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# Anatomy of the Integrated Services Digital Network's D-Channel Access Procedure



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The ISDN D-Channel Access Procedure relies heavily on the Interframe Time Fill transmission, priority mechanism, and the D-Channel multi-point contention resolution scheme. This report presents an overview of the above issues and also illustrates certain pitfalls of this methodology.

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ANATOMY OF THE INTEGRATED SERVICES DIGITAL NETWORK'S D-CHANNEL ACCESS PROCEDURE


## Summary

The evolution of the old circuit-switched network to a world-wide Integrated Services Digital Network (ISDN) has become a reality. ISDN has been under the auspices of the International Telegraph and Telephone Consultative Committee (CCITT) for over ten years. The current CCITT I Series Recommendations[1] describe the ISDN Basic Rate Interface (BRI) as consisting of two B-channels and one D-channel (2B + D). Each B-channel, which provides full duplex 64 kbps bandwidth, is used to carry digitized PCM voice in circuit mode as well as digital data in either circuit or packet mode. The D-channel, which provides full duplex 16 kbps bandwidth, is used to carry signaling information to control circuit-switched calls on the associated B channels and can also be used for packet switching. With the proper set up, the ISDN BRI allows for a number of Terminal Equipments (TEs) to access the network in a multi-point configuration. A D-channel access procedure has been defined in order to provide a fair mechanism for the TEs to access the D-channel. The access procedure relies heavily on the Interframe Time Fill transmission, priority mechanism, and the D-channel multi-point contention resolution scheme. This paper presents an overview of the S/T Interface Frame structure, examines the D-channel access control approach, and illustrates certain pitfalls of this methodology.


## 1.0 Introduction

The CCITT Study Group XVIII defines the Integrated Services Digital Network (ISDN) as a network which *"evolved from the Telephony Integrated Digital Network (IDN) that provides end-to-end digital connectivity to support a wide variety of services, to which users have access by a limited set of standard multipurpose customer interfaces."* Figure 1 shows the various reference points (interfaces) and functional groupings of the ISDN BRI[2].

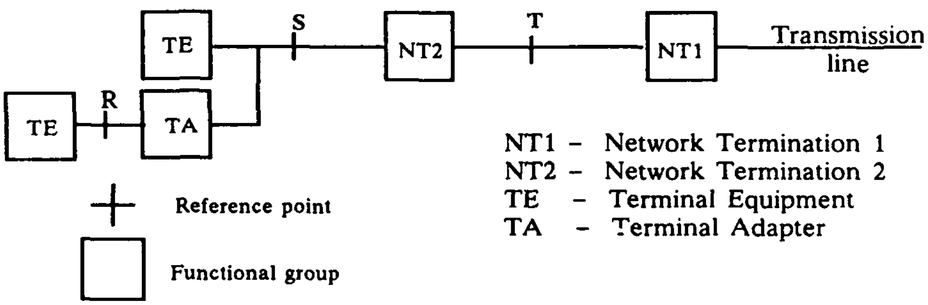


**Figure 1. Reference Configurations for the ISDN-User Network Interface**

The NT1 converts the signals at reference point T to signals suitable for transmission on the transmission line and vice versa. It also provides functions such as line transmission termination, interface termination, maintenance, and contention resolution. The main function of Network Termination (NT2) is to allow the joint use of a network access by more than one TE. The functional group TE is defined as either a terminal equipment specially designed for the ISDN and connected directly to the reference point S, or a terminal equipment with a conventional interface (e.g. RS232) connected via a terminal adapter (TA). The T Reference point provides the connection between the NT1 and the customer. The S Reference point is the interface between the NT2 and the ISDN terminals. The R Reference point serves as a connection between TA and any non-ISDN terminal. The S/T Reference point allows two modes of operation: point-to-point and point-to-multipoint (passive bus) operations. In the passive bus configuration, a maximum of eight Terminal Equipments (TEs) can be connected at random points along the interface cable. To allow these TEs to gain access to the D-channel in an orderly fashion, a D-channel access control procedure has been defined. This procedure permits only one TE to complete transmission of its information on the D-channel at any given time.

To complete the description of Figure 1, it is necessary to point out that each TE, in a passive bus configuration, is assigned and identified by a unique Terminal Endpoint Identifier (TEI) number. These TEI numbers will be assigned either by the switch or by the user depending upon the type of switch at the local Central Office (CO). In any event, no two TEs should have the same TEI number within the same ISDN user network interface. It will be helpful at this point to examine some of the basic characteristics of the Physical (Layer 1) and Link (Layer 2) layers of the ISDN user-network interfaces.

Physical Layer

The physical layer, which is presented to the user at either reference point S or T, provides functions such as the full duplex transmission of data for both B and D channels, transmission of timing signals, D-channel contention access, power feeding, and others. The current transmission code used is called *pseudo ternary code* as shown in Figure 2. For this line code, binary zero is represented by either a positive or negative pulse on the line, while a binary one is represented by no pulse (no line signal). Successive pulses (binary zeros) will alternate in polarity. If a pulse does not adhere to the alternating polarity, it is defined as a *bipolar violation*.

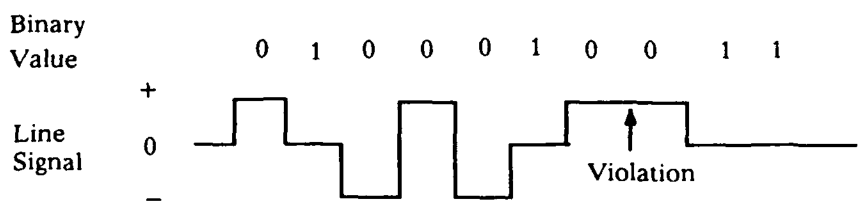


**Figure 2. Alternating Zero Inversion Line Code**

The S/T interface frames contain 48 bits transmitted at the rate of 192 kbps. Each frame is composed with various bits as shown in Figure 3. A detailed functional description of these bits can be found in reference[1]. Our discussion will only examine the D and E bits which are the D-channel and the D-echo channel bits, respectively.

TE → NT1

| F L B1* L D L Fa L B2* L D L B1 L D L B2 L D L |
|---|

NT1 → TE

| F L B1 E D A Fa N B2 E D M B1 E D S B2 E D L |
|---|

* Each B1 & B2 time slots contain 8 bits.

**Figure 3. S/T Interface Structure**

Within each frame transmitted in the direction from TE to NT1, the D-channel bits are located at the twelfth, twenty-fifth, thirty- sixth, the forty-seventh bit positions. They are used to carry signaling information for circuit switching calls through the ISDN network. It can also be used to interleave low speed X.25 packet data to the network when not used to carry signaling information. To accommodate multiple TEs to access the common D-channel, the D-channel bits can only be a binary 0 (pulse) in the negative direction or a binary 1 (no pulse). This is to avoid invalid situation as shown in Figure 4.

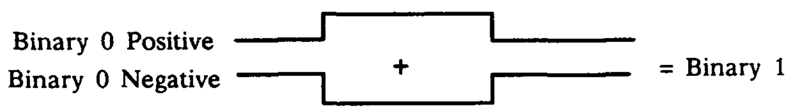


**Figure 4. Invalid condition for S/T Interface D-channel bit**

When the D bits reach the NT1, the NT1 implements a logic "AND" operation on the D bits, and echos the logically operated D bits back to the TEs through the E (D-echo) channel. These E-channel bits are located at the eleven, twenty-forth, thirty-fifth, the forty-sixth bit positions of each frame transmitted by the NT1. All TEs are required to monitor these E-channel bits to autonomously control their D-channel access. A TE with no information to send will send binary ones on the D-channel. This is known as Interframe Time Fill. The main purpose of the Interframe Time Fill is to correspond to absence of line signal on the channel.

<u>Link Layer</u>

Each D bit is used to construct a layer 2 frame as in Figure 5. The first octet of the frame is called the flag. The flag is composed of one zero bit followed by six consecutive ones followed by a zero bit (01111110 or 7F hex). It is used specifically to achieve byte synchronization. The second octet is composed of the Service Access Point Identifier (SAPI) bits, the Command/Response (C/R) bit, and the Extended Address (EA) bit. The third octet is composed of the Terminal Endpoint Identifier (TEI) bits and others. The details of the layer 2 frame will not be repeated here, interested readers should refer to other articles.[3]

## 2.0 Access Procedure

### Priority Mechanism

To ensure that signaling (e.g. call control) information will be transmitted over all other types of information, the signaling information is given priority class 1 (P1) while all other types of information are assigned with priority class 2 (P2). Each priority class can be further subdivided into two levels (i.e. normal or lower level). For priority class 1, the normal level is represented by eight binary ones while the lower level is represented by nine binary ones. For priority class 2, the normal level is represented by ten binary ones and the lower level is represented by eleven binary ones. The priority mechanism is based on the requirement that a TE can only start any layer-2 frame transmission upon completion of the following:

(1) A TE shall monitor the D-echo channel, counting the number of consecutive binary ones. The current value of the count is stored in counter C.

(2) A TE can only start layer-2 frame transmission when C is equal to, or exceeds, the value of its own priority at that stage.

When a TE has successfully transmitted a layer-2 frame of that priority class, the value of P1 or P2 is changed from the normal level to the lower level of priority. This will allow other TEs with the same priority class to gain access to the D-channel in the next round. The value of P1 or P2 will change from the lower level back to the normal level of the same class when counter C is equal to the value of the lower level priority class. This priority mechanism provides the first basic contention resolution for multiple TEs to access the D-channel without any actual contention taking place.

### Collision Detection/Resolution

After attaining the D-echo bit priority count, the TE will try to immediately take control of the D-channel by sending the layer-2 frame. If more than one TE has the same priority class with the

| Octet | | | |
|---|---|---|---|
| 1 | FLAG | | |
| 2 | Service Access Point Identifier (SAPI) | C/R | EA |
| 3 | Terminal Endpoint Identifier (TEI) | | EA |
| | Control (1 or 2 Octets) | | |
| | Information (0 to 260 Octets) | | |
| | Frame Check Sequence | | |
| | Frame Check Sequence | | |
| | FLAG | | |

**Figure 5. Layer 2 Frame**

same level, each device will start to send the flag bits, then follow by the Service Access Point Identifier (SAPI) bits. The SAPI has the following values:

| SAPI Value | Related layer 3 or management entity |
|---|---|
| 0 | Call control procedures |
| 1 | Reserved for packet mode communications using Q.931 call control procedures. |
| 16 | Packet communication conforming to X.25 Level 3 Procedures. |
| 63 | Layer 2 Management procedures |
| All others | Reserved for future standardizations |

The TE will still monitor the D-echo bit by comparing the last transmitted bit with the next available D-echo bit while transmitting information in the D channel. If the transmitted bit is the same as the received D-echo bit, the TE will continue its transmission. However, if the received D-echo bit is different from the transmitted bit, the TE will cease transmission immediately and return to the initial monitoring state. Thus for device A which sent a "1" versus device B which sent a "0" on the D-channel at the same time, the reflected D-echo bit will be a "0" (due to the AND operation performed by the NT). When that happens, device A will cease transmission immediately and return to the D-channel monitoring state.

The TE, which has call control information with a SAPI value of "0" to send, will apparently take control of the D-channel. However, if more than 2 devices have the same priority as well as the same SAPI value, the difference between their TEIs values will provide the final contention resolution. All but one will eventually detect the collision, and the TE(s) that detect a collision will immediately stop the transmission on the D-channel and return to the monitoring state.

## 3.0 Discussion

Because both detection and resolution of collisions are left to the TEs, there are interesting aspects that need to be addressed. Given that the above scenario will work perfectly if all devices (TEs) are functioning properly, many questions arise if one of the TE fails to follow the rules or if error occurs in the S-bus as a result of noise. For example, consider the situation in which one TE starts to transmit the flag bits (01111110) at all times on a passive bus configuration. These flag bits, which contain six binary ones, will echo back through the D-echo channel and invalidate the priority count of other monitoring TEs. A minimum priority count of nine ones can never be attained by other TEs. The malfunctioning TE will appear to have precedence over other TEs which might have either P1 or P2 priority. As a result, signaling and information from other devices will not be transmitted through the D-channel. When this happens, the outgoing BRI ISDN line will seem inoperable to the users. Consequently, because no data link layer (layer 2) can be established for the incoming call set up, the incoming BRI ISDN line will be inoperable as well. To make matters worse, the management of the link depends on transmission of the link layer (LAPD Unnumbered Format) frame. Without link set up, the CO switch might not have a way to detect/correct this problem. The actual recovery process, therefore, will perhaps rely solely on the users.

In addition to the above potential problem, there are other unanswered questions as well[4]. What if the D-channel echo bits are corrupted and all TEs on a passive bus assume that they have the D-channel and begin transmitting? What if all devices attempting to access the D-channel observed the 'echoed address' with a number higher than their own? It is unclear at this point as to what will happen to the CO switch? Will the CO switch go into reconfiguration or diagnostic mode or will it just re-synchronize the link? If the CO switch does intend and has the ability to resolve the problems, what is the delay incurred on each of the stations on the bus and on the network as a whole?

## 4.0 Conclusion

ISDN, in its current state of deployment, is capable of meeting the majority of base level voice and data networking needs. But in order to fully utilize and benefit from this advanced technology, it would be necessary to gain a full understanding of the protocols involved. The D-channel access control mechanism is one which continuously holds our interest because of its complexity and integrity requirements. It is generally perceived that the D-channel will sustain numerous networking problems under a multi-vendor environment. Perhaps some of these problems might be implementation dependent and some might be protocol definitions dependent. In any case, actions should be taken to safe guard the performance of the D-channel. All newly acquired TE or NT should be tested by testing equipment (e.g. protocol simulator) to ensure that they meet the ISDN standards.[5] Firmware should be built-in for each basic device to allow the detection, notification, or correction of the error(s) in order to maintain daily operations. It might also be helpful to provide user training to allow end-users to detect/correct some of the basic problems. As a whole, the basic motivation of this paper is to promote a better understanding of the D-channel and to lay the ground work for our further research within AIRMICS in the ISDN D-channel performance and characteristics areas.

## References

[1] CCITT Recommendation I.430, October 1984.

[2] American National Standards Institute T1.601, 1988.

[3] William Stallings. *Integrated Services Digital Networks (ISDN).* IEEE Computer Society, 1988.

[4] "Technical Issues in Evolving ISDN", Final Report, AIRMICS, dated Feb 91.

[5] W. Kirchner and P. Wagner, "ISDN D Channel Protocol Simulator," Electrical Communication, vol 61, pp. 97-103, 1987.