A DATA SWITCHING UNIT WITH MICROPROCESSOR CONTROL

UNE UNITÉ DE COMMUTATION DE DONNÉES CONTROLÉE PAR UN MICROPROCESSEUR

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Dans cet article est présentée une unité de commutation de données qui peut être tilisée ou bien comme un système de commutation autonomme ou bien comme module de commutation dans un système combiné pour la voix et les données.
Seule la commutation de circuitsest considerée.
Sont étudiées en detail les unités suivantes:

- Le Réseau de connexion auquel sont raccordées des lignes à 64 kbps (selon X.51).
- L'unité de signalisation qui traite en temp partagé la signalisation des lignes d'abonnés.
- Le processeur qui supervise et contrôle les unités mentionnées plus haut.

De plus est developpée une procédure de signalisation semblable à X.21 entre l'équipement de terminaison de circuit de données et le réseau.

A data switching unit is presented which can be used as an autonomous data switching exchange as well as a data switching module of a combined (voice and data) switching system.
Only line switching is considered.
The following components of the data switching unit are dealt with in detail:

- The data switching array to which 64 kbps multiplex data lines (according to X.51) are connected.
- The signalling processing unit which handles all data subscriber signalling information in a time sharing mode.
- The data switching processor to supervise and control the above mentioned components.

Furthermore, a signalling procedure similar to X.21 between DCE and the network is developed.

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1. Introduction

In many countries public data networks exist and are growing rapidly. Switching exchanges for line switching, packet switching and combinations of both have been published in numerous interesting publications e.g. /3..20/ . Furthermore, many papers have been presented regarding the problems and the design of integrated services digital networks (ISDN) carrying both, telephone and data traffic, resp.

In /1/ a switching system has been suggested which carries mainly telephone traffic but additionally enables the connection of data subscribers and provides data links to one or more data networks.

This combined local switching system for voice and data was not developed for fully integrated networks. Its field of application lies in areas where pure data exchanges are uneconomic.

The data line switching unit (DSU) discussed in detail in this paper has been applied as a module within the combined system mentioned above. However, it is also applicable as an autonomous data line switching exchange for a total of 2880 kbps (information bit).

In the second chapter, the technical recommendations to be regarded are dealt with, and the third chapter reviews the tasks to be performed by the DSU. For those readers who are interested in details of the architecture and operating mode of the DSU, Chapter 4 deals with the procedures for call establishment and clearing between DCE and DSU, and the components of the DSU are described in detail in chapter 5.

A list of abbreviations can be found at the end of the paper.

2. Technical Recommendations to be Regarded

According to CCITT X.1 data subscribers are considered of the user classes 3 to 7 (i.e. 0.6 - 48 kbps, synchronous mode, signalling with user speed and alphabet ITA No. 5).

These subscribers (DTE) use interface protocols between DTE and DCE, especially X.21 (Fig.1). Between DCE and the data switching unit, a DCE signalling procedure (DCSP) has to be defined. This will be dealt with in Chapter 4. The DCSP supports X.21, but also other interface protocols might be possible.

The DCSP bases on the use of (8+2) "envelopes" (see Fig.2). This means that each envelope consists of one character plus one bit for alignment (A-bit) and a second one, the status bit (S-bit). The S-bit is for the distinction between data and signalling characters, resp.

The recommendation CCITT X.51 on subchannel multiplexing within a 64 kbps bitstream is also applied. The decision to use (8+2) envelopes bases on investigations published at the ISS'76 /2/.

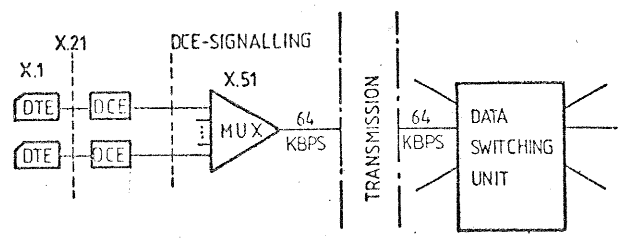


FIG. 1: CONNECTING PRINCIPLE AND SIGNALLING PROCEDURES FOR DATA SUBSCRIBERS

According to recommendation X.1 the standard bitrates of subscribers are 0.6, 2.4, 4.8, 9.6, 48 kbps. Using (8+2) envelopes this corresponds to 0.75, 3.0, 6.0, 12, 60 kbps. Therefore a capacity of 4 kbps is idle (64 - 60 kbps). Dividing the total bitrate of 60 kbps by 0.75 kbps (being the lowest bitrate) one obtains 80 subchannels. Therefore the above standard bitrates occupy 1, 4, 8, 16 or 80 subchannels, resp. (Fig.3).

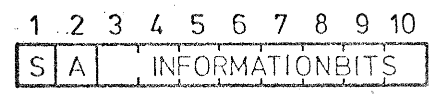


FIG. 2: 8+2 ENVELOPE STRUCTURE

This 4 kbps bitstream consists of the socalled padding bits which are insertet into the 60 kbps bitstream after every 15th bit (Fig.4). These bits are used for frame synchronisation. The normal way would be to built a frame, which embraces 80 subchannels. This frame would have 853.333 bits (80 x (8+2) + 800/15 padding bits). This non-integer number is not applicable. Therefore, a frame with 3 x 80 subchannels (= 240 x 10 bits + 160 padding bits = 2560 bits) has been chosen.

User speed (data bitrate)	Bitrate with (8+2) envelopes	Number of necessary subchannels	Sequence of subchannels
0.6 kbps	0.75kbps	1	every 80th
2.4 kbps	3.0 kbps	4	every 20th
4.8 kbps	6.0 kbps	8	every 10th
9.6 kbps	12 kbps	16	every 5th
48 kbps	60 kbps	80	every

FIG. 3: MULTIPLEX SCHEME USING (8+2) ENVELOPES

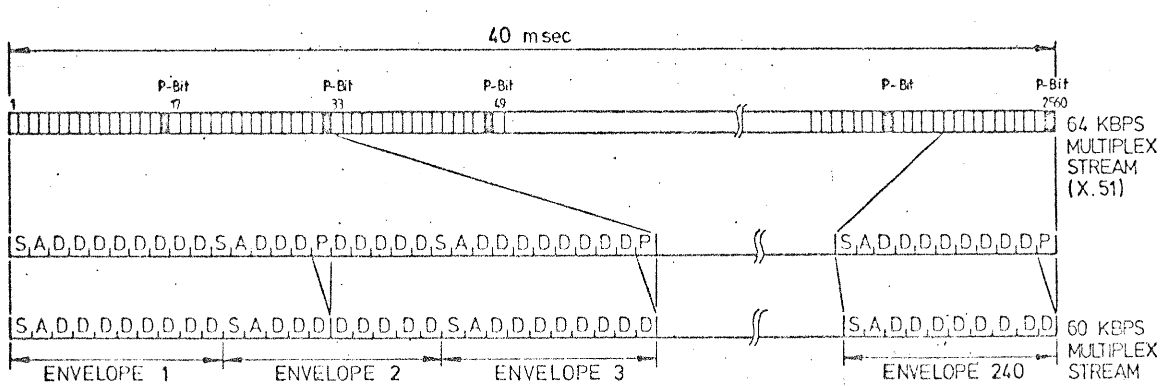


FIG. 4: MULTIPLEX-FRAME FOR 8+2 ENVELOPES (X.51)

The advantage, using (8+2) envelopes is:

By means of the padding bits, one knows the beginning of each frame. After having extracted these padding bits one can simply detect the envelopes belonging to each data connection by the aid of counters.

Furthermore, one envelope contains, if the subscriber is in the signalling phase, one full signalling character. During the data phase, bit sequence independence is granted.

3. The Concept of the DSU

Fig. 5 shows the overall structure of the DSU.
The function sharing is as follows.
The central switching processor (CSP) has to perform all tasks related with
- digit translation
- call supervision
- subscriber related data
- connecting of subscribers
- charging/billing
- interoffice signalling
  fault detection, maintenance etc.

The remaining tasks are:
- Detection of envelopes with signalling information
- Preprocessing of signalling information with respect to the status of the subscriber and with respect to the status of the system
- Providing of signalling information for the subscriber (like "proceed to select","incoming call")
- Connecting of subscribers via the switching array.

These functions are performed by three units:
- the data switching array DSA
- the signalling processing unit SPU
- the data switching microprocessor DSP (Fig.5).

The data switching array is a one stage nonblocking time switch. First, in each 64 kbps stream the padding bits are extracted (4 kbps) by the padding bit suppressors (PS). Next, the remaining 60 kbps streams (max. 60X60 kbps) are multiplexed with 10 bits parallel each. Via the central highway the multiplexed data stream is transmitted to the time stage T. The stage T has a 10 bit storage location for each subchannel (60X80 = 4800 subchannels). The T stage is written at random and read out cyclically. It performs the switching function .

The relation between incoming data streams (≥1 subchannel) and outgoing ones to the desired routes or subscribers (via MUX and DCE's, resp.) is stored within the control memory (COM). The COM is updated by the DSP.

The central highway has two ports. One port copies all signalling envelopes of the central highway to the SPU. The other port can break the central highway for the time interval of one envelope to send one signalling envelope from the switching system to the DCE of a subscriber.

The SPU examines all envelopes (envelope decoder) and hands it over to the decision logic together with the contents of the subscriber status memory. This memory contains the present status of all subscribers.

According to the contents of the subscriber status memory and the contents of the envelope, the decision logic sends a message to the DSP (e.g. call request, selection signals,) and changes the subscriber status if necessary. It negelects the envelope as far as it contains only repeated signalling information or only data information.

The SPU can be blocked for further call attempts by the DSP for reasons of overload protection.

The microprocessor DSP
- updates the control memory (COM) for data switching
- controls the signalling memory which cares for signalling to local data subscribers, e.g. "incoming call","proceed to select" etc.

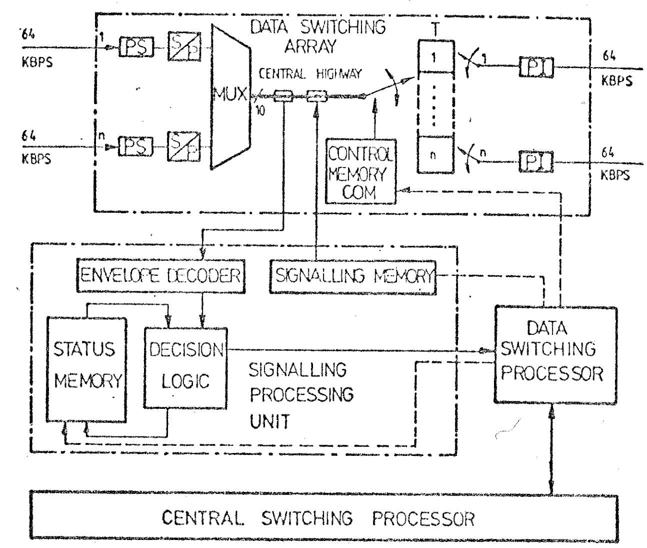


FIG. 5: STRUCTURE OF THE DATA SWITCHING UNIT (DSU)

- sets an inhibit bit (IB) which blocks the SPU for further call attempts as long as overload protection is necessary
- sends messages to the central switching processor (CSP), e.g. call requests,clear requests, selection signals etc.
- receives control informations, e.g. connecting information for the COM,
- supervises the subscriber behaviour, in particular with regard to mal-functions.

The central switching processor (CSP) for data traffic is necessary if the DSU works as an autonomous data switching exchange. On the other hand, the DSU can be applied as a data switching module of a combined switching exchange for voice and data, as described in /1/. In this case the CSP can serve both,telephone and data traffic. Investigations have shown that a remarkable part of the software can be used commonly.

4. Procedure for Call Establishment and Clearing

The DCE signalling procedure (DCSP) is described in this chapter. As no international recommendation concerning the signalling between DCE and the network exists, a suitable DCSP had to be developed.

This procedure should meet the following demands:
- As far as synchronous data subscribers are concerned, the procedure should be similar to CCITT X.21, to simplify the DCE.
- To meet the requirements of X.51 (8+2 envelopes) which has been adopted in this system, information transfer should be done within envelopes.
- Only two information channels (DCE-DSU) are available,one for each information transfer direction.
- Signalling should be done by means of 8-bit characters (to meet the 8+2 envelope).
- Signalling characters should be marked by means of the statusbit S of the envelope.

According to these demands the DCE signalling procedure has been developed. Fig.6 shows the signalling sequence diagram."Transmit data line"denotes the data line from the DCE to the DSU;"transmit status bit" indicates the status bit of the envelope; similarly"receive data line"denotes the data line from the DSU to DCE, and "receive status bit"the status bit of the envelope.

Signalling is exclusively done by means of characters together with the status bit.

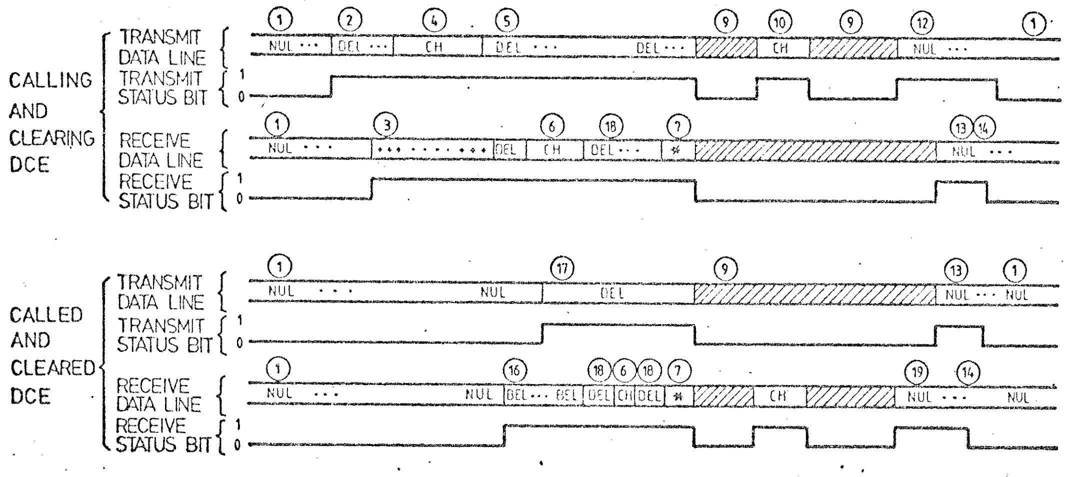


FIG. 6: DCE-SIGNALLING SEQUENCE DIAGRAM

The characters NUL,DEL, +, *, BEL of the ITA No.5 are used, furthermore CH denotes other characters of the ITA No.5.
"BEL" and "+" have the same meaning as defined in X.21
" * " is an additional control character with the meaning "connected" to indicate that the data phase can start.

The possible states of a DCE are indicated by circled numbers within Fig.6. A state transition diagram for call establishment and for clearing is given in Fig.7.

The diagrams are self-explaining.

One special feature, however, has to be pointed out. During the data transfer phase (state 9) a network recall for signalling can be done simply by changing the statusbit from 0 to 1 and sending one or more signalling characters. The character "NUL" is not allowed, as this would indicate "clear request". This feature is possible if a data switching unit (DSU) is provided which monitors permanently all subscriber lines and is able to detect the signalling characters.

These signalling envelopes are also transmitted to the other side (DCE of the connected other subscriber). They are neglected there, because their status bit equals 1 and the transmitted character is not "NUL".

5. Components of the DSU

5.1 The Data Switching Array (DSA)

The data switching array (Fig.8) is a one-stage non-blocking time switch for up to 60 channels with 64 kbps each. The 64 kbps data channels may e.g. be transmitted using PCM-transmission systems. In this case, a demultiplexer and a speed conversion from 2.048 Mbps to 64 kbps is necessary for the incoming direction and vice versa for the outgoing one .

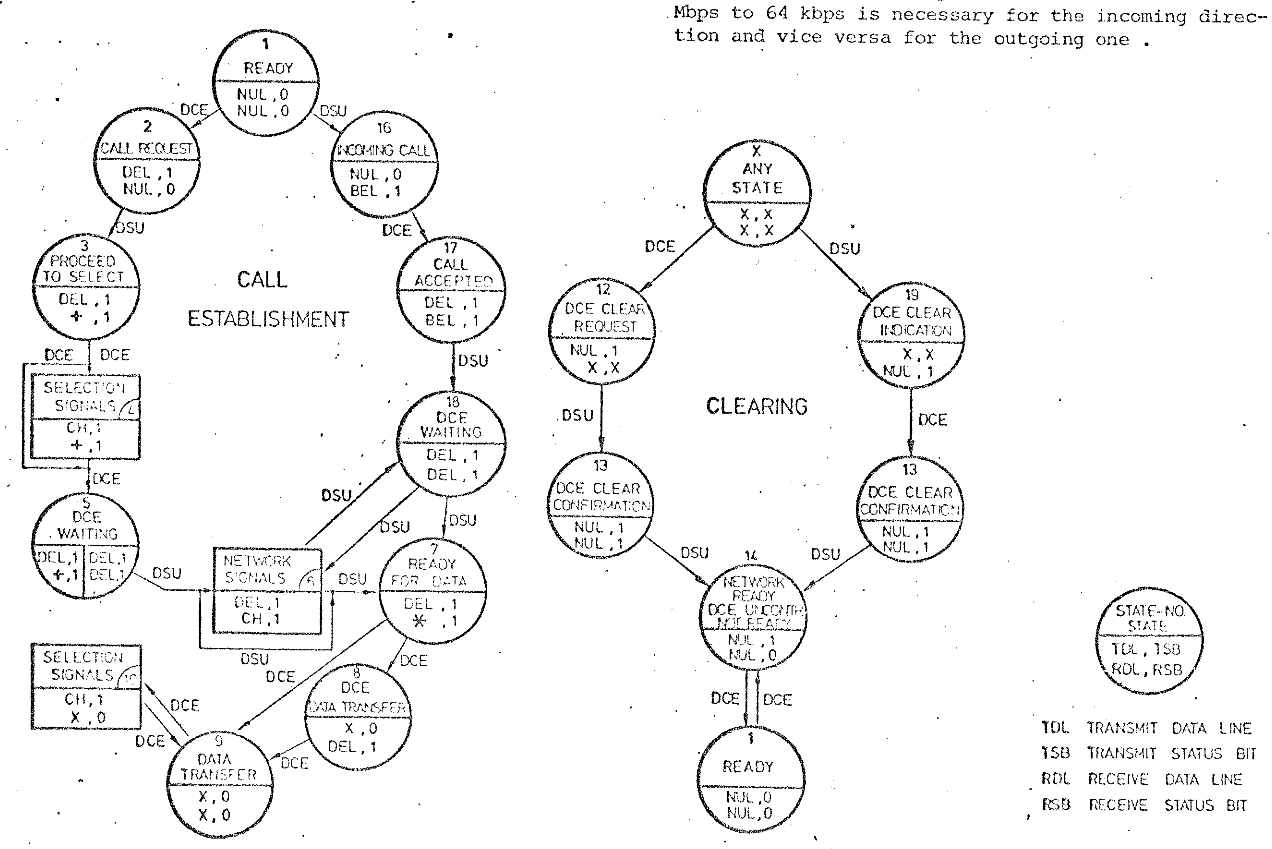


FIG. 7: STATE TRANSITION DIAGRAM (STD) FOR DCE SIGNALLING (CALL ESTABLISHMENT AND CLEARING)

The 64 kbps bit-streams are linked to padding-bit suppressors (PS) which extract the padding bits, and perform the 64 to 60 kbps conversion.
The padding bits are collected within the frame tester (FT) to supervise the frame synchronisation. If this synchronisation fails, a frame detector (FD) must be connected to the PS to search for the frame synchronisation pattern.

After a serial to parallel conversion the envelopes are multiplexed to the 10 bit parallel central highway. The transmission capacity of the central highway is 60 x 60 = 3.6 Mbps which results in a clock frequency of 360 KHz of the central highway.

Each subchannel (600 bps/750 bps) belonging to a certain local subscriber (using one or more subchannels corresponding to his bitrate) is permanently assigned to a subchannel of the internal central highway having 4800 subchannels.
Analogeously each subchannel of incoming data links has its permanently assigned subchannel on the internal central highway.
From this follows that the total number of subchannels of the local subscribers plus incoming data links is limited to 4800, i.e. blocking can occur only with regard to outgoing data links.

An envelope branch (EB) copies any envelope to the SPU. The envelope change (EC) is for inserting signalling envelopes to the subscriber (e.g. the character "+" which means "proceed to select").This EC is controlled by the envelope sender (EVS). The EVS itself makes use of the character generator (CHG) and the character aligner (CAL).

Each envelope on the central highway is written into one storage place of a certain time stage T.
The selected T-stage determines the outgoing 64 kbps bit stream of the desired direction.
The selected storage place within the T-stage determines the number of the subchannel, occupied within the selected 60 kbps bit stream.

The decision which storage place has to be used is done by the control memory (COM) which is loaded by the DSP. The storage places of the T-stage are read out cyclically. The 10 bit envelopes per storage place are read out serially. The padding bit inserter (PI) adds the padding bits obtained from the padding bit generator (PBG).They form the synchronization pattern.

It should be pointed out that data switching and traffic distribution for bitrates < 48 kbps (subchannel mode) can by no means be performed only by a PCM telephone switching array. The reason is:
- In a "telephone" PCM switching array the T-stages have one 8 bit storage place per time slot (= 64 kbps). However, for subchannel mode data switching, one needs 80 storage places per 64 kbps having 10 bit each. This enables also up to 80 individual outgoing connections.

5.2 The Signalling Processing Unit (SPU)

In Chapter 4 the signalling procedure DCSP between DCE and DSU has been described in detail. According to the DCSP two functions have to be performed by the DSU:
- Processing of signalling information being sent from the DCE to the DSU
- Generating of signalling information and sending it from the DSU to the DCE.

The first function , i.e. recognizing and processing of signalling is carried out by the signalling processing unit (SPU) described in this section. Generating and sending of signalling characters is done by co-operation of the data switching processor (DSP) and the data switching array (DSA), see Section 5.1.
The SPU processes signalling information from all DCE's connected to the DSU in a time sharing mode. This leads to the following tasks:
- Check any envelope transmitted on the central highway of the DSA and

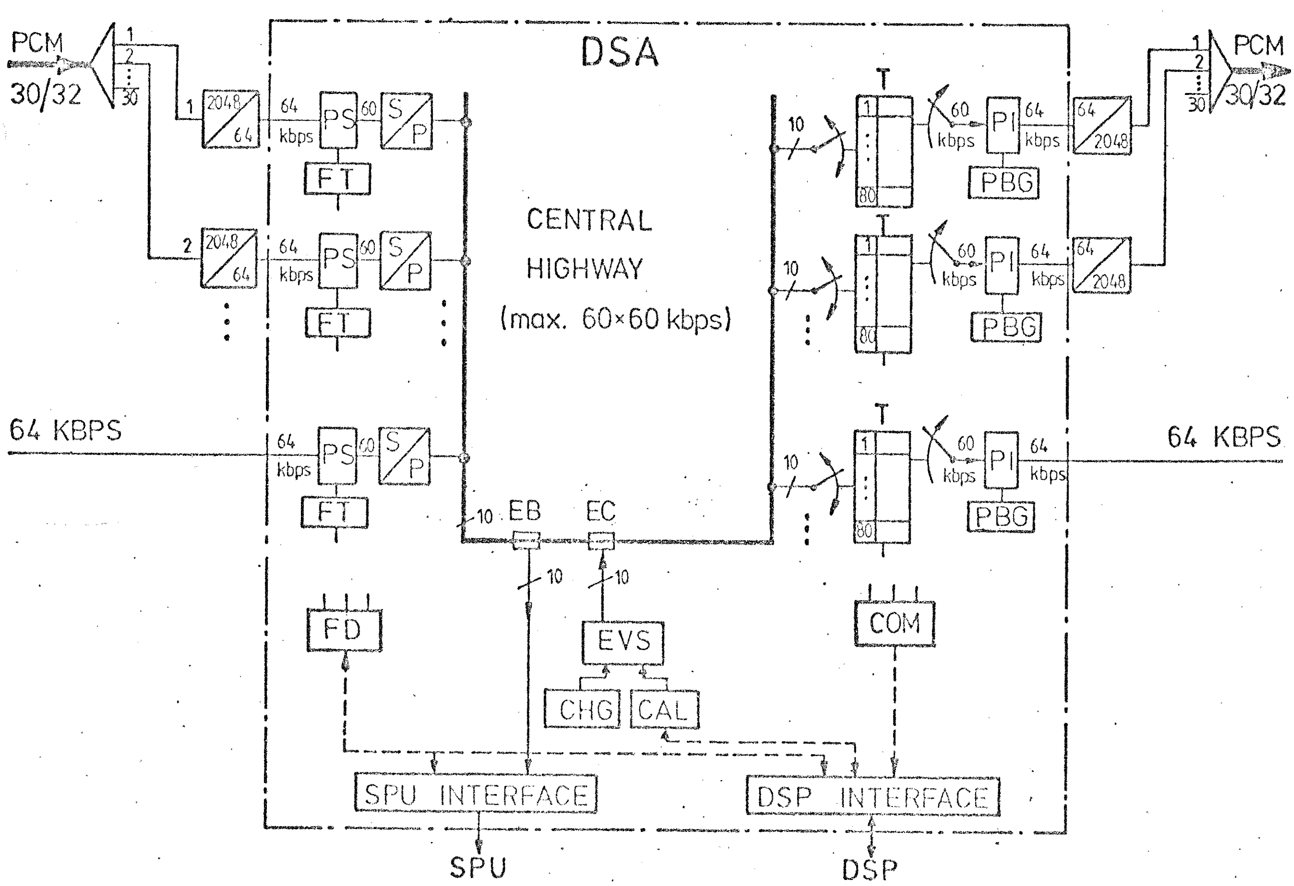


FIG. 8: THE DATA SWITCHING ARRAY

- decide, whether this envelope contains signalling information or not.
- Distinguish between different signalling characters.
- Check the contents of any envelope with regard to the present status of the subscriber and with regard to the internal control information of the SPU.
- Generate messages and send them to the data switching processor (DSP)
  - if a new signalling information arrives from the DCE which leads to a change of the subscriber status (e.g. call request, clear request ,...),
  - if information for call establishment is sent by the DCE (e.g. selection signals),
  - if the information within the envelope does not match with the present subscriber status; in this case an error message has to be sent to the DSP.
- Generate no message if the information in the envelope is redundant, i.e. already known.

These tasks are performed within the functional blocks of the signalling processing unit (SPU) shown in Fig.9. The operation of the SPU is described now.

The contents of any envelope is copied from the central highway into the envelope decoder (ED). The ED distinguishes between data and various signalling informations. It generates a corresponding ED-code (see Fig.10) and transfers it to the decision logic (DLO).

This input to the decision logic is completed by (see Fig.9):
- A bit indicating an overflow of that buffer containing the messages to be sent to the data switching processor. As long as this bit is set, no further messages are generated in the decision logic.
- A bit that is set when there is a command from the data switching processor to change a subscriber status.
- An inhibit bit which is set by a command from the data switching processor in case of overload. (If this bit is set no further call request is accepted)
- The present subscriber status which was stored in the subscriber status memory (SSM). (This subscriber status is one out of the full sequence shown in Fig. 10.)

For any envelope this input information,as mentioned above,is given to the decision logic (DLO).

The conditions for a transition from one status to another, as well as the type of the message to the DSP are also given in Fig.10. For example, if the subscriber is in the state "ready" (state No. 0) then he can proceed to state 1 "call request" if the ED-code is 1 and the CSB is 0. In this case the transition is indicated to the DSP by sending message No.1.

According to the STD the DLO changes the subscriber status within the SSM and sends a message to the DSP, if necessary.

If a message has to be sent, the following informations are written into a special buffer (see Fig.9):
- The internal channel No. (ICN)
- The message code (see Fig.10) and
  - if the message code is not equal to 5, the preceeding status of the subscriber and the ED-code
  - if the message code is equal to 5 (error) the bits of the character within the envelope.

Furthermore, a state transition has to be performed by a command from the DSP, via the status control (see Fig.9), if the considered state transition can

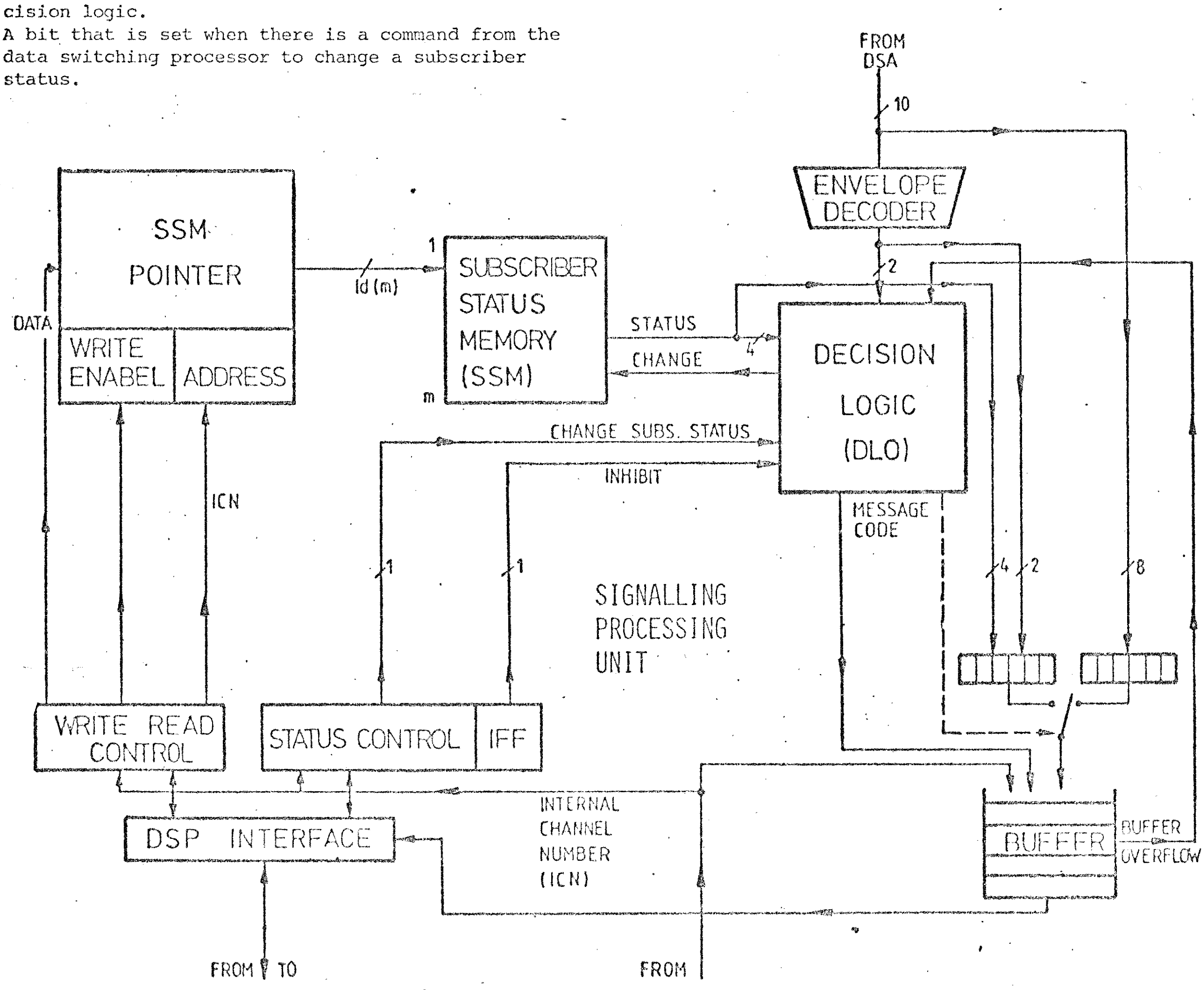


FIG. 9: THE SUBSCRIBER SIGNALLING PROCESSING UNIT (SPU)

only be performed by the DSP (e.g. state 3 to 4). In this case no message is transmitted to the buffer but an acknowledgement is sent from the status control to the DSP.
Another STD can easily be implemented if the ROM of the decision logic(DLO)is replaced by another one.

Next the assignement between a certain subchannel on the internal central highway to the corresponding local subscriber is explained. In this context it must be regarded, that for subscriber bitrates > 600 bps, more than one subchannel is occupied simultaneously on the internal central highway (4,8,16 or 80, resp.). The permanent assignment between each (external) subchannel of a subscriber and the corresponding internal subchannel number (ICN) on the internal central highway is stored in the DSP.

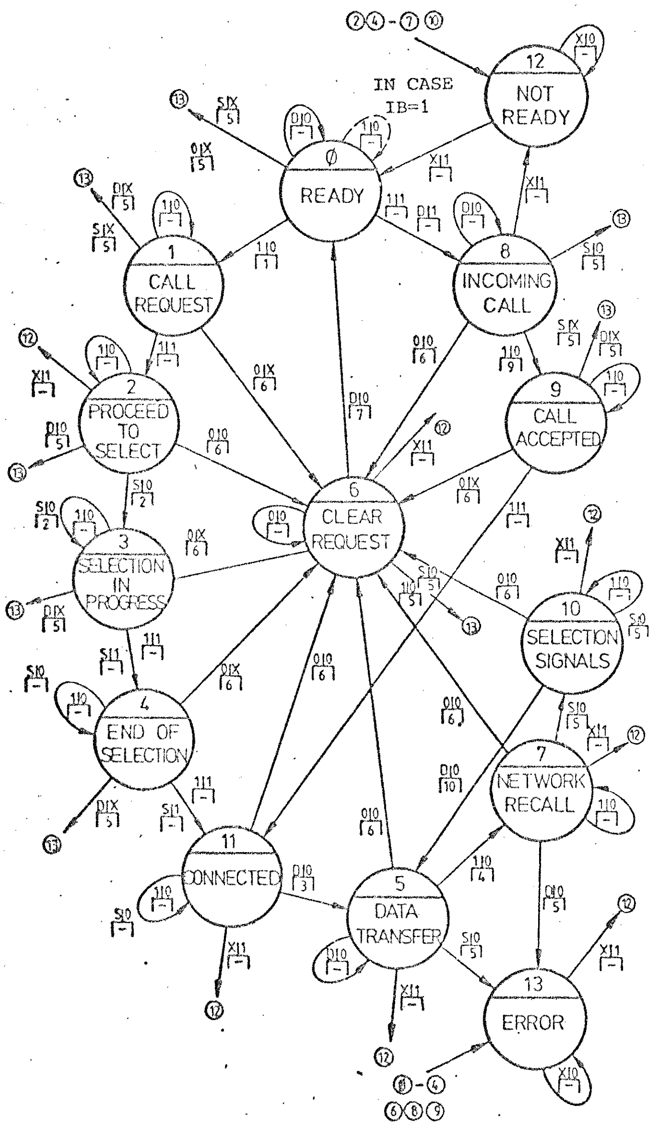
The momentary status of any local subscriber is stored in a certain address of the subscriber status memory (SSM) of the SPU. This address is found as follows:

The SSM pointer (RAM with 4800 storage locations) is cyclically addressed by the ICN's. Each storage location of the SSM pointer contains an address of the SSM. The storage location belonging to this SSM address contains the momentary status of that subscriber which uses this ICN. The DLO reads that addressed storage location (subscriber state) and writes back a new status, if necessary.

If an updating of the SSM-Pointer is necessary, this is done by a command from the DSP memory. Then, the new data are written into the pointer under responsibility of the read-write control.
This updating is necessary
- if a subscriber is connected to or disconnected from the DSU
- if a subscriber wants to change his bitrate
- if a resynchronisation of the frame sequence within the 60 kbps bit stream is necessary.

5.3 Example for the Flow of Signalling Information

Fig.11 gives an example for the flow of signalling information between the different units. On the left hand side, the states according to the DCSP (see Fig. 6,7), and in the middle the states according to



ED | CSB
M

CSB: Change-Status Bit

MESSAGE (M)	MEANING
1	call request
2	selection signal
3	data transfer
4	network recall
5	error
6	clear request
7	ready
8	call accepted

Messages for the DSP

ED-CODE	S-BIT	CHARACTER
1	1	DEL
0	1	NUL
S	1	CH
D	0	any bit sequence

ED-Code for the DLO

FIG. 10: STATE TRANSITION DIAGRAM (STD) USED IN THE SPU

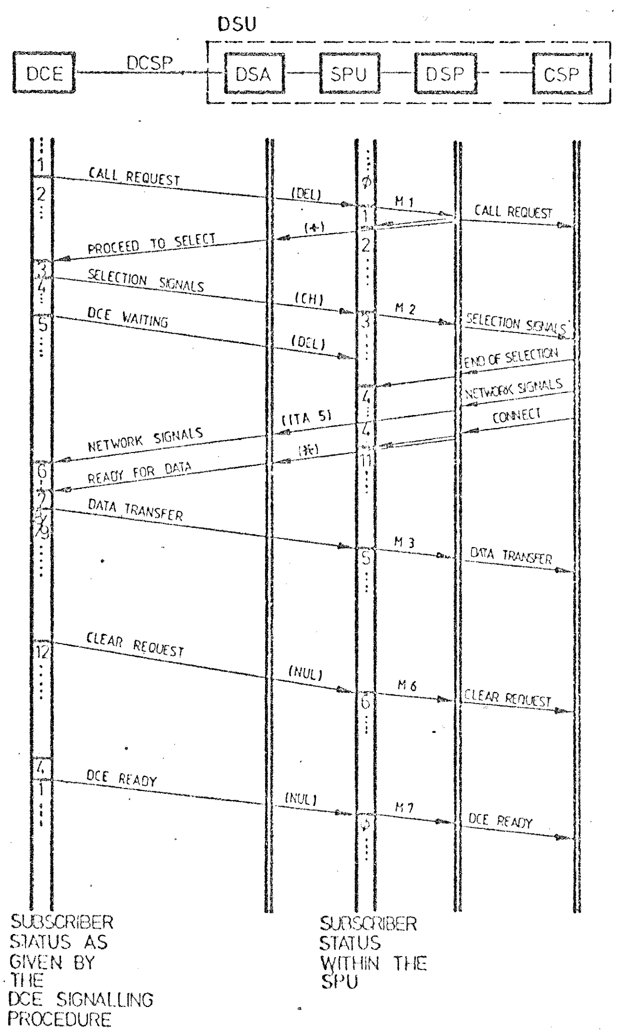


FIG. 11: FLOW OF SIGNALLING INFORMATION

the STD of the SPU (see Fig.10) are given. The messages between SPU and DSP correspond to those in Fig. 10.

If the DCE generates a call request (character DEL with the status bit set to one) the state changes from state 1 to state 2. The DSA copies the signalling envelope to the SPU. The SPU changes the subscriber status to 1 and sends message M1 to the DSP. The DSP sends the message "call request" to the central switching processer CSP. Furthermore, the DSP generates a command to the DSA to send "proceed to select" to the subscriber and a second command to the SPU to change the subscriber status into 2. ("proceed to select"). Incoming selection signals change the subscriber status within the SPU to 3 ("selection in progress"). Selection signals are transmitted to the CSP. As to the further flow of signalling informtion see Fig.11.

6. Conclusion

A data subscriber switching unit was described using a one stage nonblocking switching array and a time division multiplex signalling processing unit. Both units are controlled and supervised by means of a data switching processor DSP (microprocessor).
The data switching unit can be used as an autonomous data exchange (for line switching). On the other hand it can be applied as a data switching module of a combined switching system for voice and data as described in / 1 /. In this case the function of the central switching processor can be implemented in a common switching processor of the combined switching exchange.

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LIST OF ABBREVIATIONS	
A	alignment-bit
BEL	character out of ITA 5
CAL	character aligner
CH	character
CHG	character generator
COM	control memory
CSB	change-status bit
D	data
DCE	data circuit terminating equipment
DEL	character out of ITA 5
DLO	decision logic
DSA	data switching array
DSP	data switching processor
DTE	data terminal equipment
EVS	envelope sender
FD	frame detector
FT	frame tester
IFF	inhibit flipflop
NUL	character out of ITA 5
P	padding bit
PBG	padding bit generator
PI	padding bit inserter
+	character out of ITA 5
PS	padding bit suppressor
RDL	receive data line
RSB	receive status bit
S	status bit
SPU	signalling processing unit
SSM	subscriber state memory
T	time stage
TDL	transmit data line
TSB	transmit status bit

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