLISHMENT AND DISCONNECTION, SIGNALLING

6.1 Telephone Connections

The establishment of a telephone call is controlled by the telephone exchange TLE as described in Section 4, details see /12/.

6.2 Data Connections

Data connections are controlled by the TLE-DLC as well as by the DME (see Fig. 7).

A request for service of a data subscriber is detected in the data concentrator DC. According to the user class (bit rate) the concentrator control circuit XCC (see Fig. 6) in the exchange TLE selects the necessary subchannels. Furthermore the XCC informs the central processor XCP in the TLE (for signalling, updating of memories etc). The next data concentrator TLC is situated in the local telephone exchange TLE. It selects the necessary number of idle subchannels to the data exchange DME. The data multiplexer DMUX within the TJE-DMUX multiplexes the data connections only. It has no function concerning call establishing or disconnecting.

The control information flow between TLE and DME is transmitted via channel No. 16 of that PCM-system which is the host for the PCM-channels reserved for each bit rate. Therefore the control information flows via TJE. The central processor of this exchange buffers and multiplexes the signalling information which arrives from the TLEs and which is transferred again via one channel No. 16 to the DME.

If the data subscriber is connected with the DME, it will be supplied with the "proceed-to-select" signal. These signals have to be transmitted in the switched data channel. A special microprogrammed I/O processor, realized as a decentralized unit in the DME, is provided to receive and transmit signalling information from and to the subscribers (incl. selection signals). Moreover this unit converts by microprograms the "time-encoded" signals of data subscribers with asynchronous bit rates.

The selection signals received via the established data channel are processed in the DME. The further call establishing to the DC of the called subscriber is controlled by the DME of the calling subscriber via channel No. 16. Call establishing is finished by transmitting the "connect-through-signal" in the established data channel to both subscribers.

Supervision and disconnection of a data connection is also done by the DME of the calling subscriber. The disconnection can be initiated by the clear request of the called or calling subscriber.

7. SWITCHING OF BIT RATES WITH >48 KBPS AND VIDEOPHONE

In the future it may be necessary to have high speed data communications between computers, moreover for facsimile and other picture communication services, e.g. videophone. The bit rates of these data communications can be subdivided into two groups:

a) bit rates occupying more than one channel of a 30/32 PCM-system (e.g. 192 kbps, i.e. 4 channels)

b) bit rates occupying one or more entire 30/32 PCM-systems (e.g. videophone with 4 Mbps, i.e. 2 PCM-systems).

The expected number of subscribers in Group a) is very small /1/, therefore the traffic between these subscribers can be handled within the telephone network in the same manner as the above mentioned subscribers with 48 kbps. However, more than one channel has to be switched simultaneously.

Due to the high bit rate of the subscribers of Group b) and assuming that videophone will be introduced into the public communications network a separate switching network would be necessary. (Even if 1985 only one percent of the telephone subscriber use videophones /18/ they need, nevertheless, a transmission capacity which is a manifold of that capacity which is necessary for the total data transmission up to 48 kbps! On the other hand, the signalling information is comparatively small. Therefore the call establishment and disconnection could be performed by the telephone exchanges.)

8. CONCLUSION

This paper describes the structure of an integrated data and telephone switching system. It has been shown how data terminals of various bit rates (50 bps...48 kbps) can be connected with this network.

This system aims at a compromise between separate data and telephone networks on the one hand and a fully integrated system on the other hand. It avoids the disadvantage of separate networks where separate local exchanges are necessary without respect to the comparatively small amount of data traffic.

It avoids also the problems arising in a fully integrated system where every channel can be occupied by any type of traffic. In this case every telephone channel must be able to work as a data channel with variable subdivisions for data. Thus the costs per PCM-channel increase considerably in spite of the fact that less than one percent of the channels will be in use for data connections, only.

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