Understanding and Testing V5.1 and V5.2 Interfaces

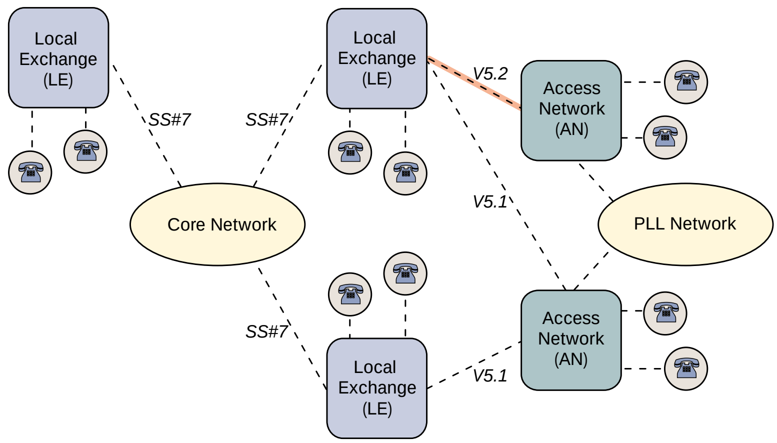

FIGURE 1
Example of a V5.1/V5.2 link in the context of the telecommunication network.

Introduction

As telecommunications markets become increasingly deregulated, subscriber access networks become correspondingly more important. To enable end users to be connected to the telecommunications network, a growing number of service providers are bringing solutions to market for varied types of access networks. These diverse solutions have one thing in common: they require an interface to the core network that should be as manufacturer-independent and comprehensive in its functioning as possible. ETSI has provided a proven solution to this problem by defining the V5.1 and V5.2 interfaces.

This technical brief describes the key functions and structure of the V5.x interfaces and discusses briefly some important factors to consider when testing these interfaces.

Purpose of the V5.x Interface

A V5.x interface is a standardized means of connecting remote subscriber access units. Figure 1 shows that V5.x forms the interface between the core network and the access network (AN).

The AN is connected to a core network element called the local exchange (LE). V5.x is the interface for this connection. In some cases, an AN can also be connected to different types of networks (e.g., PSTN, leased line and packet networks) via a number of different interfaces. V5.x is only used for connections to the PSTN core network. Connections to other types of networks are most likely not V5.x-based. However, an AN may be connected to several LEs in the core network by using several V5.x interfaces.

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V5.x enables the exchange of analog line signals and ISDN signaling, and allows user ports to be blocked or unblocked via special mechanisms and protocols. The structure of these protocols closely resembles that of the ISDN. However, different messages and information elements are used in layer 3 (L3). V5.1 is defined for a single 2,048 kbit/s link and V5.2 for up to 16 2,048 kbit/s links.

V5.1

ETSI document EN 300 324-1 (ITU-T G.964) defines the V5.1 interface. Signaling information is transferred in up to three time slots (16, 15, and 31). At a minimum, time slot 16 must be used. Typically, an AN may be linked with one or more LEs over several V5.1 interfaces. In practice, quite often the greater part of the distance to the user is covered within the AN, so parts of the AN may be closely linked to the LE. Consequently, in some circumstances the actual V5.1 interface covers only a few meters. V5.1 supports analog subscriber lines (PSTN) as well as ISDN Basic Rate Access in the AN.

Function

The V5.1 interface is a non-concentrating interface. This means that the number of subscriber speech channels n is less than or equal to the number of bearer channels m on the V5.x E1 link to the local exchange. In a concentrating interface such as V5.2, on the other hand, more subscribers could be connected to the access network than the number of bearer channels to the local exchange (e.g., n subscriber speech channels are multiplexed on m bearer channels on the V5.x E1 link(s), where n is typically around four times m. As V5.1 is a non-concentrating interface, n Note that ISDN user ports have up to two subscriber speech channels. Therefore, in V5.1, a fixed time slot on the 2,048 kbit/s link is assigned to every PSTN subscriber, and up to two fixed time slots to every ISDN subscriber having a basic rate interface. All voice channels of any given subscriber must be assigned to time slots on the same V5.1 interface.

V5.1 can transport ISDN LAPD frames transparently between the AN and the LE. ISDN layers 2 (L2) and 3 (L3) are terminated in the LE and in the ISDN terminal. The Port Control protocol of V5.1 is used for activating and deactivating ISDN layer 1 (L1). The different ISDN user accesses are identified over the EF address (EFaddr).

V5.1 provides the PSTN protocol for transferring analog line signals. As a connection-oriented protocol, V5.1 uses a three-phase communication process. The first phase establishes a connection for further information exchange (as, in informal conversation, saying “Hello, how are you?” and hearing your colleague say, “Fine, thanks, how are you?”). Phase 2 brings the exchange of information, indicating or requesting a change in line status, e.g., discussing what you want to discuss. When the information exchange is complete (“Nice talking with you; see you soon,” and, “You’re welcome; have a nice day.”), the connection is explicitly terminated.

The LE can initiate a change in the line status (impedance, voltage or level) at the AN. Signaling transmitted within the voice channel via DTMF tones is analyzed within the LE. All other in-band signaling is analyzed by the AN, and then sent to the LE via the PSTN protocol. The different analog user accesses in the AN are identified over the L3 address (L3addr).

To enable transmission of the ISDN protocol for various connections, and also transmission of the V5 protocols on the same communication channel (time slot), V5.1 defines an additional function below L2. This function may be referred to as the EFaddr multiplexer.

The provisioning of subscriber data is not controlled and set up over the V5.1 interface. Instead, a Q3 interface is recommended for this purpose for both the LE and the AN side. However, this interface is not defined within the V5.1 standard. Because the Q3 interface is not well defined and is rarely used, there is a chance that the data for the same interface may be set up differently on the LE and AN side. Errors may result, and they range from a totally non-functional interface to incorrect connections of bearer channels to user ports.

V5.1 Protocols

The V5.x L3 protocols are based on a V5-specific L2 protocol, the LAPV5. The LAPV5 is very similar to the LAPD for ISDN point-to-point connections. The main differences occur in the structure of the address field, the lack of TEI management procedures and the lack of most messages regarding the termination of the L2 connection.

The V5.x L3 protocols all use the same structure, as shown in Figure 2.

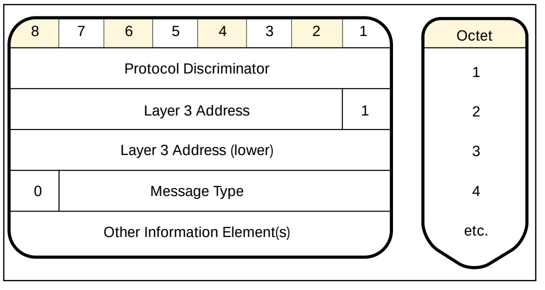

FIGURE 2
Structure of the V5.x layer 3 messages.

The information elements have the same structure as in the ISDN protocol, but the content is different.

Figure 3 shows a typical V5.1 reference model.

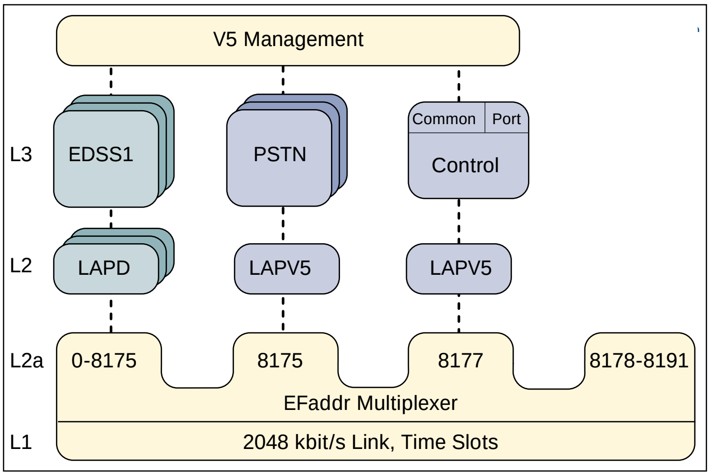

FIGURE 3
A V5.1 reference model.

EF Address (EFaddr) Multiplexer

The EFaddr multiplexer function (V5.x frame-relay sub-layer) is an L2 sub-function. It enables transportation of L2 frames from various sources over the same time slot. For this purpose an additional address field is added, which identifies the sources/destinations. The address field has the structure shown in Figure 4.

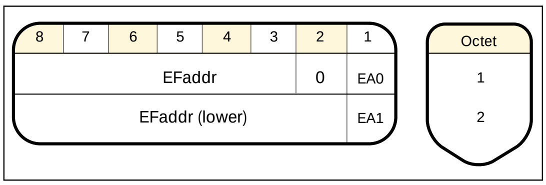

FIGURE 4
Structure of the EFaddr.

EFaddr values range from 0 to 8191. Values from 0 to 8175 are used for the unique identification of ISDN user ports, while values from 8176 to 8191 are reserved to identify the various L2 connections for the V5.x protocols. In the latter case, the L2 address is the same as the EFaddr.

The EFaddr is attached as shown in Figure 5.

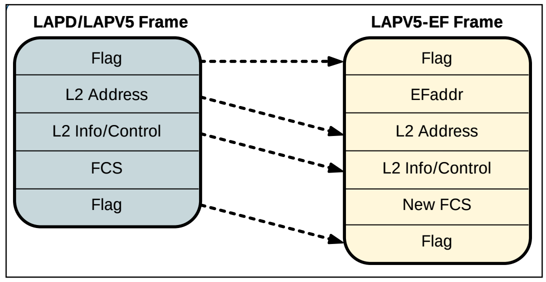

FIGURE 5
How the EFaddr function works.

Control Protocol

The Control Protocol is used to manage the V5.1/V5.2 interface and the user ports in the AN. The V5.1 Control Protocol is connectionless and consists of two parts, Common Control and Port Control. Common Control is used to manage the entire interface. Port Control is used to change the operating status of the user ports in the AN and to operate the L1 of ISDN user ports.

The Control Protocol consists of four messages, two each for the Common Control and the Port Control Protocol. Each message transports information, or is an acknowledgment message (ACK) for the other type of message. An acknowledgment message confirms receipt of the information message, but not of the information/action included in it. Another information message per L3addr is sent only when the previous one has been acknowledged. The Control Protocol uses its own LAPV5 connection, and the EFaddr 8177.

Common Control

This protocol uses the COMMON CONTROL and COMMON CONTROL ACK messages. The L3addr is a copy of the EFaddr. These messages are relevant for an entire V5.x interface, and perform the following procedures:

- **Verify Variant and Interface ID:** Every V5.x interface within an AN or an LE must be assigned a unique 24-bit Interface-ID. The AN or the LE may query this ID from its opposite party. Telephone traffic can take place only if the queried ID conforms to the ID of the querying AN or LE. This procedure ensures that the correct physical connections are established between the AN and LE. The Variant that is also exchanged with this procedure indicates which set interface configuration data should initially be used.
- **Restart Procedure:** This procedure forces all PSTN L3 state machines into a neutral status using a three-phase acknowledgment procedure. The procedure can be initiated by the AN, LE or both.
- **New Variant Switch-over:** This procedure, rarely used in practice, enables coordinated switching to a new set of interface configuration data, previously defined separately in the AN and in the LE.

Procedures 1 and 2 (not in 2nd Edition) must be executed to boot the V5.x interface after starting. They can also be triggered by either side at any time for various reasons, such as an operator request, detection of a temporary link failure, repeated PSTN protocol errors or PSTN L2 failure, or restart of internal state machines or processors.

Port Control

This protocol uses the PORT CONTROL and PORT CONTROL ACK messages to manage the user ports in the AN. For ISDN user ports, the L3addr is a copy for the EFaddr of the ISDN user port; for PSTN user ports, it is a 15-bit number (the L3 address of the PSTN protocol). The two address ranges differ in the first bit of the first byte of the L3addr. Port Control performs the following procedures:

- **Coordinated Port Unblocking:** This procedure operates with two-phase acknowledgment and allows coordinated unblocking of user ports. If this procedure has been run for all user ports, AN and LE have a common understanding of which user ports are ready for operations and which are not. To unblock ports faster, the Accelerated Port Unblock Procedure has been defined as an amendment to the standard. This Procedure must be run for all user ports that are expected to be ready for operation while the V5.x interface is started.
- **Port Blocking:** This procedure typically operates with two-phase acknowledgment, but in an emergency it can be substantially shortened. It is used to block user ports, e.g., if you don't want to use them any more, or for maintenance.
- **Activate/Deactivate ISDN Access:** This procedure operates with two-phase acknowledgment, and enables the LE to direct the AN to activate or deactivate L1 for a specific ISDN user port. The AN, on the other hand, can use this procedure to show a change in the L1 status of an ISDN user port.

Additional procedures are provided for ISDN user ports. However, these will not be addressed here as the detail is not relevant to the purposes of this brief.

PSTN Protocol

The PSTN protocol is a connection-oriented L3 protocol for transmitting analog line signals. To enable transmission, a PSTN L3 connection has to be established for the corresponding analog user port (with ESTABLISH and ESTABLISH ACK messages). The L3addr identifies the user port. Once a protocol connection is established, line status changes can be sent from the AN to the LE with SIGNAL messages, and changes to the line status can also be initiated by the LE. The most commonly used signals are defined as follows:

- **STEADY SIGNAL:** Change in the line status from one stable state to another (e.g., picking up the handset generates a steady signal OFFHOOK).
- **PULSED SIGNAL:** A sequence of status changes connected in time (e.g., hook pulse generates the pulsed signal REGISTER RECALL).
- **DIGITS:** Pulses recognized as digits in the IWV (Impuls Wähl Verfahren, meaning pulse dialing in German) by the AN.

When a conversation or a signaling transaction is finished, the DISC and DISC COMPL messages terminate the L3 connection.

The PSTN protocol provides several additional functions—for example, to send metering pulses or to run time-critical sequences autonomously in the AN. The PSTN protocol was defined to take into consideration most (in the sense of all known) of the available international analog signaling types. For example, the German telecom uses three types of PSTN signaling (one each for POTS, in-dialing analog PABX and emergency phones).

Within the PSTN protocol, the AN has the task of converting detected line-signal changes on analog user ports into PSTN messages, and received PSTN messages into line-signal changes. The LE operates the logic for analog signaling, evaluation of the DTMF tones and implementation of tones and announcements (with the exception of the metering pulse).

The PSTN protocol uses its own LAPV5 connection and uses the EFaddr 8176.

ISDN Protocol

The ISDN protocol is not a component of the V5.x definition. However, with the EFaddr multiplexer, V5.x is able to transport ISDN LAPD frames transparently from the AN to the LE. Signaling for the ISDN L2 and L3 is handled in the LE. The AN only handles the ISDN L1, which is controlled by the LE using the Port Control Protocol.

The EFaddr range from 0 to 8175 is reserved for transferring the protocol for the ISDN user ports.

V5.2: A Concentrator Interface

The V5.2 interface is an advancement of the V5.1 interface; it is defined in ETSI document EN 300 347-1 and is based on up to sixteen 2,048 kbit/s links. Signaling information is transferred in up to three time slots (16, 15, 31) per 2,048 kbit/s link. As a minimum, time slot 16 on two 2,048 kbit/s links must be used for signaling, except in single-link mode.

The following discussion of V5.2 explains the major differences between it and V5.1; aspects not discussed are identical in both protocols.

Function

V5.2 is a concentrator interface. The assignment of time slots as voice paths to the 2,048 kbit/s links is handled dynamically with a special protocol. Time slots can be assigned when a connection is established and then released or permanently assigned when the V5.2 interface is started. In addition to the access types that V5.1 allows on the AN, V5.2 supports ISDN primary rate accesses.

V5.2 also provides mechanisms that allow signaling channels to be transferred to other intact 2,048 kbit/s links if a 2,048 kbit/s link fails.

Protocols

Figure 6 illustrates a typical V5.2 reference model. In addition to the protocols and mechanisms of V5.1, V5.2 defines the Bearer Channel Control (BCC), Protection and Link Control protocols.

Bearer Channel Control Protocol

The BCC protocol enables the concentrator functionality. BCC protocol allows the LE to direct the AN to connect voice channels on user ports with voice channels on one of the 2,048 kbit/s links, while in operation. The BCC protocol operates on a transaction basis. The most important primitives are:

- **Allocation:** The LE requests that a voice channel of a user port be connected with a free channel on the V5.2 interface.
- **De-allocation:** The LE requests the termination of a voice channel connection.
- **Audit:** The LE queries the connection status of a specific user port or a specific channel from the AN.

To implement the BCC protocol, the AN and LE must have an implemented channel management instance. Resource management must be implemented in the LE for the channel assignment to be possible.

The BCC protocol uses its own LAPV5 connection and uses the EFaddr 8178.

Protection Protocol

In case of an error in the associated 2,048 kbit/s link, V5.2 can transfer signaling channels to other reserved but free signaling channels. If signaling is detected as defective, all current protocol connections on the channel are transferred to a free standby signaling channel in the same protection group. This switch-over can be requested by the AN and initiated by the LE with the Protection protocol. This process provides two types of security:

- Protection Group 1 comprises the time slots 16 on two 2,048 kbit/s links, where a distinction is made between the primary and the secondary link. Initially, on the primary link the Control, BCC, Link Control and Protection protocols at a minimum are operating. The secondary link is used for security on the primary link and redundant transfer of the Protection protocol.
- Protection Group 2 is optional. The PSTN or ISDN protocol can be transferred over the links of the 2,048 kbit/s links belonging to this group. Here fewer (or even no) standby channels than active signaling channels can be defined.

The Protection protocol is transferred over both 2,048 kbit/s links of protection group 1. For this purpose, as shown in Figure 6, one L2 per 2,048 kbit/s link is established. The L3 messages are processed in a state machine that receives the messages from both L2. In each case, the second version of the same message is detected by its sequential number and discarded.

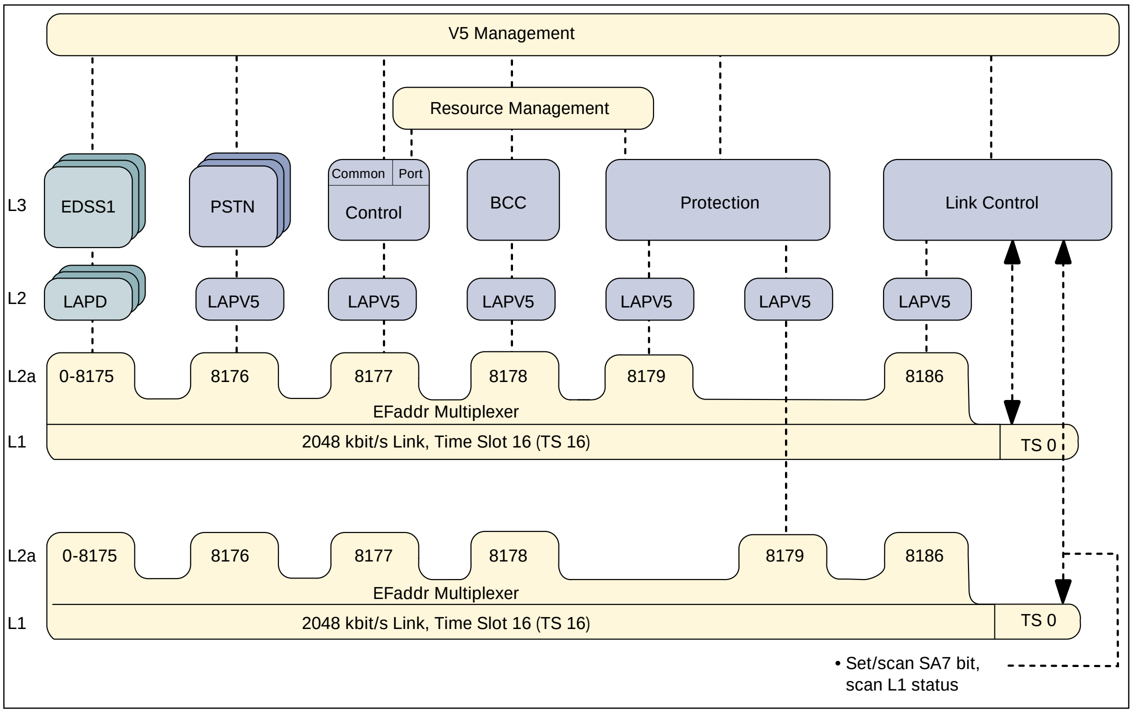

FIGURE 6
A V5.2 reference model.

The following events indicate the failure of a signaling channel:

- An error on layer 1 of the associated 2,048 kbit/s link
- An error in flag monitoring. For this purpose flags are continuously transferred on all signaling channels (active and standby). If no flag is detected for one second, it is assumed that this channel is defective
- An error in data-link monitoring. If one of the L2 connections on a signaling channel fails for a long time in some circumstances, the channel is seen as defective

The Protection protocol uses its own LAPV5 connection on both (primary & secondary link) 2,048 kbit/s links and uses the EFaddr 8179.

Link Control Protocol

Because V5.2 connects up to 16 2,048 kbit/s links per interface between the AN and the LE, it is possible that the links may be connected incorrectly. The Link Control protocol provides a means of automatically detecting incorrect connections. If such connections are established, either the entire interface does not work because the signaling is then done on different physical links, or an incorrect through-connection of bearer channels occurs, since both assume a different link. In this case, there will be no or incorrect bearer-channel handling for the users. In addition, it is also possible to use this protocol to coordinate bringing complete 2,048 kbit/s links in or out of operation on the basis of various L1 errors, or by operator intervention.

The Link Control protocol consists of an L3 part, which is typically transferred within the primary link of protection group 1 on the basis of its own LAPV5 connection, and of monitoring and control functions within the L1 of the individual 2,048 kbit/s links.

The link identification procedure works according to the following principle: One communication partner requests the other over the L3 part to activate the SA7 bit in channel 0 of the specified 2,048 kbit/s link, which is identified by a number. The other side acknowledges the request and switches the SA7 bit on (to zero). Now the initiator of the procedure checks whether the SA7 bit is activated on the appropriate 2,048 kbit/s link. If the SA7 bit is not detected, an error message is sent to the management of the V5.2 interface. After finishing the check of the SA7 bit, the initiator of the procedure requests the other party to reset the SA7 bit and the procedure is finished. This procedure can be initiated by the AN and the LE, and may be executed during the initiation process of the V5.2 interface for all 2,048 kbit/s links. In one V5.2-capable network element only one link ID check is allowed at any given time.

The link control protocol uses its own LAPV5 connection and uses the EFaddr 8180.

Additional V5.x Considerations

To reduce the number of lines that the V5.x interface(s) form(s), increasingly in practice the frames of the individual 2,048 kbit/s links are transferred in part over channels of other broadband transfer media, e.g., E3, and therefore, combined in one physical line. This is accomplished by multiplexing the E1 links into SDH frames or using ATM as a multiplexing medium.

Telcordia, formerly Bellcore, with its GR303, meets V5.x-like functions, but has defined other methods and protocols for that.

To support broadband user access such as B-ISDN UNI, ETSI has defined a broadband variation of V5.x in the form of the VB5.1 and VB5.2 standards based on ATM.

V5.x Interface Testing

A simulating test instrument for the upper layers must be able to meet several basic requirements arising from the structure of the V5.x interfaces. Because of the complexity of these interfaces and the need to run multiple instances of the protocol state machines simultaneously, keeping track of what is being observed, and when, is very difficult without the help of highly capable test instruments.

Basic requirements for V5.1 testing in simulation mode include:

- EFaddr multiplexer function
- Different L2 protocols (LAPD and LAPV5) with several simultaneous instances of the specific protocol state machines
- Simultaneous, different L3 protocols with several instances of each, i.e., multiple protocol state machines, all running independently
- The option of having different L3 instances synchronized with one another and exchanging data
- Full ISDN L2 and L3 functionality

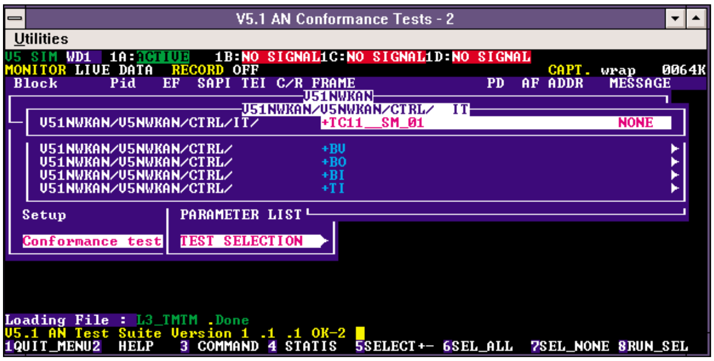

FIGURE 7
Classic V5.1 test case selection.

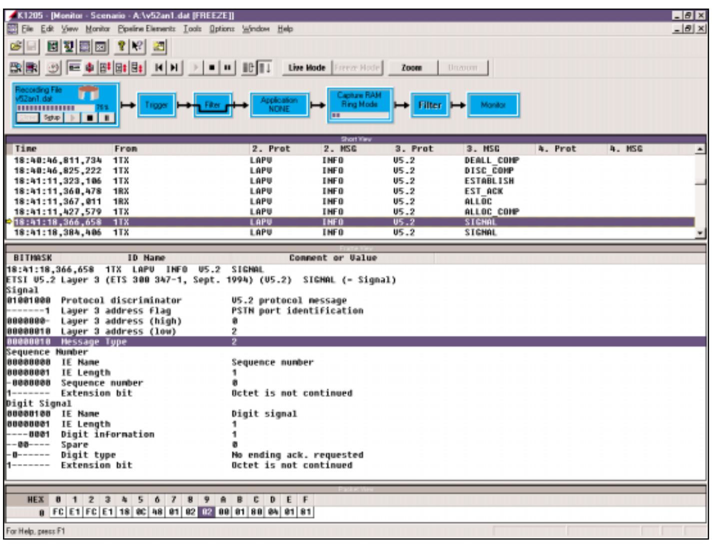

FIGURE 8
Typical V5.2 test sequence

Basic requirements for V5.2 testing in simulation mode include:

- Up to 16 interfaces for 2,048 kbit/s links
- For the Protection protocol, the option of connecting an L3 instance with up to two L2 instances, simultaneously
- The ability to move L2 connections from one channel to another, while active, over 2,048 kbit/s links
- Influencing and monitoring the SA7 bit

A V5.x monitor instrument must be able to show the above-noted aspects clearly. Figures 7 and 8 show representative test sequences for V5.1 and V5.2, respectively.

Monitoring

You use monitoring primarily to check and observe the interplay of various V5.x implementations. The monitor can find errors and is often also embedded in simulating instruments.

An effective V5.x monitoring instrument must display messages so that the operator can distinguish among the various V5.x protocols and the individual connections within these protocols. Further, it must be capable of masking individual protocols and protocol layers completely or partially. And, its display should help the user observe the different (two) directions of the messages at a glance, without any doubt.

Instruments such as the Tektronix K1205 signaling protocol analyzer (shown in Figure 9) offer these capabilities and also provide comprehensive filters and analysis tools. Because a large quantity of signaling-data traffic can appear on a V5.2 interface, the K1205 integrates a fast memory recording function with the option of off-line processing. This is useful, for example, when you are monitoring a V5.x interface connected to a large AN under heavy load. Here, you may not wish to conduct the analysis online. Instead, you may want to record all transactions completely, without losing messages, for later analysis off-line.

FIGURE 9
The Tektronix K1205 Signaling Protocol Analyzer.

Conformance Tests

Manufacturers and purchasers of V5.x equipment typically want to verify that their equipment conforms to the appropriate V5.x standards. In conformance testing, you operate more in a "Go/No Go" mode to determine whether the equipment operates within the standard specifications. ETSI has developed conformance tests corresponding to its standards, in the form of Tree Tabular Combined Notation (TTCN) test suites, with appropriate documentation. Separate test suites are defined for testing L3 state machines on the AN and LE sides.

These test cases attempt to consider all possible options of the standards and can be configured using Protocol Implementation eXtra Information for Testing, or PIXITs. PIXITs are used to configure test suites written in TTCN in accordance with the configuration that is to be tested.

For example, Tektronix offers an implementation of these test suites for its K1297 protocol tester. This provides an efficient and economical way to verify conformance of a V5.x system under test to the standard.

Functional/Integration Tests

The development of V5.x systems and system-error simulations requires a versatile instrument that can be programmed quickly and that can simulate specific aspects of an AN or an LE. This is necessary because V5.x requires the simulation of not just one protocol, but up to five at the same time—all inter-working with each other. For example, the Tektronix K1297 protocol tester can be programmed in an SDL-like scripting language, enabling the simulation of all possible situations in V5.x signaling.

An effective test instrument must automatically confirm specific V5.x messages and continuously count sequential numbers (in the Control, PSTN, and Protection protocols) autonomously, to reduce the programmer's workload.

In testing a V5.x interface, the V5.x interface must be started before call-handling traffic can be transmitted over the V5.x interface. With V5.1, this means that the Common and Port Control protocols must come into operation first. With V5.2, only the error-free interplay of the Control, Protection and Link Control protocols enables the start of the interface. Many test challenges lie in wait for the tester, and to explain them all would go far beyond the scope of this article.

Emulation

Emulation is defined as simulation with a test instrument of (almost) all functions of an AN or an LE, in conformity with a standard. For example, from the point of view of an AN, the attached test instrument should behave as if it were an LE. This enables an AN manufacturer to test his system as if it were under "actual" operation without having to connect it to an expensive LE. Simple emulations are also integrated into load testing.

The Tektronix K1297 is able to emulate the basic functions of an LE and AN. Virtual subscribers are implemented in it to initiate or receive conversations over the V5.x interface.

Load Tests

System behavior under load is important for the practical use of a V5.x system. Particularly in the case of V5.2, where channel switching in the AN is dynamic, insufficient load capacity in high-traffic periods can result in protocol sequence malfunctioning and unsuccessful voice-channel establishment or waiting periods for users.

To test such behavior requires test instruments that can generate the previously defined signaling load on a V5.x interface. For this purpose, the basic functions of an AN or an LE must be emulated to simulate calling or called PSTN or ISDN subscribers.

Conclusion

The V5.x protocols are heavily based on the structure of ISDN. Even though this brief has not addressed all aspects of the V5.x interfaces, it does show that the number of different protocols, along with their relationships and interdependencies, may make testing V5.x interfaces a major challenge.

With V5.x, the functionality is apparent in the controlled interplay of the different protocols. When testing V5.x, you must ensure that no protocol can perform a useful function alone. Here, V5.x is more than the sum of its individual protocols.

Comprehensive testing tools, such as those offered by Tektronix, can greatly simplify V5.x testing.

List of Abbreviations

2,048 kbit/s link	E1 connection, or E1 frames
ACK	ACKnowledge (confirmation)
AN	Access Network (subscriber access network)
DTMF	Dual Tone Multi-frequency (tone dialing procedure)
EFaddr	Envelope Function address, the address of the EF address multiplexer function
ETSI	European Telecommunication Standards Institute
ID	Identification number
ISDN	Integrated Services Digital Network
IWV	Impuls Wähl Verfahren, meaning pulse dialing in German
K1205	Tektronix monitor instrument
K1297	Tektronix simulation tool and conformance tester
L1	Layer 1 (physical layer)
L2	Layer 2 (data link layer)
L2addr	Layer 2 address (LAPD, LAPV5) address
L3	Layer 3 (transport layer)
L3addr	Layer 3 address in the V5.x protocols
LAPD	ISDN L2 protocol
LAPV5	V5.x L2 protocol
LE	Local Exchange
PIXIT	Protocol Implementation eXtra Information for Testing
PSTN	Public Switching Telephone Network PSTN user is an analogue user in V5.x
SS#7	Signaling System No. 7
TEI	Terminal Endpoint Identifier
V5.x	Designation for V5.1 and V5.2

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