

Implementation of X.25 for the TDX-10 Packet Switching

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TDX-10 패킷 교환기능중 X.25의 실현

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ABSTRACT

This paper presents how X.25 state machines are defined and procedures are implemented into the TDX-10 switching system, which is being developed as an ISDN exchange in Korea.

Packet switching is an important aspect of ISDN. Packet switched services in ISDN are defined by X.31, which provides for the use X.25 over ISDN B- and D-channels between a user and an X.25 packet handler. To implement X.25 into an ISDN exchange which includes a packet handler, X.25 state machines and procedures should be adjusted within the ISDN exchange.

要 約

ISDN 교환기에서 패킷서비스를 제공하기 위하여 CCITT X.31이 권고되었으며, 사용자와 패킷처리간 B 채널 혹은 D 채널로 서비스된다. ISDN용으로 개발되는 TDX-10에 패킷교환기능을 제공하기위해 X.31에 근거를 두며, DTE와 DCE 접속용으로 권고된 X.25 프로토콜의 패킷레벨처리를 TDX-10 ISDN 환경하에 적합하도록 설계하였다.

1. Introduction

For a number of applications packet switching has clear advantages, especially flexible bandwidth allocation and multiple simultaneous use of the same physical channel by virtual connections. For these reasons the introduction of packet switching into ISDN is well understandable. With the CCITT Rec. X.31 a pragmatic approach has been

defined for packet switching in ISDN. This approach allows to use existing X.25 terminal equipments and protocols.

To do this, X.31 distinguishes two main cases : access to a PSPDN through the ISDN, and use of an ISDN virtual circuit service. In the second case, the Packet Handler(PH) can be located in a local ISDN exchange or a remote exchange. ISDN provides access to the PH for packet data on B-channel and on D-channel. D-channel supports the signaling information for the establishment of the telecommunication path between the terminal and the PH. For packet-switched servi-

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ces over a B- or D-channel, the full X.25 Packet Layer Protocol (PLP) is used.

To support X.25 PLP within the PH, X.25 state machines and procedures should be adjusted according to the PH's architecture. In other words, several states of X.25 PLP such as p state, d state, and r state must be rearranged in order to be suitable to the PH's architecture.

This paper presents how X.25 state machines are designed and procedures are implemented into the TDX-10 switching system, which is being developed as an ISDN exchange in Korea. In the subsequent section, the packet switching architecture of the TDX-10 system is explained briefly. Section 3 describes the design of X.25 state machines and procedures in the TDX-10 system. Section 4 presents how X.25 protocol is implemented. In section 5, performance analysis of packet switching treated in a PHM is given. Section 6 describes how the application S/W related to X.25 is tested and verified. Finally, we give the conclusion of this paper.

2. The TDX-10 Packet Switching Architecture

The TDX-10 switching system is designed and implemented on the basis of distributed control, modularity of equipment and centralized maintenance and administration. The key elements of

ISDN implementation in the TDX-10 system are integrated voice /data subscriber access, packet switching and SS No.7 signaling. Fig.1 shows the packet hardware architecture of the TDX-10 system. For the ISDN user access in the TDX-10 system, as shown in Fig.1, three ISDN user interfaces are designed to meet the basic access (2B+D), the primary access (23B+D, 30B+D) and the multiplexed basic access (n(2B+D)) capability.

-Packet processing for D-channel

The DSI, PSI, and BAMI separate the packet data and signaling information within the D-channel. The separated packet data is transferred to the FMXP via a special bus (DP bus). These packet data are statistically multiplexed and then transferred to the Packet Handler (PH) via semi-permanent path where layer 2 and layer 3 functions of X.25 are processed.

-Packet processing for B-channel

By the D-channel signaling information, the packet data of B-channel is transferred to the PH through T-S-T switching network.

-Functions of the PH

The PH can be divided into the layer 2 processing and the layer 3 processing part. The

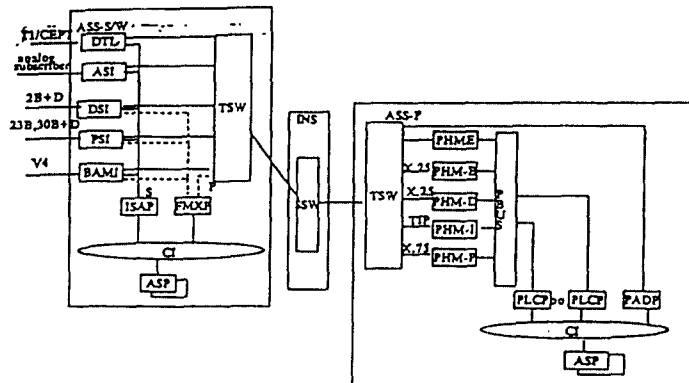


Fig. 1 TDX-10 packet hardware architecture

layer 2 functions are processed by several types of PHMs. Functions of each PHM are assigned separately according to the channel type. The PHM-B and PHN-D process packets transferred through the B- and D-channels respectively. PHM-I handles packet calls between the TDX-10 systems using the TDX-10 Internal Protocol (TIP). PHM-P is used to interwork with a PSPDN. Internal Protocol (IP) is used for transmission of a packet data between PHMs.

Up to 8 DTEs can be connected to a PHM-B, abbreviated as PHM in this paper, which processes B channel Packet switching in the TDX-10. There are two types of a virtual call in the TDX-10. The first one is PHM intra-call, that is, an originating call and a terminating call are connected to the different PHMs.

PHM intra-call has higher throughput than PHM inter-call because it doesn't need internal communication between PHMs. After the ASP analyzed necessary information in CR packet, it must select the same PHM number to increase throughput as far as an idle link of the PHM exists.

3. X.25 State Machines and Procedures in the TDX-10

Each of the logical channels, which is available in a PHM, can be in one of several states. If it is free, i.e., no call is in existence on it, then it is in the "ready"(p1) state. When a call is in existence it is in the "data transfer"(p4) state. Several other states occur in the transition between p1 and p7 states, i.e., in the call setup and disconnect phases.

X.25 PLP states are classified into three kind : "p" state related to call set-up, data transfer and call clearing, "d" state related to reset and "r" state related to restart. p, d, and r state has 7, 3, and 3 substates respectively. The developed countries designed states of X.25 enhanced by the addition of a new capabilities both to the X.25

interface and to the end-to-end service in their ISDN exchanges. According to the PH's architecture, packet layer state processing of the TDX-10 is considered as follows :

3.1 p State

There are seven states used for normal operation, which are p1, p2, p3, p4, p5, p6 and p7 given in Fig.2. N_packet in Fig. 2 means internal packet type being occurred tries to send an X.25 packet already received from the DTE to the corresponding PHM. Clear confirmation between PHMs isn't needed because IP guarantees reliable transmission between them.

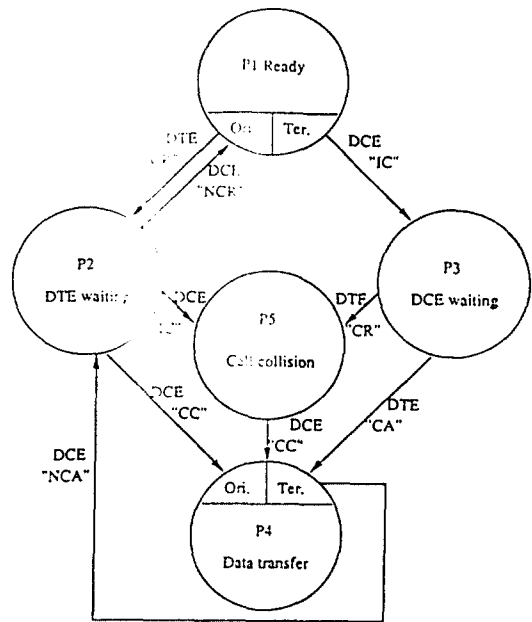


Fig. 2 Call set-up phase

3.1.1 Call set-up

A switched virtual call is established when the call request issued by the calling DTE is accepted by the called DTE. The states related to call set-up are p1, p2 and p3. The request of call set-up is initiated with CR or NCR packet and CA or NCA packet to the response of CR or NCR packet. All the virtual calls are initially in the p1

state. In the normal call processing, CR packet is received in case of PHM intra-call, while CR packet or NCR packet is received in case of PHM inter-call.

Once the PHM checks basic format of the CR packet received from the calling DTE, it sends information needed for CR packet validation to the PLCP and the originating call state is entered to the p2 state. If the PHM receives positive answer about CR packet validation from the PLCP and information that the called DTE and the calling DTE are connected to the same PHM, it decides that the virtual call occurs in the same PHM, so to speak, PHM intra-call. If the called DTE and the calling DTE are connected to the other PHMs, it decides that the virtual call occurs between each other PHMs, so to speak, PHM inter-call. In case of PHM intra-call, the PHM sends information needed for IC packet validation to the PLCP. In case of PHM inter-call, the PHM transmits NCR packet to the corresponding PHM and the remote PHM sends information needed for IC packet validation to the PLCP. If the PHM receives positive answer about IC packet validation from the PLCP, it transmits IC packet to the called DTE and the terminating call state is entered to the p3 state. The called DTE transmits CA packet to response of IC packet.

Once the PHM checks basic format of the CA packet received from the called DTE and the termination call state is entered to p4 state, it sends information needed for CA packet validation to the PLCP. If the PHM receives positive answer about CA packet validation from the PLCP, it differentiates PHM intra-call and PHM inter-call. In case of PHM intra-call, the PHM sends information needed for CC packet validation to the PLCP. In case of PHM inter-call, the PHM transmits NCA packet to the corresponding PHM and the PHM sends information needed for CC packet validation to the PLCP. If the PHM receives positive answer about CC packet vali-

ation from the PLCP, it transmits CC packet to the calling DTE and the originating call state is entered to p4 state.

If the call collision occurs, the PHM clears the terminating call and originating call state is entered to p5 state. Therefore the PHM carries out the same action just like the case of the preceding CR packet received from the originating DTE in the p1 state and clears the corresponding virtual call which is to be established because the PHM has already transmitted IC packet to the DTE.

3.1.2 Data transfer

In the p4 state, which is the most important state explained in this paper, data, interrupt, reset and flow control packet, etc., are processed. The p4 state has three substates related to the reset operation. Various algorithms are especially recommended in treating flow control and reset processing. The TDX-10 adopts an algorithm as simple and easily implemented as possible because we don't have any experience of packet switching development.

3.1.2.1 Buffer management

There are two kind of buffers to store data packet during data transfer : DTE_buffer and Internal Interface (II)_buffer. DTE_buffer stores the data packet received from the DTE. The data packet is transmitted to the corresponding PHM in case of PHM inter-call or the corresponding DTE in case of PHM intra-call. II_buffer stores the data packet received from the corresponding PHM and transmits the datapacket to the corresponding DTE. Therefore II_buffer is used only for PHM inter-call. The static memory allocation of the DTE_buffer and the II_buffer to every logical channel being used is adopted for simplifying S/W in spite of unnecessary memory waste. Several cells are allotted to a logical channel being used. Every cell is idle at an initial state. After a data packet is copied to an idle cell, the

cell enters busy state, which is called the busy cell. The response (e.g., RR packet) to a busy cell is arrived and the cell enters the idle state.

3.1.2.2 Flow control

In the data transfer phase, user data which are conveyed in data and interrupt packets are passed transparently through the network. Virtual circuit flow control is a mechanism provided to ensure that the sending DTE doesn't generate data at rate faster than the receiving DTE can accept. This is achieved by the receiving DTE controlling the rate at which it accepts data packet across DTE/DCE interface, noting that there is an upper limit on the number of data packets which may be in the network on a virtual circuit. Thus, flow control has end-to-end significance because back pressure exerted by a called DTE is reflected back to the sending DTE.

Flow control in the TDX-10 is carried out between the DTE and the PHM (point-to-point concept) to improve the throughput using enough DTE_buffer and II_buffer to store data packet because if the sending DTE waits for the acknowledgement from the remote DTE in case of using end-to-end flow control, it takes much more time than the point-to-point flow control.

The sequence check of the data packet is carried out at the DTE/DCE interface, the PHM in the TDX-10. Original sequence number of the data packet received from a DTE is unchanged until the data packet arrives at the corresponding DCE. The corresponding DCE updates the sequence number available to its interface.

If the sequence of the data packet received from the DTE is abnormal, the reset state will be occurred. Otherwise the following procedures are carried out for both PHM intra-call and PHM inter-call.

-The PHM checks whether it can transmit the DTE data packet. If there is a data packet to be transmitted, a technique known as

piggybacking is used. Otherwise flow control packet (e.g., RR packet) is used. In case of receiving a RNR packet from the DTE, the PHM can't transmit any data packet to the DTE

-When there is no idle cell of the DTE_buffer, the PHM transmits RNR packet to the DTE to protect overwriting of the cell.

The following procedures are used only for PHM inter-call.

-The PHM checks whether it can transmit data packet to the corresponding PHM. If there is a data packet to be transmitted, a technique known as piggybacking is used. Otherwise flow control packet (e.g., RR packet) is used. In case of receiving a NRNR packet from the corresponding PHM, the PHM can't transmit any data packet to the corresponding PHM.

-When there is no idle cell of the II_buffer, the PHM transmits NRNR packet to the corresponding PHM to protect overwriting of the cell.

The PHM can do flow control between PHMs as transmitting NRNR packet to the corresponding PHM in case of the following cases.

-There are no idle cells in II_buffer because the DTE can't receive any data packet from the PHM.

-The IP is used for data transfer between PHMs. When the IP can't treat any data packet from the corresponding PHM, it requests X.25PH block to stop data transfer.

3.1.3 Call clearing

Call clearing occurs before /after data transfer. If the call is refused by the called DTE, the DTE can signal the reason for call clearing to the calling DTE with a diagnostic code. Once the call has entered the data transfer phase, either the calling DTE or the called DTE can clear the call using

the diagnostic code to signal the reason for the clearing to the remote DTE. If the call is cleared by the network, it will signal this fact and indicate a call progress signal (e.g., DTE originated) to the DTE.

All data generated by the DTE before initiation

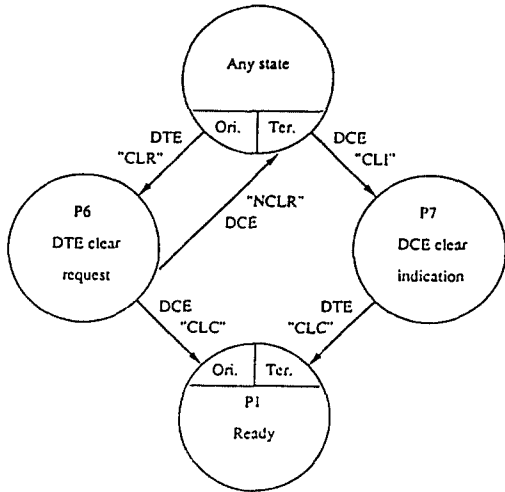


Fig. 3 Call clearing phase.

of a clear procedure must be delivered to the remote DTE before the completion of clearing at the remote DTE/DCE interface. When a DTE initiates a clear, all data by the remote DTE before the receipt of the corresponding indication are discarded by the network.

Fig. 3 shows general call clearing phase. After the PHM transmits CLI packet to a DTE, it the call state is entered to the p7 state. There are many specified states concerning with clearing in exchanges. The reason why the TDX-10 chooses two states is that IP must be responsible for a reliable transmission between PHMs in case of PHM inter-call. In case of PHM intra-call, clearing is treated at a originating link and a terminating link each in a same PHM.

3.2 d state processing

The reset procedure is used to reinitialize flow control procedure on a virtual call. That is, all se-

quence numbers set to zero and all user data which is in a network is transmitted to each direction. When the reset is initiated by the DTE, it may convey the reason for the resetting to the remote DTE via a diagnostic code. If the reset by the network, the reason is conveyed to both DTEs.

All data generated by the DTE before initiation of a reset are discarded by the network before the completion of the reset procedure at the remote DTE/DCE interface. When a DTE initiates a reset, all data by the remote DTE before the receipt of the corresponding indication are discarded by the network. Reset can occur in a point-to-point sequence number check too. But in the TDX-10 reset procedure is designed for end-to-end concept to keep efficiently up with flow control sequence number. The action of the DTE after reset state is classified into two sorts. First, the DTE clears the virtual call and retry to set up the call. Second, the DTE retransmits the DCE data packet from a specified information block according to the upper level processing. The PHM does carry out only reset processing for any cases and the reliable data packet transfer depends on the calling DTE and the called DTE. Reset can be generated by a DTE or a PHM. Reset state processing is shown in Fig. 4 briefly.

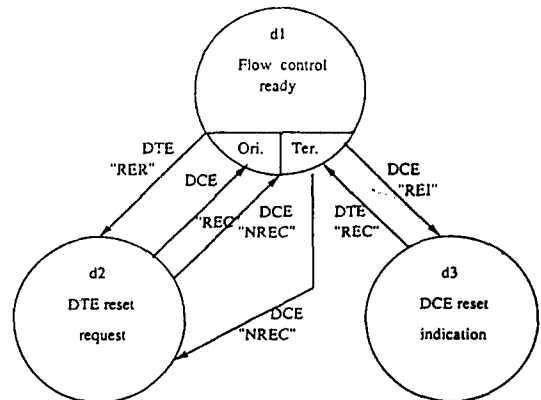


Fig. 4 Reset phase

After PHM receives RER packet from the DTE, PHM checks whether the corresponding interface finishes reset processing. If finishes, the PHM transmits the DTE REC packet. When reset happens to a PHM, the PHM checks whether the corresponding interface finishes reset processing. If finishes, the PHM transmits the DTE REI packet.

3.3 restart processing

The restart procedure provides a mechanism to recover from major failures. The issuance of a RSR packet is equivalent to sending a CLR packet on all logical channels for switched virtual circuits. Restart also happens to a DTE and a PHM. The design of the restart procedure is considered in case of receiving RSR packet from the DTE. When the PHM receives RSR packet from a DTE, it clears all virtual calls connected to the DTE and then transmits the DTE RSC packet. When the maintenance S/W is developed, the restart procedure that the PHM generates must be considered in the future.

4. Implementation of X.25

There are two S/W blocks concerned with X.25: X25LH and X25PH. X25LH does link activation and deactivation, etc., and X25PH

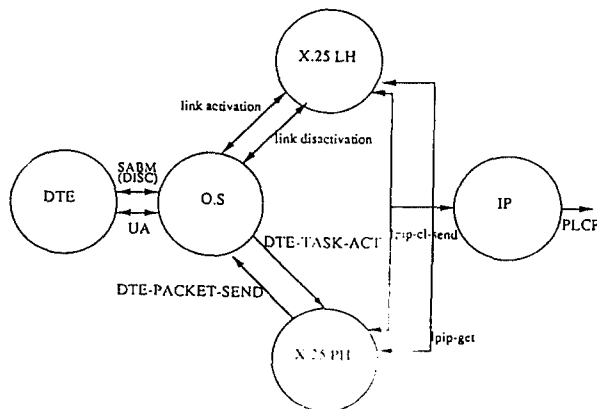


Fig. 5 S/W interaction diagram

processes the PLP. X.25PH is driven by OS, IP and PLCP as shown in Fig. 5.

- The PHM transmits a packet using DTE_PACKET_SEND procedures to the DTE and receives a packet from the DTE, DTE_TASK_ACT each.
- The PHM transmit/receives a signal information to/from the PLCP with lpip_cl_send or lpip_get procedure and a internal packet to/from a corresponding PHM in case of only PHM inter-call.

A link activation is occurred only when the first virtual call is tried to be set up on a link. A link deactivation is occurred only when the last virtual call is cleared on a link.

OS checks whether the LAPB frame received from the DTE includes the information field or not. If it doesn't include, OS drives X25LH. Otherwise, OS informs X25PH of existence of a packet. The packet is copied to the DTE_buffer and analyzed in X25PH. When there is a packet received from the called/calling DTE or the corresponding PHM, which is to be transmitted to the calling/called DTE, X25PH informs OS of the packet length and start pointer in DTE_buffer in case of PHM intra-call or II_buffer, PHM inter-call.

5. Performance Analysis

5.1 Throughput

The throughput analysis has been done for two types of packet call: PHM-intra call and PHM-inter call. PHM intra-call has higher throughput than PHM inter-call because it doesn't need internal communication between PHMs.

5.1.1 PHM-intra call

There are three main parameters which affects the calculation of throughput of PHM-intra call in the TDX-10 packet switching system.

In order to process a data packet in PHM-intra

call, the following processings are required : application S/W processing, one "DTE-TASK-ACT" procedure call from OS to the application S/W and one "DTE-PACKET-SEND" procedure call from the application S/W to OS. We obtained the processing time for each processing, based on the approximated value of the program execution time on the real target system.

- (1) application S/W processing time : 0.941 ms
- (2) "DTE-TASK-ACT" procedure call processing time : 0.473 ms
- (3) "DTE-PACKET-SEND" procedure call processing time : 0.586 ms

Assuming that the number of flow control packet occurs half of one of the data packet in case of 2 of window size according to the default window size of the CCITT X.25 recommendation and the program execution time of a flow control packet is equal to that of a data packet, the total processing time is calculated by multiplying 1.5 by the summation of the above (1), (2) and (3).

Therefore the total processing time for a data packet is 3 ms. It means that the throughput of a PHM is 333 packets in case of PHM-intra call.

5.1.2 PHM-inter call

In case of PHM-inter call, the IP processing time is added to the PHM-intra call processing time. The IP processing time is about 2.295 ms according the calculation of the program execution time.

Therefore the total processing time for a data packet is 6.443 ms. It means that the throughput of a PHM is 153 packets in case of PHM-inter call.

5.2 Call processing capacity

To estimate the call processing capacity, two main difficult problems are occurred in the TDX-10 packet switching system. At first the PH is centralized on the ISDN environment. Therefore the link setup has to be established for the

first virtual call on a link and then has not to be needed from the next virtual call on the same link. It's difficult to estimate how many calls doesn't need the link establishment. Secondly it's also difficult to get the ratio of the data packet in a virtual call under the ISDN environment.

Therefore the call processing capacity is not referred in this paper because of the problem mentioned above.

6. Tst environment

It is necessary to verify the application S/W adapts CCITT X.25 protocol into the TDX-10. Verification of this S/W is carried out with two steps. At first Chameleon32 X.25 protocol tester is used for the basic test of the S/W. Chameleon32 protocol tester consists of two ports. When these two ports are connected to two links of a PHM, Chameleon32 is treated as the simulator mode. After the basic test is finished, two DTEs are connected to two links of a PHM and the DTEs generate all sort of the packets. The DTE displays the result of X.28 protocol in the CRT. Chameleon32 is treated as the monitor mode which monitors X.25 protocol between DTE and the link of the PHM.

7. Conclusion

This paper presented how X.25 protocol is implemented into the TDX-10 packet switching system. Performance analysis and test environment are also described considering implemented S/W program. Flow control in the TDX-10 is carried out between the DTE and the PHM (point-to-point concept) to improve the throughput using enough DTE_buffer and II_buffer to store data packet. The present version of X.25 state machines and procedures in the TDX-10 will be revised according to the result of software test which is being done and the addition of maintenance functions.

Abbreviation

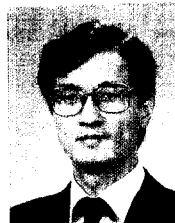
ASP(Access Switching Processor)
 BAMI(Basic Access Multiplexer Interface)
 CA(Call Accepted)
 CC(Call Connected)
 CI(Control Interworking)
 CLC(Clear Confirmation)
 CLI(Clear Indication)
 CLR(Clear Request)
 CR(Call Request)
 DSI(Digital Subscriber Interface)
 DTI(Digital Trunk Interface)
 FMXP(Frame Multiplexer Processor)
 IC(Incoming Call)
 IP(Internal Protocol)
 ISAP(ISDN Subscriber Access Processor)
 NCA(Network Call Accepted)
 NCR(Network Call Request)
 NCLR(Network Clear Request)
 NREC(Network Restart Confirmation)
 NRER(Network Reset Request)
 NRNR(Network Receive Not Ready)
 OS(Operating System)
 PHM(Packet Handling Module)
 PLCP(Packet Layer Control Processor)
 PSI(Primary Access Subscriber Interface)

REC(Reset Confirmation)
 REI(Reset Indication)
 RER(Reset Request)
 RSC(Restart Confirmation)
 RSR(Restart Request)
 SS(Signaling System)
 X25LH(X25 Link Layer Handler)
 X25PH(X25 Packet Layer Handler)

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