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SERIES G: TRANSMISSION SYSTEMS AND MEDIA, DIGITAL SYSTEMS AND NETWORKS

Digital sections and digital line system – Access networks

Overview of digital subscriber line (DSL) Recommendations

ITU-T Recommendation G.995.1

(Formerly CCITT Recommendation)

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ITU-T Recommendation G.995.1

Overview of digital subscriber line (DSL) Recommendations

Summary

This Recommendation provides the necessary guidance and an overview of the DSL family of Recommendations and is therefore informative. It also describes how the various Recommendations in this family are related. It also contains a definition of a generic system reference configuration and how it relates to the system reference models of the DSL Recommendations. Additionally, the definition of a generic protocol reference architecture for DSL Recommendations and derivations of the appropriate user or management plane protocol reference architectures for the DSL Recommendations is included. Illustrations of the data service presentation options using the DSL Recommendations are also provided. A glossary of the terms used in the DSL Recommendations is also included.

Source

ITU-T Recommendation G.995.1 was revised by ITU-T Study Group 15 (2001-2004) and approved under the WTSA Resolution 1 procedure on 9 February 2001.

FOREWORD

The International Telecommunication Union (ITU) is the United Nations specialized agency in the field of telecommunications. The ITU Telecommunication Standardization Sector (ITU-T) is a permanent organ of ITU. ITU-T is responsible for studying technical, operating and tariff questions and issuing Recommendations on them with a view to standardizing telecommunications on a worldwide basis.

The World Telecommunication Standardization Assembly (WTSA), which meets every four years, establishes the topics for study by the ITU-T study groups which, in turn, produce Recommendations on these topics.

The approval of ITU-T Recommendations is covered by the procedure laid down in WTSA Resolution 1.

In some areas of information technology which fall within ITU-T's purview, the necessary standards are prepared on a collaborative basis with ISO and IEC.

NOTE

In this Recommendation, the expression "Administration" is used for conciseness to indicate both a telecommunication administration and a recognized operating agency.

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ITU draws attention to the possibility that the practice or implementation of this Recommendation may involve the use of a claimed Intellectual Property Right. ITU takes no position concerning the evidence, validity or applicability of claimed Intellectual Property Rights, whether asserted by ITU members or others outside of the Recommendation development process.

As of the date of approval of this Recommendation, ITU had received notice of intellectual property, protected by patents, which may be required to implement this Recommendation. However, implementors are cautioned that this may not represent the latest information and are therefore strongly urged to consult the TSB patent database.

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ITU-T Recommendation G.995.1

Overview of digital subscriber line (DSL) Recommendations

1 Scope

This Recommendation provides an overview of the family of DSL Recommendations. It describes how the various DSL Recommendations are related. This Recommendation also defines a generic system reference and a protocol reference configuration for DSL Recommendations and relates it to the system reference models of the DSL Recommendations. This Recommendation is of informative nature and does not imply any specific requirements.

2 Revision History

This revision of ITU-T G.995.1 adds more clauses and text with regard to ITU-T G.991.2 and Annex H/G.992.2. Specifically, it adds:

- Text in clause 5.1 that introduces Annex H/G.992.1.
- Clause 5.4 that introduces ITU-T G.991.2.
- Text in clause 5.8 that describes relationship of ITU-T G.991.2 and Annex H/G.992.1 with the existing DSL Recommendations.
- Clause 6.1.1.4, that discusses the alignment of the G.991.2 system reference model with the G.995.1 reference configuration.
- Text in clause 6.2 that describes the user plane protocol reference architecture for ITU-T G.991.2.

3 Definitions

This Recommendation defines the following terms:

3.1 DSL Recommendations: The family of ITU-T Recommendations G.991.1, G.992.1, G.992.2, G.994.1, G.995.1, G.996.1 and G.997.1.

3.2 XDSL: Any of the various types of digital subscriber lines.

4 Abbreviations

This Recommendation uses the following abbreviations:

2B1Q	2 Binary 1 Quaternary
ADSL	Asymmetric Digital Subscriber Line
ATM	Asynchronous Transfer Mode
ATU	ADSL Transceiver Unit
ATU-C	ADSL Transceiver Unit-Central Office End
ATU-R	ADSL Transceiver Unit-Remote Terminal End
C	Common circuitry
CAP	Carrier-less Amplitude and Phase
CO	Central Office

CPE	Customer Premises Equipment
DLL	Digital Local Line
DSL	Digital Subscriber Line
GII	Global Information Infrastructure
H	HDSL transceiver
HDSL	High Bit Rate Digital Subscriber Line
h-p	high-pass
HSS-TC	Handshake Specific-Transmission Convergence
HSTU	Handshake Transceiver Unit
HSTU-C	Handshake Transceiver Unit-Central office end
HSTU-R	Handshake Transceiver Unit-Remote terminal end
I	Interface
ISDN	Integrated Services Digital Network
ISP	Internet Service Provider
l-p	Low-pass
LTU	Line Termination Unit
M	Mapping
MPS-TC	Management Protocol Specific-Transmission Convergence
NT1	Network Termination 1
NT2	Network Termination 2
NTU	Network Termination Unit
PHY	Physical Layer
PMD	Physical Media Dependant
PMS-TC	Physical Media Specific-Transmission Convergence
POTS	Plain Old Telephony Service
REG	Regenerator
SM	Service Module
SNI	Service Node Interface
STM	Synchronous Transfer Mode
TA	Terminal Adapter
TC	Transmission Convergence
TCM	Time Compressed Multiplex
TPS-TC	Transport Protocol Specific-Transmission Convergence
XNI	Access Network Interface
XTU	xDSL Transceiver Unit
XTU-C	xDSL Transceiver Unit-Central Office End
XTU-R	xDSL Transceiver Unit-Remote Terminal End

5 Overview of the Family of DSL Recommendations

The family of DSL Recommendations includes the following: ITU-T G.992.1, G.992.2, G.991.1, G.991.2, G.996.1, G.994.1, G.997.1 and G.995.1. ITU-T G.991.1, G.991.2, G.992.1 and G.992.2 have developed techniques for transmitting a range of bit rates over the existing copper local network from relatively short distances at high bit rates, and to long distances at relatively lower bit rates. ITU-T G.994.1, G.996.1, and G.997.1 support ITU-T G.992.1 and G.992.2 by providing common handshake, management and testing procedures. These Recommendations include mandatory requirements, recommendations and options; these are designated by the words "shall", "should" and "may", respectively. The word "will" is used only to designate events that take place under some defined set of circumstances.

In clauses 5.1-5.7, the DSL Recommendations have been introduced. In clause 5.8, the relationship of these Recommendations with each other is described.

5.1 ITU-T G.992.1: Asymmetric Digital Subscriber Line (ADSL) Transceivers

ITU-T G.992.1 specifies the physical layer characteristics of the Asymmetric Digital Subscriber Line (ADSL) interface to metallic loops. ITU-T G.992.1 has been written to help ensure the proper interfacing and interworking of ADSL transmission units at the customer end (ATU-R) and at the network operator end (ATU-C) and also to define the transport capability of the units. Proper operation is to be ensured when these two units are manufactured and provided independently.

A single twisted pair of telephone wires is used to connect the ATU-C to the ATU-R. The ADSL transmission units must deal with a variety of wire pair characteristics and typical impairments (e.g. crosstalk and noise). The transmission system is designed to operate on two-wire twisted metallic cable pairs with mixed gauges. ITU-T G.992.1 is based on the use of cables without loading coils, but bridged taps are acceptable in all but a few unusual situations.

An ADSL transmission unit can simultaneously convey all of the following: downstream simplex bearers, duplex bearers, a baseband analogue duplex channel, and ADSL line overhead for framing, error control, operations, and maintenance. ITU-T G.992.1 supports a minimum of 6.144 Mbit/s downstream and 640 kbit/s upstream net data rate.

Two categories of performance are specified. Category I performance is required for compliance with ITU-T G.992.1; performance enhancement options are not required for category I equipment. Category II is a higher level of performance. Category II performance and characteristics are not required for compliance with ITU-T G.992.1.

ADSL provides a variety of bearer channels in conjunction with other services:

– ADSL transmission on the same pair with voiceband transmission (including POTS and voiceband data services).
– ADSL transmission on the same pair with ISDN, as defined in Appendices I and II/G.961. The ADSL occupies a frequency band above the ISDN, and is separated from it by filtering.
– ADSL transmission on the same pair with voiceband transmission (including POTS and voiceband data services), and with ISDN in an adjacent pair as defined in Appendix III/G.961.
– In the direction from the network operator to the customer premises (i.e. downstream) the bearer channels may consist of full duplex low-speed bearer channels and simplex high-speed bearer channels; in the other direction (i.e. upstream) only low-speed bearer channels are provided.

Specifically, ITU-T G.992.1:

– defines the combined options and ranges of the simplex and full-duplex bearer channels provided;
– defines the line code and the spectral composition of the signals transmitted by both ATU-C and ATU-R;
– specifies the transmit signals at both the ATU-C and ATU-R;
– describes the electrical and mechanical specifications of the network interface;
– describes the organization of transmitted and received data into frames;
– defines the functions of the operations channel;
– defines the ATU-R to service module(s) interface functions;
– defines the Transmission Convergence Sub-layer for ATM transport.

In separate annexes it also:

– describes the transmission technique used to support the simultaneous transport on a single twisted-pair of voiceband services and both simplex and duplex bearer channels;
– describes the transmission technique used to support the simultaneous transport on a single twisted-pair of ISDN services as defined in Appendices I and II/G.961, and both simplex and duplex bearer channels;
– describes the transmission technique used to support the simultaneous transport on a single twisted-pair of voiceband services and both simplex and duplex bearer channels when they are subject to cross-talk from ISDN as defined in Appendix III/G.961;
– describes those specifications that are unique to Synchronized Symmetric Digital Subscriber Line (SSDSL) transceivers for use in the same cable binder as TCM-ISDN defined in ITU-T Appendix III/G.961. This SSDSL transmission method allows symmetric data rates in the range of 192 kbit/s to 1.6 Mbit/s with 32 kbit/s granularity using a scheme synchronized with TCM-ISDN. The 1.544 Mbit/s STM data transport capability is optionally supported.

ITU-T G.992.1 defines several optional capabilities and features:

– echo cancellation;
– trellis coded modulation;
– loop timing at either the ATU-C or the ATU-R;
– dual latency;
– transport of a network timing reference;
– transport of STM and/or ATM;
– reduced overhead framing modes.

By negotiation during initialization, G.992.1 in combination with G.994.1 provides for U-interface compatibility and interoperability between transceivers complying with ITU-T G.992.1 and between those transceivers that include different combinations of options.

5.2 ITU-T G.992.2: Splitterless asymmetrical digital subscriber line (ADSL) transceivers

ITU-T G.992.2 describes a transmission system that interfaces the telecommunications network and the customer installation in terms of their interaction and electrical characteristics. The requirements of ITU-T G.992.2 apply only to a single asymmetric digital subscriber line. ITU-T G.992.2 allows the provision of simultaneous voiceband transmission, including POTS and V-series data transmission, and a number of digital channels.

A single twisted pair of telephone wires is used to connect the ATU-C to the ATU-R. The ADSL transmission units must deal with a variety of wire pair characteristics and typical impairments

(e.g. crosstalk and noise). The transmission system is designed to operate on two-wire twisted metallic cable pairs with mixed gauges and over the customer premises wiring. ITU-T G.992.2 is based on the use of cables without loading coils, but bridged taps are acceptable in all but a few unusual situations.

G.992.2 transmission unit can simultaneously convey a downstream and upstream simplex bearer, a baseband analogue duplex channel, and ADSL line overhead for framing, error control, operations, and maintenance. ITU-T G.992.2 supports a maximum of 1.536 Mbit/s downstream and 512 kbit/s upstream net data rates.

Specifically, ITU-T G.992.2:

– defines the line code and the spectral composition of the signals transmitted by both ATU-C and ATU-R;
– specifies the transmit signals at both the ATU-C and ATU-R;
– describes the electrical specifications of the network interface;
– describes the organization of transmitted and received data into frames;
– defines the functions of the operations channel;
– defines the ATU-R to service module(s) interface functions;
– defines the Transmission Convergence Sub-layer for ATM transport;
– defines the fast retrain procedure for use in the presence of non-linear off-hook phones in a splitterless environment;
– defines the power saving procedures for CPE and CO equipment;
– loop timing at the ATU-R.

In its separate annexes it also:

– describes the transmission technique used to support the simultaneous transport on a single twisted-pair of voiceband services and both simplex upstream and downstream bearer channels;
– describes the transmission technique used to support the simultaneous transport on a single twisted-pair of voiceband services and both simplex upstream and downstream bearer channels when they are subject to cross-talk from TCM-ISDN as defined in Appendix III/G.961;
– description of the transmission technique to support the simultaneous transport on a single twisted-pair of ISDN services as defined in Appendices I and II/G.961, and both simplex upstream and downstream bearer channels has been left for future study.

ITU-T G.992.2 defines several optional capabilities and features:

– transport of a network timing reference.

By negotiation during initialization, ITU-T G.992.2 provides for U-interface compatibility and interoperability between transceivers complying with ITU-T G.992.2 and between those transceivers that include different combinations of options.

5.3 ITU-T G.991.1: High bit rate digital subscriber line (HDSL) transceivers

ITU-T G.991.1 describes a transmission technique called High Bit Rate Digital Subscriber Line (HDSL), as a means for the transportation of several types of applications. The Recommendation defines the requirements for the individual HDSL transmission system, the transmission performance, the HDSL maintenance requirements and procedures.

An individual HDSL transceiver system is a two-wire bidirectional transceiver for metallic wires using the echo cancellation method. Three systems may be utilized, one transporting a bit rate of

784 kbit/s over each of two or three pairs used in parallel, a second with an increased bit rate of 1168 kbit/s and two pairs in parallel only and a third with a more increased bit rate of 2320 kbit/s on one pair only.

The line code of systems specified in ITU-T G.991.1 is 2B1Q and CAP. The implementers may choose the one or the other of these alternatives, only one line code has to be realized in a transmission system.

In the main body of ITU-T G.991.1, systems with 2B1Q for 2048 kbit/s applications are described. In Annex A/G.991.1, the G.704 frame structure for 1544 kbit/s applications on two pairs is described. Systems using a CAP line code are covered in Annex B/G.991.1.

ITU-T G.991.1 defines the common circuitry for combining and controlling one, two or three HDSL transceiver systems, depending on the bit rate of the transceiver system used. The common circuitry and the necessary number of HDSL transceiver systems form the HDSL core, which is independent from the possible applications.

ITU-T G.991.1 does not specify all the requirements for the implementation of NTU, LTU or REG. It serves only to describe the functionality needed.

Appendices in ITU-T G.991.1 describe examples of a number of telecommunication services that may be supported.

5.4 ITU-T G.991.2: Single-pair High-speed Digital Subscriber Line (SHDSL) transceivers

ITU-T G.991.2 describes a symmetric transmission method for data transport in telecommunications access networks. G.991.2 transceivers are designed for duplex operation over mixed gauge two-wire twisted metallic pairs. Four-wire operation is optionally supported for extended reach applications. Optional signal regenerators for both single-pair and two-pair operation are also specified. G.991.2 transceivers are capable of supporting selected symmetric user data rates in the range of 192 kbit/s to 2312 kbit/s in increments of 8 kbit/s and an optional four-wire operational mode that is capable of supporting user data rates from 384 kbit/s to 4624 kbit/s in increments of 16 kbit/s, using a Trellis Coded Pulse Amplitude Modulation (TC-PAM) line code. Regional requirements may limit the specific user data rates for use within particular regions. G.991.2 transceivers are designed to be spectrally compatible with other transmission technologies deployed in the access network, including other DSL technologies specified in ITU-T G.991.1, G.992.1 and G.992.2. G.991.2 transceivers do not support the use of analogue splitting technology for coexistence with either POTS or ISDN. Regional requirements, including both operational differences and performance requirements, are specified in separate annexes. Symmetric transmission method for data transport in networks with existing TCM-ISDN service (as specified in Appendix III/G.961) is specified in Annex H/G.992.1 and is referenced in Annex C/G.991.2.

The principal characteristics of ITU-T G.991.2 may be summarized as follows:

- provisions for duplex operation over mixed gauge two-wire or optional four-wire twisted metallic pairs;
- specification of the physical layer functionality, e.g. line codes and forward error correction;
- specification of the data link layer functionality, e.g. frame synchronization and framing of application and OAM data;
- provisions for optional use of repeaters for extended reach;
- provisions for spectrum compatibility with other transmission technologies deployed in the access network;
- provisions for regional requirements, including functional differences and performance requirements.

5.5 ITU-T G.994.1: Handshake procedures for digital subscriber line (DSL) transceivers

ITU-T G.994.1 defines signals, messages and procedures for exchanging these between Digital Subscriber Line (DSL) equipment, when the modes of operation of the equipment need to be automatically established and selected, but before signals are exchanged which are specific to a particular DSL Recommendation.

The principal characteristics of ITU-T G.994.1 are as follows:

a) use over metallic local loops;

b) provisions to exchange capabilities information between DSL equipment for identifying common modes of operation;

c) provisions for DSL equipment at either end of the loop to select a common mode of operation or to request the other end to select the mode;

d) provisions for exchanging non-standard information between DSL equipment;

e) provisions to exchange and request service and application related information;

f) support for both duplex and half-duplex transmission modes.

5.6 ITU-T G.997.1: Physical layer management for digital subscriber line (DSL) transceivers

ITU-T G.997.1 specifies the physical layer management and the clear embedded operations channel for ADSL transmission systems based on the usage of indicator bits and eoc messages defined in ITU-T G.992.x. It specifies Network Management Elements and their content for configuration, fault and performance management.

5.7 ITU-T G.996.1: Test procedures for digital subscriber line (DSL) transceivers

ITU-T G.996.1 describes the testing procedures for G.99x-series Recommendations. ITU-T G.996.1 provides descriptions of the test procedures, test configurations, test loops, crosstalk models. ITU-T G.992.1 and G.992.2 reference ITU-T G.996.1 for testing procedures and configurations. Performance requirements for ITU-T G.992.1 and G.992.2 are outlined in each of the respective Recommendations.

5.8 Relationship among the DSL Recommendations

The DSL Recommendations are related to each other as explained below.

The ITU-T G.992.1, G.992.2, G.991.1 and G.991.2 are metallic digital physical layer interface specifications for use over the twisted copper pair plants. All of them are for transmission of digital data over the copper pair. However, the type of applications, range of date rates, symmetry or asymmetry in the two directions, and the loop plant coverage, and the linecode technologies are what differentiate one from the other. From the perspective of symmetry, ITU-T G.991.1 and G.991.2 provide symmetric data rates whereas ITU-T G.992.1 and G.992.2 provide asymmetric data rates in the upstream and the downstream direction. ITU-T G.991.1 and G.991.2 do not allow simultaneous transmission of G.991.1 or G.991.2 and the voiceband transmissions. A fully equipped G.991.1 consists of one 2320 kbit/s, two 1168 kbit/s or two or three 784 kbit/s symmetric data rate service. ITU-T G.991.2 supports a range of symmetric user data rates from 192-2312 kbit/s over a single twisted copper wire pair. The G.992.1 systems support a minimum of 6.144 Mbit/s downstream and 640 kbit/s upstream data rate. In the case of G.992.2, systems support a maximum of 1.536 Mbit/s downstream and 512 kbit/s upstream data rate. The data rates for both G.992.1 and G.992.2 are asymmetrical. G.992.1 has higher downstream to upstream asymmetry ratio than G.992.2. From the loop plant coverage perspective, G.991.1 has shorter loop length compared to G.991.2, G.992.1 and G.992.2. The length of G.991.1 may be increased through the use of regenerators. Regenerators are not specified on the G.992.1 and G.992.2 loops. Bridge taps are allowed on the G.991.1, G.992.1 and

G.992.2 loops. From the applications perspective, G.991.1 is most often used for the business application. G.992.1 may be used for both business and home applications. The large downstream bandwidth in G.992.1 is suitable for facilitating some of the broadcast applications such as video-on-demand. The other data centric applications are possible under the constraint of lower upstream data rates when compared to G.991.1. G.992.2's main focus is simplified installations. It is suitable for high speed Internet Access when compared to the voiceband data transmission. G.991.1, G.992.1 and G.992.2 specify the achievable or target bit rates and are accordingly suitable for numerous applications. G.992.2 and G.992.1 use the same DMT line code principles. G.991.1 provides a choice of a 2B1Q or CAP linecode.

In some respects, ITU-T G.992.1 and G.992.2 are closely related. There are other aspects that differentiate them. The close relation of the two lies in the use of the same core DMT line code and its associated parameters. ITU-T G.992.2 has been developed with considerations for possible interoperability with ITU-T G.992.1. ITU-T G.992.2 is based on modifications to ITU-T G.992.1 to meet the key objectives of lower equipment complexity, lower power consumption and splitterless operation. Extended reach G.992.2 is under consideration for future revisions or modifications of ITU-T G.992.2. Some of the differentiating features of G.992.2 are the reduced IDFT size for the downstream transmitter, smaller parameter set for the FEC coding and the Interleaving and the simpler reduced overhead framing structure. Other G.992.2 specific features are the fast retrain and the power saving mechanisms. Fast retrain procedure is used to cater for those situations in which a non-linear phone goes off hook and thus changing the channel characteristics in a significant manner in a splitterless environment.

When a twisted pair is subject to crosstalk from TCM-ISDN, as defined in Appendix III/G.961, both ITU-T G.992.1 and G.992.2 provide Annex C which describes the asymmetric transmission techniques synchronized with TCM-ISDN. The symmetric transmission technique when they are subject to cross-talk from TCM-ISDN is described in Annex H/G.992.1. Annex H/G.992.1 specifies DMT line code synchronized with TCM-ISDN as a symmetric extension of Annex C/G.992.1. Annex C/G.991.2 is a pointer to Annex H/G.992.1.

ITU-T G.991.1 and G.991.2 are related in that both address transmission of symmetric user data over metallic copper wires, support T1 and E1 replacement and other business applications on two pairs of metallic copper wires and do not support the use of analogue splitting technology for coexistence with either POTS or ISDN. However, ITU-T G.991.2 is different from ITU-T G.991.1 in that it supports a range of user data rates from 192-2312 kbit/s over a single twisted copper wire pair, while ITU-T G.991.1 supports only 2048 and 1544 kbit/s user data. The transmission technologies are also different in that ITU-T G.991.2 employs Trellis Coded Pulse Amplitude Modulation (TC-PAM), while the 2B1Q and CAP line codes are specified in ITU-T G.991.1.

For service flexibility, central office implementations may choose to include one or more than one DSL scheme as specified in ITU-T G.992.x-series Recommendations, or elsewhere. Details of these implementations, whether in hardware or software, are beyond the scope of this Recommendation.

ITU-T G.994.1 provides a common mode of automatic selection and operation of the G.992.x equipment. G.994.1 messages signals and procedures take place before those signals are exchanged which are specific to a particular DSL Recommendation. The use of ITU-T G.994.1 is an integral part of the ITU-T G.992.1 and G.992.2. ITU-T G.991.1 does not support ITU-T G.994.1. ITU-T G.994.1 is expected to be used in the future DSL Recommendations and the future revision of the current Recommendations. ITU-T G.994.1 has no implications for ITU-T G.997.1 and G.996.1.

ITU-T G.996.1 provides a common resource of test procedures, loop specifications and noise models to facilitate the performance testing of the G.99x-series Recommendations. Both ITU-T G.992.1 and ITU-T G.992.2 use the test procedures, loop specifications and noise models in ITU-T G.996.1 when the performance requirements are specified. ITU-T G.991.1 is self-contained in this regard. Future ITU-T G.990-series Recommendations are expected to continue to use the G.996.1 resources in the specification of their performance requirements.

ITU-T G.997.1 specifies the physical layer management and the clear embedded operations channel for ADSL transmission systems based on the usage of indicator bits and eoc messages defined in ITU-T G.992.x. It specifies Network Management Elements and their content for configuration, fault and performance management. ITU-T G.997.1 does not preclude the use of eoc as currently defined in ITU-T G.992.1 and G.992.2. All the network elements may not be relevant to a particular ITU-T G.992.x Recommendation (e.g. fast data stream management elements for ITU-T G.992.2).

6 The Reference Configuration for ITU-T G.99x-series Recommendations

Two generic reference configurations are used to relate the G.99x-series Recommendations. First reference configuration is based on the reference configuration used for the N-ISDN in ITU-T I.410 and described in 6.1. The other reference configuration is a protocol reference configuration to provide a view of the G.99x-series Recommendations from the protocol architecture point of view and is described in 6.2.

6.1 Generic Reference Configuration

Figure 1 depicts a generic reference configuration for a generic xDSL system based on the reference configuration used for N-ISDN in ITU-T I.411.

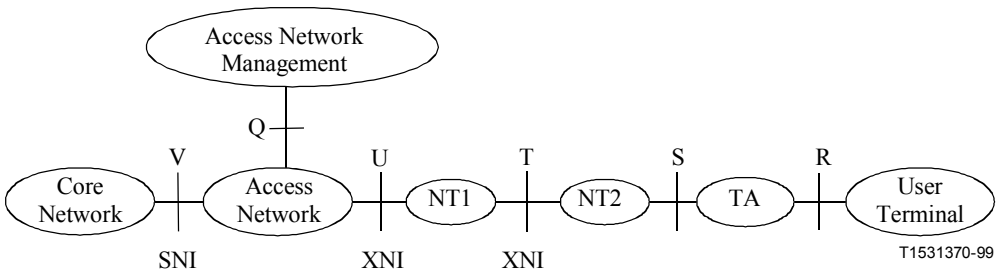


Figure 1/G.995.1 – A reference configuration for a generic G.99x system

This reference configuration identifies the reference points in the context of access network.

The generic reference configuration consists of seven elements:

1) Core Network.
2) Access Network.
3) Network Termination 1 (NT1).
4) Network Termination 2 (NT2).
5) Terminal Adapter (TA).
6) User Terminal.
7) Access Network Management.

Core Network and Access Networks are separated at the V interface. Access Network Management Element depicts the management functionalities. Access Network and the Access Network Management elements are separated at the Q reference point. The NT1 makes physical connection to the Access Network at the U reference point, and provides service presentation to a customer on a logical or physical interface at the T reference point. The NT1 terminates the Access Digital Section of the Broadband connection allowing management and performance monitoring. An NT1 may not terminate the transport protocol (e.g. ATM) for user traffic, but may implement transport protocol functions such as rate adaptation required to support different T/U reference point/interface characteristics. An NT2 connects to the network at the T reference point, may connect to multiple

user terminals on S reference point interfaces. The NT2 terminates the transport protocol (e.g. ATM) for user traffic, and may implement switching/routing functions. The NT2 may be integrated with an NT1 to form an NT1/2. The NT term is used for generic Network Termination for various services. For some services it could be part of the Access Network and for others not. The inclusion of the NT in the Access Network and vice versa does not necessarily imply the ownership. A TA adapts the transport protocol to the specific requirements of a user terminal.

One or more of the elements in the reference configuration may be null in some scenarios; therefore, one or more of these reference points may be merged. The reference points may also correspond to the functional interfaces, although, existence of a physical interface is not implied. Some of these reference point/interface are the subject of ITU-T G.99x-series Recommendations, whether by inclusion or by reference to other Recommendations or specifications. When two or more functional groupings are present in a real device, the interface between them need not be exposed, even if it is the subject of these Recommendations.

There may be more than one interface specification for each of these reference points. The exact interpretation at these reference points will depend upon the local network architecture and regulatory environment.

The reference configurations in this clause show abstract functional groupings, which may or may not correspond to real devices. Real devices may comprise one abstract functional grouping, more than one abstract functional grouping or a portion of an abstract functional grouping.

6.1.1 Relation of the Generic Reference Configuration to the ITU-T G.99x-series Recommendations

The reference models of the DSL Recommendations may be viewed with respect to the generic reference configuration described in 6.1.

6.1.1.1 Relation with ITU-T G.992.1

Figure 2 illustrates the G.992.1 system reference model aligned with the reference configuration shown in Figure 1.

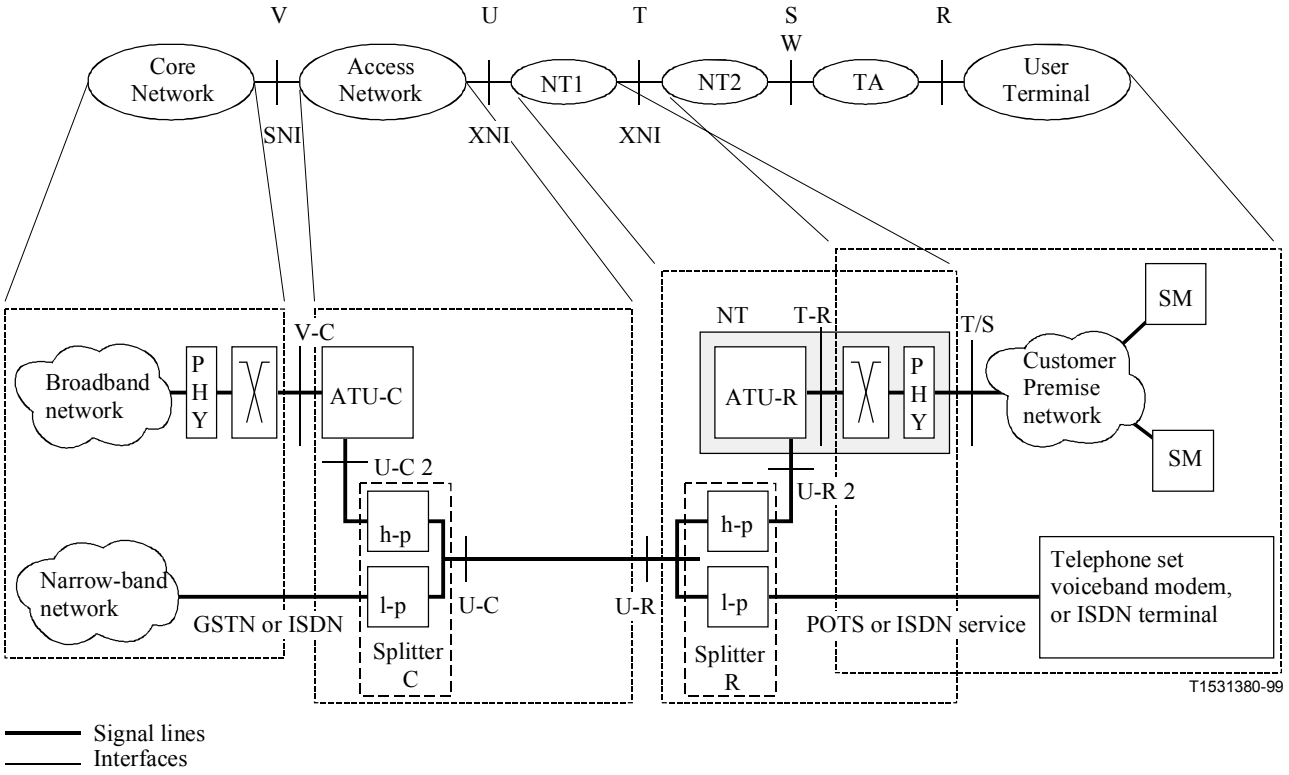


Figure 2/G.995.1 – G.992.1 system reference model and its alignment with the generic reference configuration

The G.992.1 system reference model shows the functional blocks necessary to illustrate an ADSL transmission system. With reference to the alignment with the generic reference configuration, the Core Network may contain the following functions:

1) Concentrator and/or switch.

2) Interface to the Broadband and Narrow-band network.

The ADSL Access Network consists of the following:

1) ADSL Transceiver Unit-Central Office end (ATU-C).

2) POTS splitter to separate the POTS and ADSL channels.

3) Copper Loop Plant.

The ADSL-NT1 may consist of the following functions:

1) ADSL Transceiver Unit-Remote Terminal end (ATU-R).

2) Multiplexer/Demultiplexer.

3) Higher layer functions.

4) Interface to the User terminal or a Home Network.

The ADSL-NT2, Terminal Adapter and User Terminal may share some or all of the NT1 functionalities.

In ITU-T G.992.1, interfaces are defined at the V, U and T reference points namely U-C, U-R, V-C and T-R interfaces.

The U-C and U-R interfaces are fully defined in ITU-T G.992.1. Due to the asymmetry of the signals on the line, the transmitted signals are distinctly specified at the U-R and U-C reference points.

The V-C and T-R interfaces are defined only in terms of logical functions. The V-C interface may consist of interfaces to one or more (STM or ATM) switching systems. Implementation of the V-C and T-R interfaces is optional when interfacing elements are integrated into a common element. One or other of the high-pass filters, which are part of the splitters, may be integrated into either of the ATU-C or ATU-R; if so, then the U-C2 and U-R2 interfaces become the same as the U-C and U-R interfaces, respectively. A digital carrier facility (e.g. SONET/SDH extension) may be interposed at the V-C.

The T/S interface is not defined in ITU-T G.992.1. The nature of the customer installation distribution and customer premise network may be varied, e.g. bus or star, or type of media. Therefore, more than one type of T-R interface may be used, and more than one type of T/S interface may be provided from an ADSL NT (e.g. NT1 or NT2 types of functionalities).

6.1.1.2 Relation with ITU-T G.992.2

Figure 3 illustrates the G.992.2 system reference model aligned with the reference configuration shown in Figure 1.

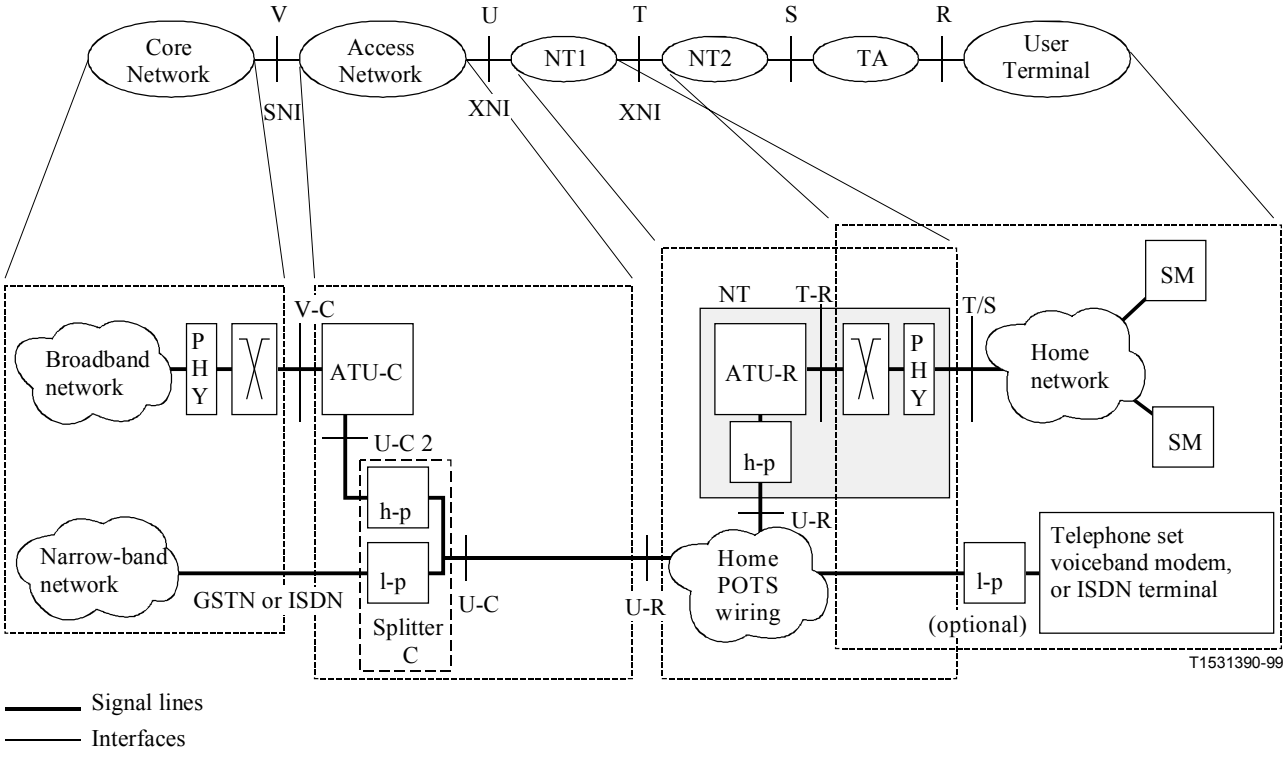
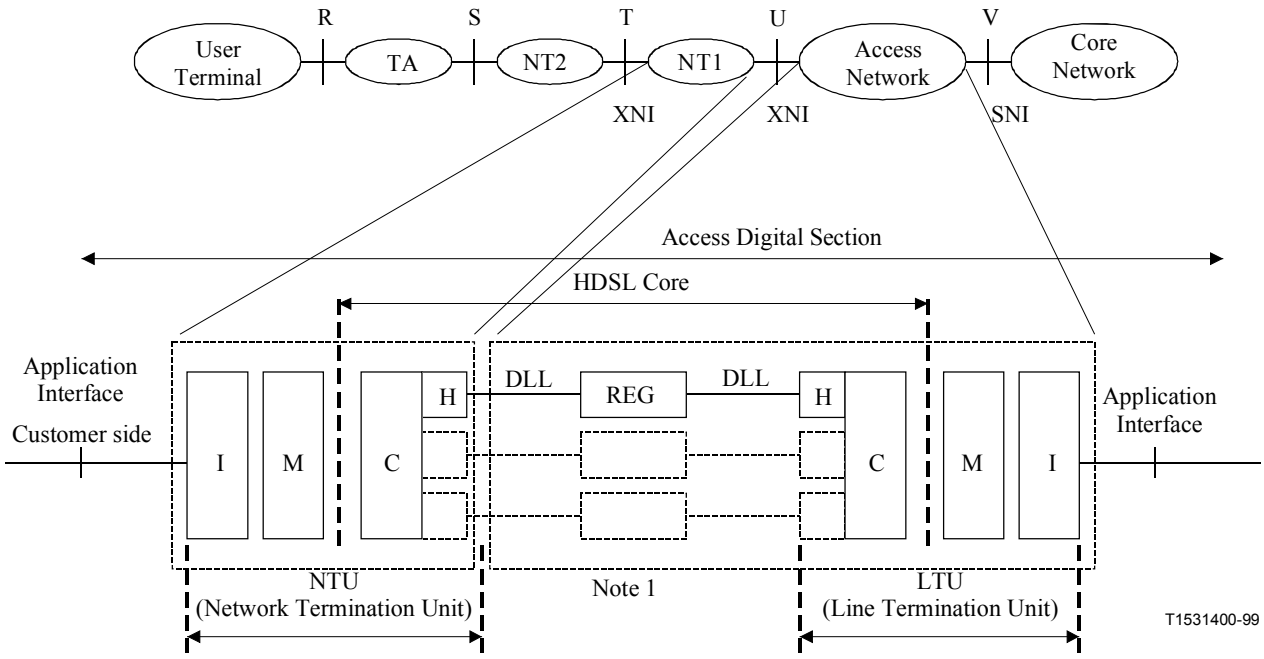


Figure 3/G.995.1 – G.992.2 system reference model and its alignment with the generic reference configuration

The G.992.2 system reference model shows the functional blocks useful to illustrate a G.992.2 transmission system. When comparing Figure 3 to the Figure 2 in 6.1.1.1, it may be observed that the main difference in the system reference model pertains to the absence of a separate POTS splitter functionality. The POTS splitter functionalities have now been distributed. The high pass filter functionality has been shown integrated in the NT1. And an optional low pass filter is depicted next to the POTS, ISDN or user terminal. This does not preclude the use of G.992.2 transmission system with splitter as shown in ITU-T G.992.1. The U-R2 interface does not exist in ITU-T G.992.2. The remaining discussion of 6.1.1.1 also applies here.

6.1.1.3 Relation with ITU-T G.991.1

Figure 4 illustrates the G.991.1 system reference model aligned with the reference configuration shown in Figure 1.



Description of functional blocks:

C	Common circuitry
H	HDSL transceiver
I	Interface
M	Mapping
REG	Regenerator
DLL	Digital Local Line

NOTE 1 – A fully equipped HDSL core consists of one, two or three H, REG and DLL combinations depending on G.991.1 data retransmission rate.
NOTE 2 – REGs are optional.

Figure 4/G.995.1 – G.991.1 system reference model and its alignment with the generic reference configuration

An access digital section which uses HDSL technology can be considered as a number of functional blocks as shown in Figure 4. Depending upon the HDSL transceiver (H) transmission rate, a fully equipped HDSL core consists of one 2320 kbit/s, two 1168 kbit/s or two or three 784 kbit/s HDSL transceiver pairs connected by Digital Local Lines (DLLs) (which are linked by some common circuitry (C)). The HDSL core is application independent. Operation with a non-fully equipped HDSL core is also permitted.

If enhanced transmission range is required the HDSL core may contain optional regenerators (REGs). The regenerator may be inserted at any convenient intermediate point in the HDSL core with the appropriate insertion loss consideration. In addition there may be further restrictions in line length due to power feeding.

An application is defined by the interface (I) and mapping and maintenance (M) functionalities.

The functionalities at the exchange side constitute the Line Termination Unit (LTU) and act as master to the (slave) customer side functionalities, which collectively form the Network Termination Unit (NTU) and the REGs where applicable.

While aligning the HDSL functional model with the generic reference configuration, the access network comprises the Line Termination Unit and the loop plant including the repeaters. The NT1 comprises the HDSL Network Termination Unit with the functionality described above.

6.1.1.4 Relation with ITU-T G.991.2

Figure 5 illustrates the G.991.2 system reference model aligned with the reference configuration shown in Figure 1.

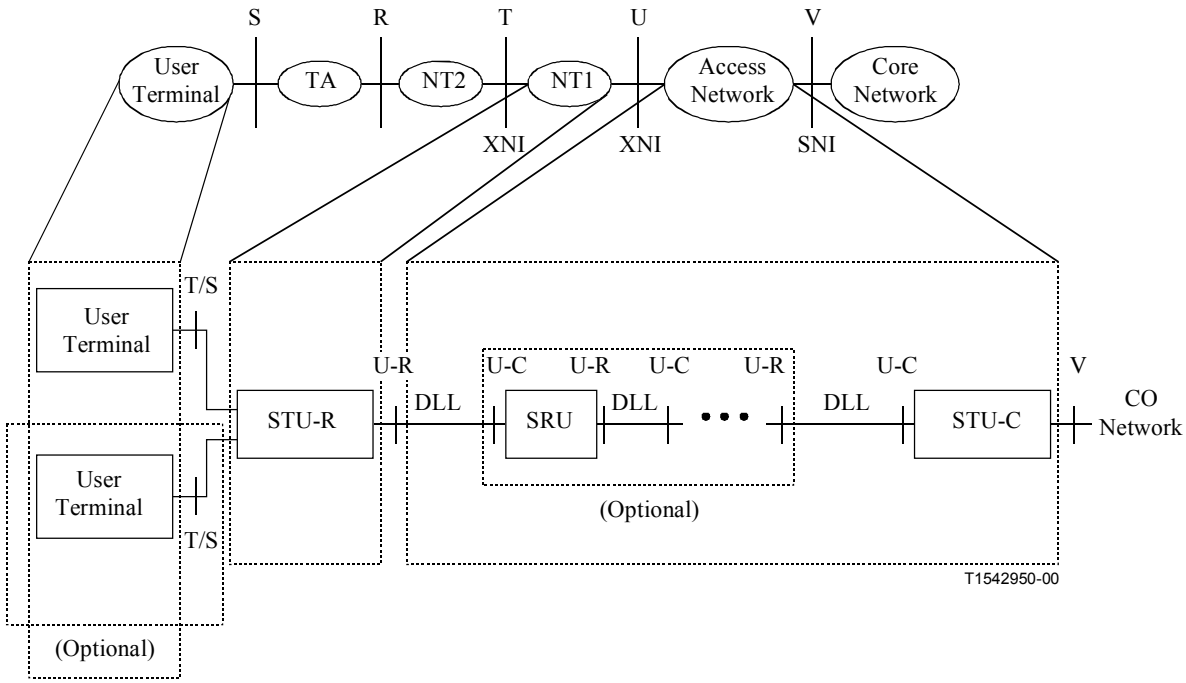


Figure 5/G.995.1 – G.991.2 system reference model and its alignment with the generic reference configuration

The G.991.2 system reference model shows the functional blocks necessary to illustrate an SHDSL transmission system. When aligned with the reference configuration, the core network functionalities, that are not shown here, include Central Office equipment connected to the access network through V interface. The access network comprises DLL, SHDSL Repeater Units (SRU) and the STU-C. The connection between STU-R and STU-C may optionally contain one or more SHDSL signal regenerators (SRUs). The connections to the DLLs that interconnect STUs and SRUs are designated U reference points. For each STU-x and SRU, the Network side connection is termed the U-R interface and the Customer side connection is termed the U-C interface. The STU-C typically connects to a Central Office equipment at the V reference point. The NT1 comprises the STU-R functions. Alternatively, the NT2, Terminal Adapter and User Terminal may share some or all of the NT1 functionalities. An STU-R will typically connect to one or more user terminals, which may include data terminals, subtended telecommunications equipment, or other devices. These pieces of terminal equipment are connected to the Access network through T/S reference points.

6.1.1.5 Relation with ITU-T G.994.1

Figure 6 illustrates the G.994.1 system reference model aligned with the reference configuration shown in Figure 1.

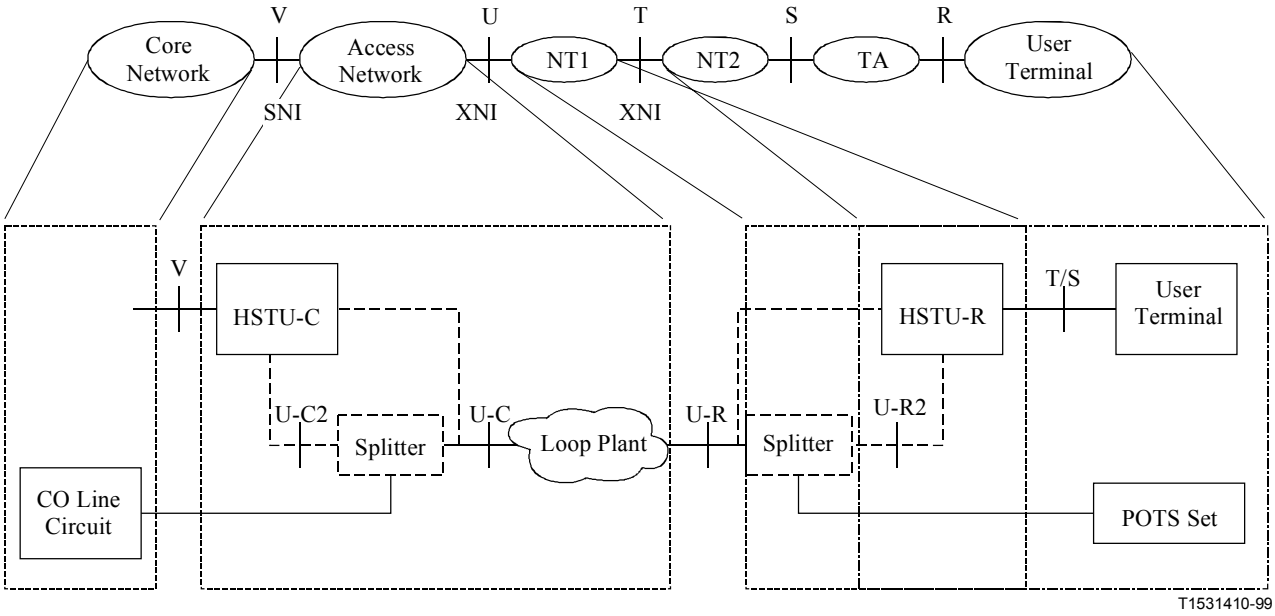


Figure 6/G.995.1 – G.994.1 system reference model and its alignment with the generic reference configuration

G.994.1 system reference model is a simplification of the G.992.1/G.992.2 reference model that attempts to identify the necessary functional blocks and the reference points and/or interface points that may be used or have implications in G.994.1. The Handshake Transceiver Unit (HSTU) is used to signify that the G.994.1 transceiver function is different from ITU-T G.992.1 and G.992.2.

When aligned with the reference configuration, the access network comprises the HSTU-C, splitter and the loop plant. The NT1 comprises the Splitter and the HSTU-R. Alternatively, the NT1 functionality may just contain the splitter whereas the NT2, TA and User terminal may collectively contain the HSTU-R and other user terminal functionality.

6.1.1.6 Relation with ITU-T G.997.1

Figure 7 illustrates the G.997.1 system reference model aligned with the reference configuration shown in Figure 1.

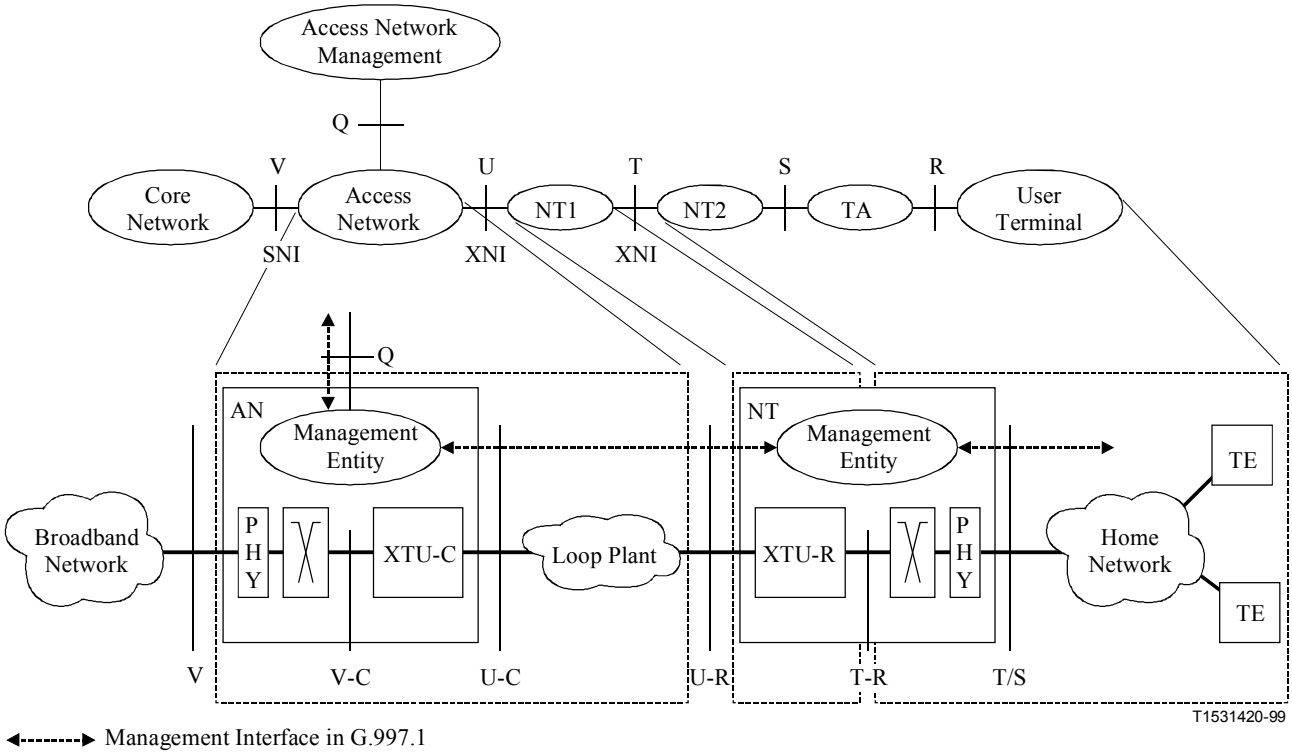


Figure 7/G.995.1 – G.997.1 system reference model and its alignment with the generic reference configuration

The G.997.1 reference model, similar to the G.994.1 system reference model, is a simplification of the G.992.1/G.992.2 reference model that attempts to identify the necessary functional blocks and the reference points and/or interface points. The xDSL Transceiver Unit (XTU) is used to signify that the G.997.1 transceiver function is applicable for both ITU-T G.992.1 and G.992.2. A management entity functional block is added in both Access Node (AN) and the NT to depict the management functionalities. A new reference point Q has been added.

When aligned with the reference configuration, the core network functionalities are the broadband network or other functionalities that are not shown here. The access network comprises AN, and the loop plant. The NT1 comprises the NT functions. Alternatively, the NT1 functionality may just contain the XTU-R whereas the NT2, TA and User terminal may contain the remaining user terminal functionalities.

6.1.1.7 Relation with ITU-T G.996.1

Figure 8 illustrates the G.996.1 system reference model aligned with the reference configuration shown in Figure 1.

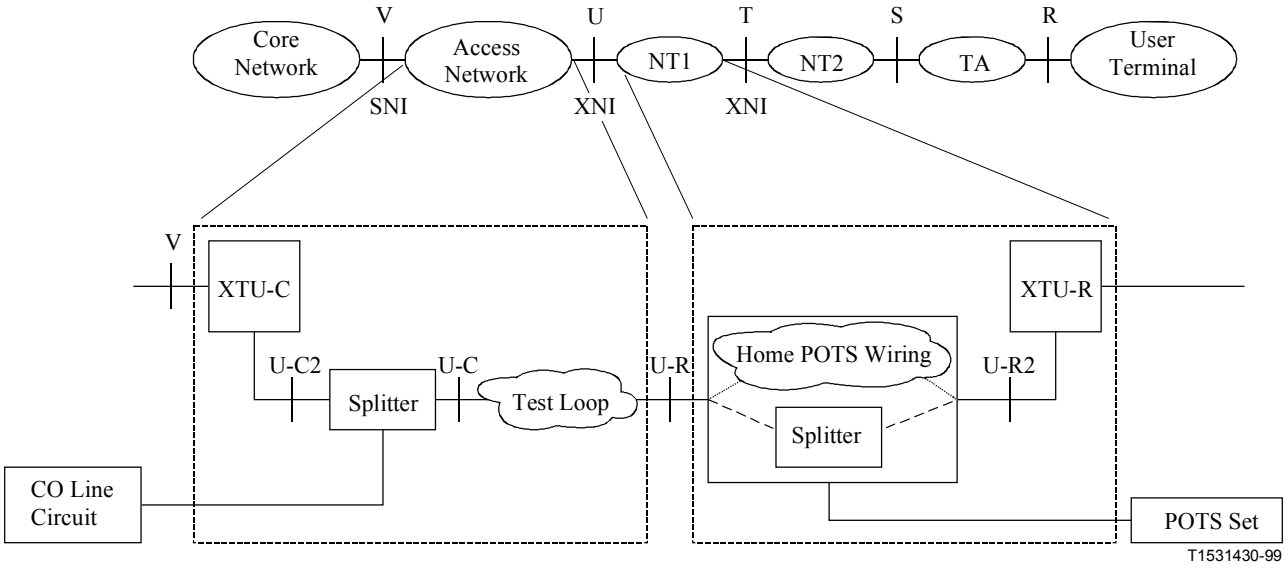


Figure 8/G.995.1 – G.996.1 system reference model and its alignment with the generic reference configuration

The G.996.1 system reference model is a simplified test system version of the G.992.1 and G.992.2 system reference models to show the general arrangement for testing of the compliant modems. The terminology XTU refers to the fact that this model is to be used for ITU-T G.992.1, G.992.2 and also any new future G.99x Recommendations.

The following potential sources of impairment are simulated in a laboratory set-up that includes test loops, test sets, and interference injection equipment, as well as the test system itself:

– crosstalk coupling from other systems;

– background noise;

– impulse noise;

– POTS signalling.

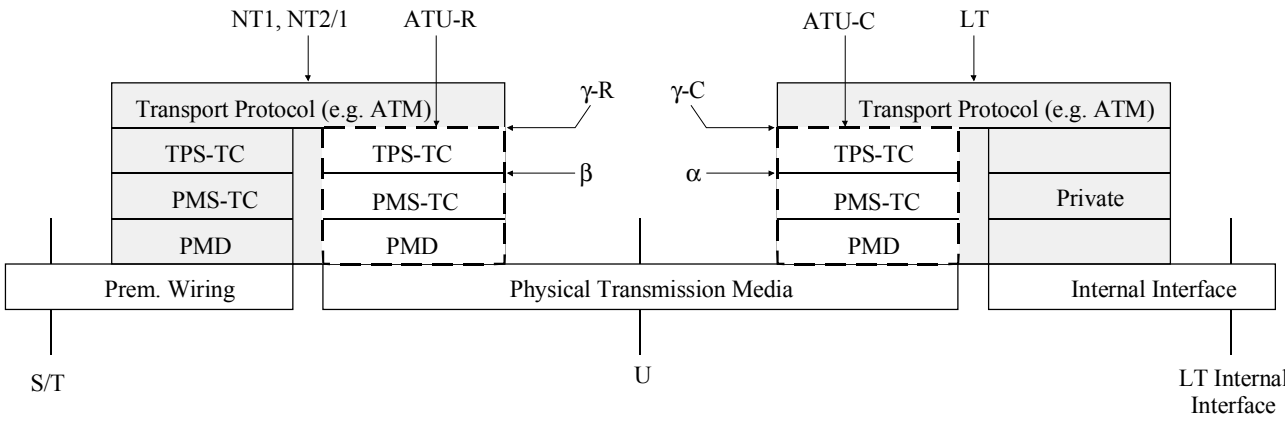
The crosstalk and impulse noise interfering signals are simulations that are derived from a consideration of real loop conditions and measurements. The test procedure is to inject the interference into the test loops and measure the effect on system performance by a bit error test simultaneously run on the system information channels.

When aligned to the reference architecture, only two elements apply to ITU-T G.996.1, i.e. access network and NT1. Access network comprises of the XTU-C, POTS splitter, and test loops. The NT1 comprises of the home POTS wiring or POTS splitter and the XTU-R.

6.2 Reference Layered Protocol Architecture for ITU-T G.99x Recommendations

In this clause, a reference layered protocol architectural view of the G.99x-series Recommendations is presented in user and management planes as appropriate.

Figure 9 depicts the user plane protocol reference architecture that may apply in general to DSL Recommendations.



TPS-TC Transport Protocol Specific – Transmission Convergence Layer (e.g. ATM)
PMS-TC Physical Media Specific – Transmission Convergence Layer
LT Line Terminal
γ-R, γ-C xDSL Transport Protocol Reference Point (e.g. ADSL T-R, V-C)
α, β Hypothetical Application (transport protocol) Independent Reference Points

Figure 9/G.995.1 – User plane protocol reference architecture

Both ATU-C and ATU-R are encapsulated in a dashed box and comprise of PMD, TPS-TC and PMS-TC. From the perspective of the OSI layered stack, all of the three may be considered as sub-layers of the physical layer.

Line Terminal is shown as a shaded box and includes ATU-C. NT1 or combined NT2/1 are also shown dashed and include the ATU-R.

The U, T/S reference points/interfaces are shown here. The V reference point/interface has been shown as an LT internal interface and may not need elaboration as being implementation dependent and private to service providers. On the remote side, T reference point/interface may be assumed if an NT1 is assumed to have implemented the shown layered functions. Under the assumption that both NT1 and NT2 share the shown layered functions, an S reference point/interface may be assumed at the remote side.

Figure 10 depicts the user plane protocol layered protocol architecture for both ITU-T G.992.1 and G.992.2.

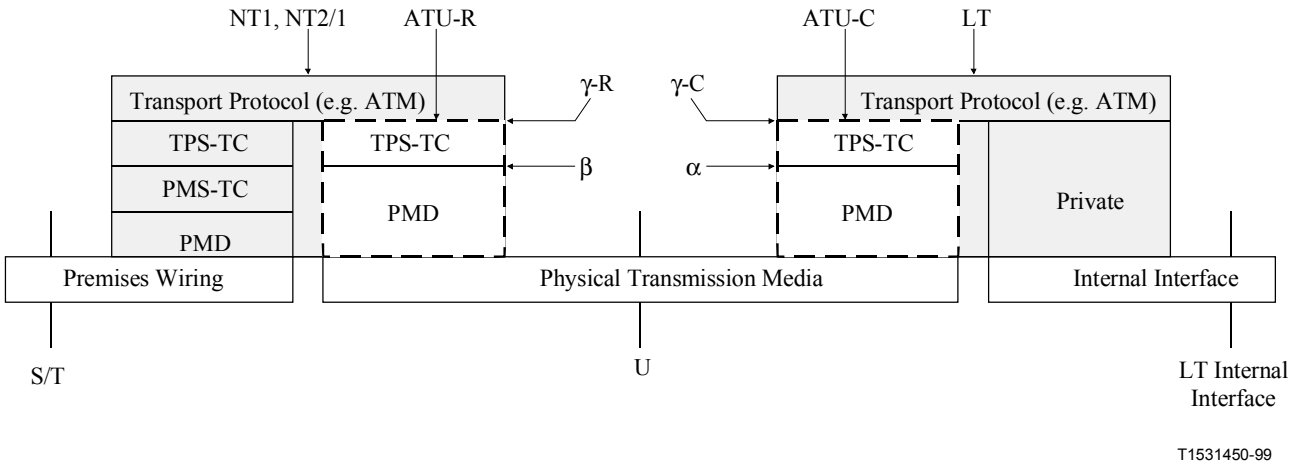


Figure 10/G.995.1 – User plane protocol reference architecture for ITU-T G.992.1 and G.992.2

Both ITU-T G.992.1 and G.992.2 do not clearly define the functional separation between the PMD and PMS-TC sub-layers. As a result, the two sub-layers are merged into one and is referred to as the PMD sub-layer. The term PMD is used in both ITU-T G.992.2 and G.992.1.

For ITU-T G.991.1, that contains two line code specifications, Figure 11 is an appropriate representation of the layered protocol architecture.

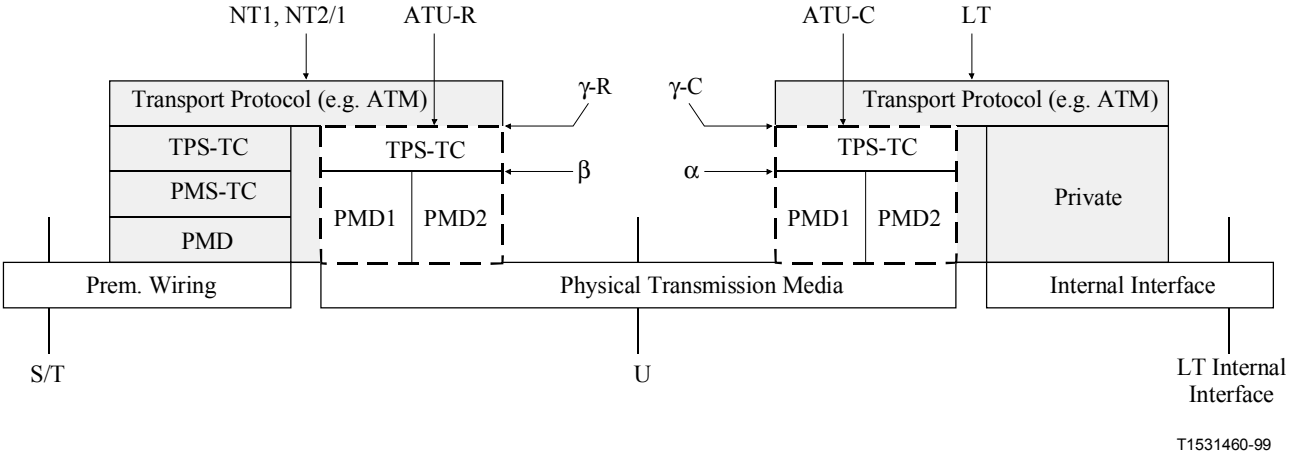


Figure 11/G.995.1 – User plane protocol reference architecture for ITU-T G.991.1

Two PMDs are shown to reflect the choice of one of the two line codes.

Figure 12 depicts the user plane protocol layered protocol architecture for ITU-T G.991.2.

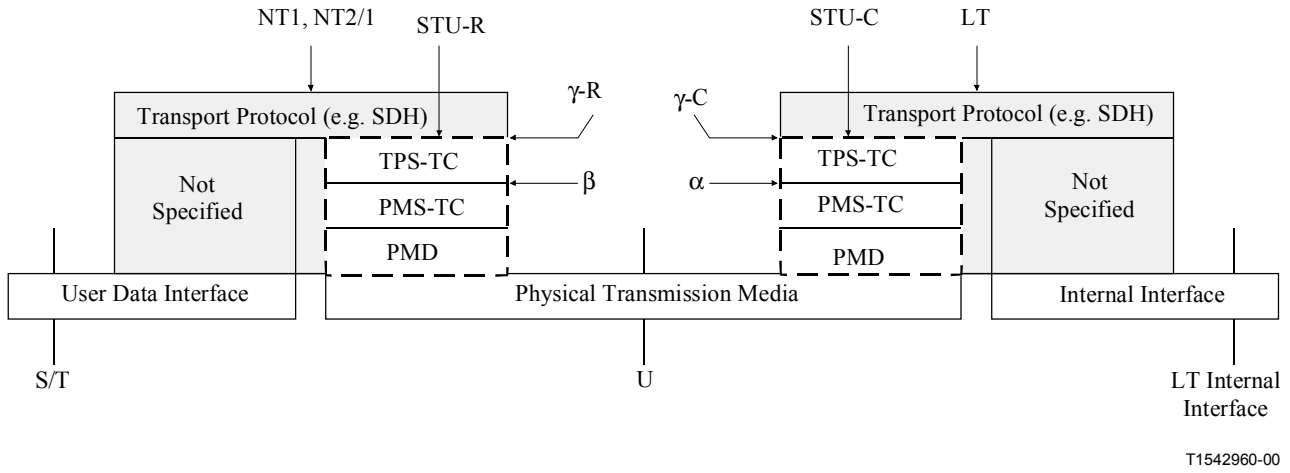


Figure 12/G.995.1 – User plane protocol reference architecture for ITU-T G.991.2

The principal functions of the G.991.2 PMD layer are symbol timing generation and recovery, coding and decoding, modulation and demodulation, echo cancellation, line equalization, and link activation.

The PMS-TC layer contains the framing and frame synchronization functions, as well as the scrambler and descrambler. The PMS-TC is connected across the α and β interfaces in the STU-C and STU-R, respectively, to the TPS-TC layer. The TPS-TC is application specific and consists

largely of the packaging of user data within the SHDSL frame. This may include multiplexing, demultiplexing, and timing alignment of multiple user data channels.

The TPS-TC layer communicates with the Interface blocks across the γ_r and γ_c interfaces. Depending upon the specific application, the TPS-TC layer may be required to support one or more channels of user data and associated interfaces. The definition of physical interfaces is beyond the scope of this Recommendation.

The α, β, γ_r, and γ_c interfaces are only intended as logical separations and need not be physically accessible.

ITU-T G.994.1 may be viewed from the perspective of user plane layered protocol architecture as shown in Figure 13.

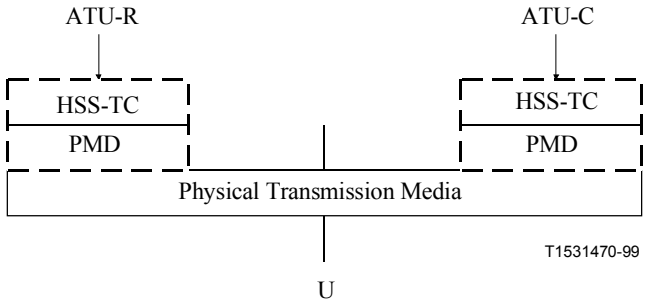


Figure 13/G.995.1 – User plane protocol reference architecture for ITU-T G.994.1

The simplicity of Figure 13 is reflective of the limited layered protocol architectural scope for G.994.1. ITU-T G.994.1 uses a different modulation format and transmissions convergence function when compared to ITU-T G.992.1 or G.992.2. Therefore, Figure 11 signifies that the PMD function and the "Handshake Specific-Transmission Convergence (HSS-TC)" is not the same as that of ITU-T G.992.1 or G.992.2.

As the handshake procedure takes place before the initialization and showtime of G.992.1 and G.992.2, a G.992.1, G.992.2 and G.994.1 compliant modem may be viewed to have changed its layered protocol architecture from that in Figure 13 to that in Figure 10 in continuous time.

Figure 14 depicts the management plane protocol reference architecture for G.99x Recommendations that may be considered appropriate for ITU-T G.997.1.

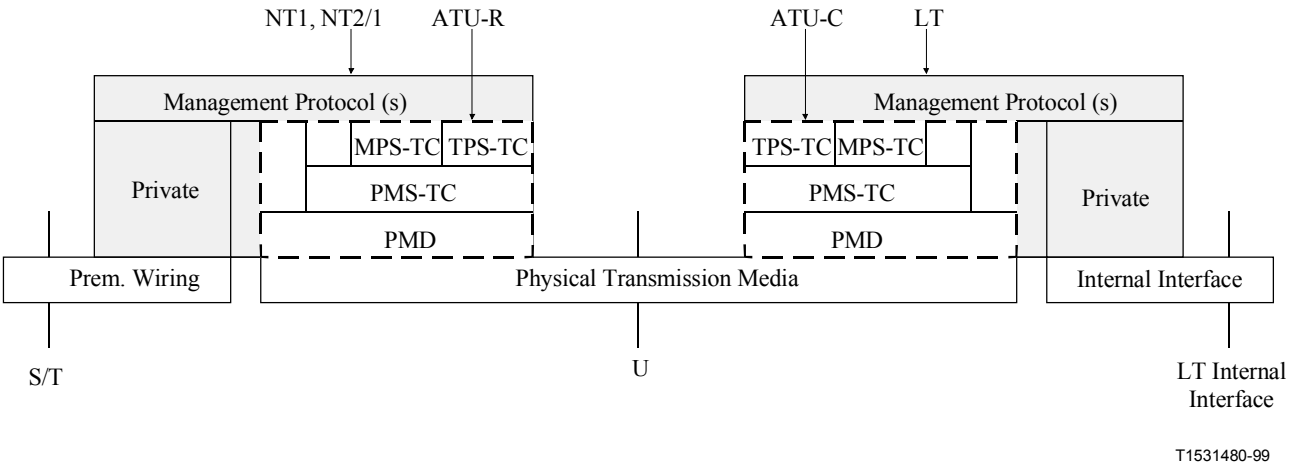


Figure 14/G.995.1 – Management plane protocol reference architecture for G.99x Recommendations

In Figure 14, MPS-TC stands for Management Protocol Specific – Transmission Convergence. This figure attempts to depict four ways the management plane functions may be implemented by the management protocol. A combination of them may be used in some implementations. It must be noted that management protocol may have direct access to the PMD management functions, or through the PMS-TC (e.g. AOC, EOC), or it may have access through a management protocol specific transmission convergence layer or MPS-TC (e.g. SNMP), or management may be part of the normal user plane functions through TPS-TC (e.g. ATM).

ITU-T G.996.1 need not be viewed from the layered architecture perspective.

7 Illustration of Data Service Using DSL Recommendations

A data-centric connection is described by reference to the ISDN reference configuration and its standard R, S, T, U and V reference points. It includes CPE to ISP connections and by reflection also includes CPE-CPE connections. GII reference points are also shown for comparison.

There are apparently two key network connection options; the customer's terminal or home network can be connected to the public network either via separate Network Termination (NT1) equipment, by using a Network Interface card plugged into a Terminal Equipment incorporating an embedded NT1, or by a "Home Gateway" incorporating both NT1 and NT2 functionality.

7.1 End-To-End Data-Centric Connection

Figure 15 shows the relationship between reference points from the generic reference configuration and equivalent reference points from the G.902 GII model in the context of end-to-end data centric reference connection. It illustrates the scope of ITU-T G.992.2 and G.992.1 in relation to an overall broadband system reference model.

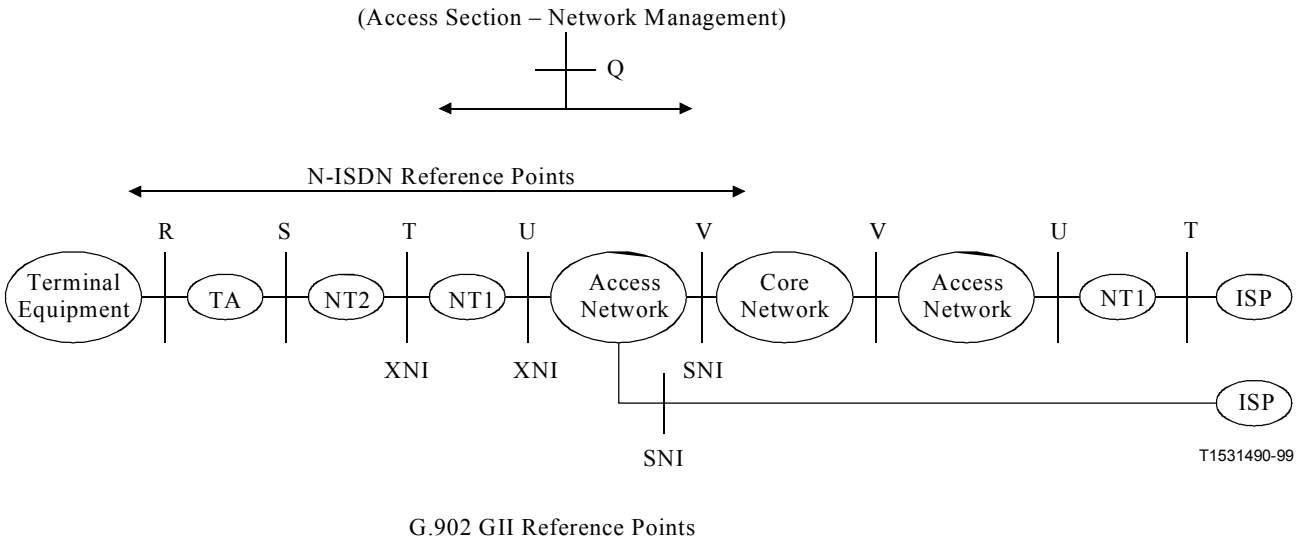


Figure 15/G.995.1 – Illustration of a generic xDSL data Connection

7.2 Illustration of Service Presentation Options

In the following subclauses several potential service presentation options are described.

7.2.1 Service Presentation at the T interface

Service Presentation at a T interface is shown in Figure 16.

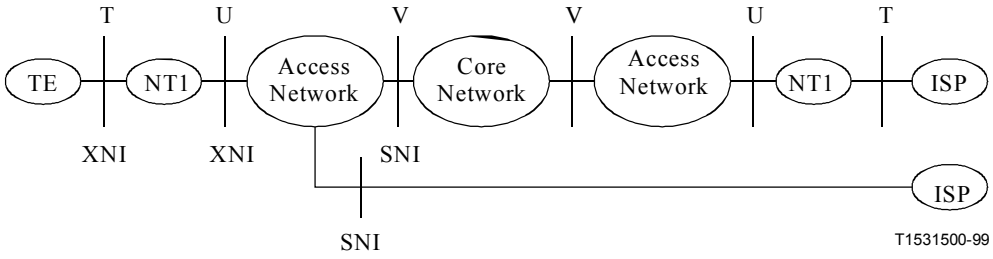


Figure 16/G.995.1 – Data service presentation at the T interface

In the case of G.992.1, the NT1 may be provided as a separate box owned by the network operator or the customer as in North American and European Narrow-band ISDN practice, respectively. The User Network Interface is expressed at the T reference point on a physical interface. TE may implement NT2 and TA functions for connection to a home network. Figure 17 depicts a separate NT1 model for G.992.1.

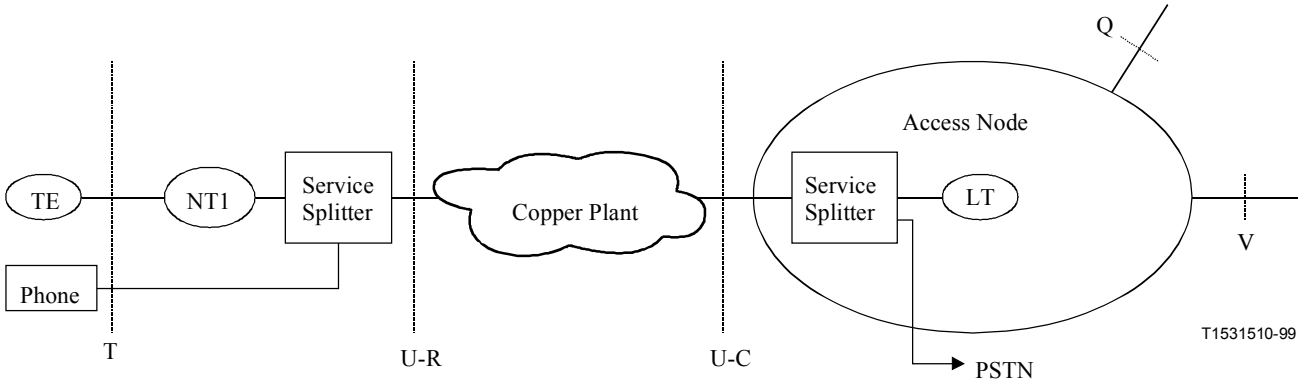


Figure 17/G.995.1 – G.992.1 data service presentation at the T interface

In the case of G.992.2, the above is true except the Service Splitter between Copper Plant and the NT1 is not present as shown in Figure 18.

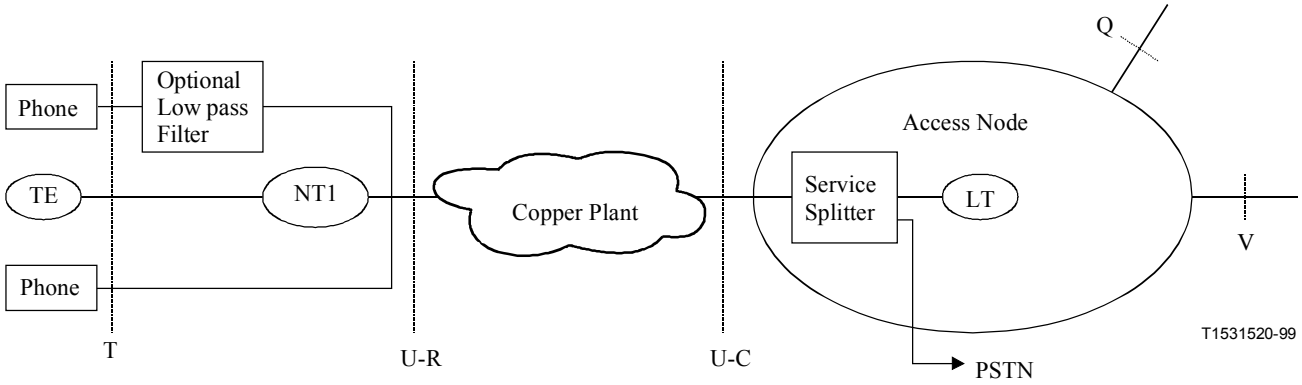


Figure 18/G.995.1 – G.992.2 data service presentation at the T interface

7.2.2 Service Presentation at the U interface

Service Presentation at a U interface is shown in Figure 19.

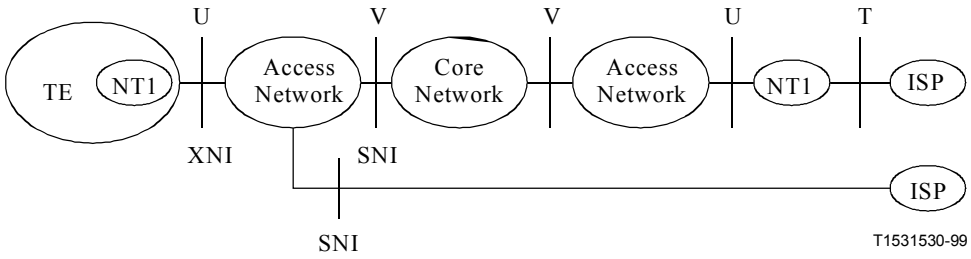


Figure 19/G.995.1 – Data service presentation at the U interface

When NT1 is embedded on a TE Interface Card for G.992.1, NT1 may be part of the network operator's Access Network Management Domain. The User Network Interface is expressed physically at the U reference point (equivalent to GII XNI), and logically inside the TE at a hypothetical T reference point. The TE may implement NT2 and/or TA functions. Figure 20 depicts an integrated NT1 model for G.992.1.

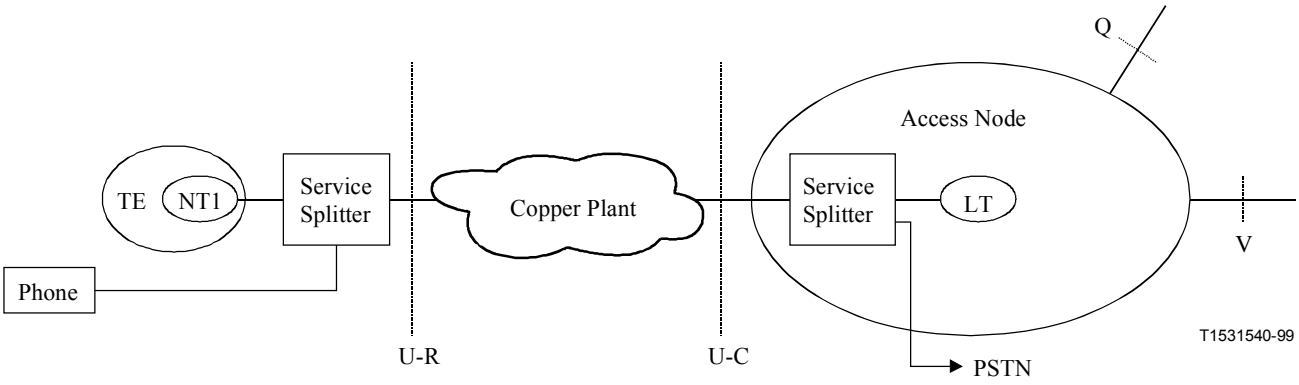


Figure 20/G.995.1 – G.992.1 data service presentation at the U interface

When NT1 is embedded on a TE Interface Card for G.992.2, NT1 may still be part of the network operator's Access Network Management Domain. The User Network Interface may be expressed physically at the U reference point (equivalent to GII XNI), and logically inside the TE at a hypothetical T reference point. The TE may implement B-NT2 and/or TA functions. Figure 21 depicts an integrated NT1 model for G.992.2.

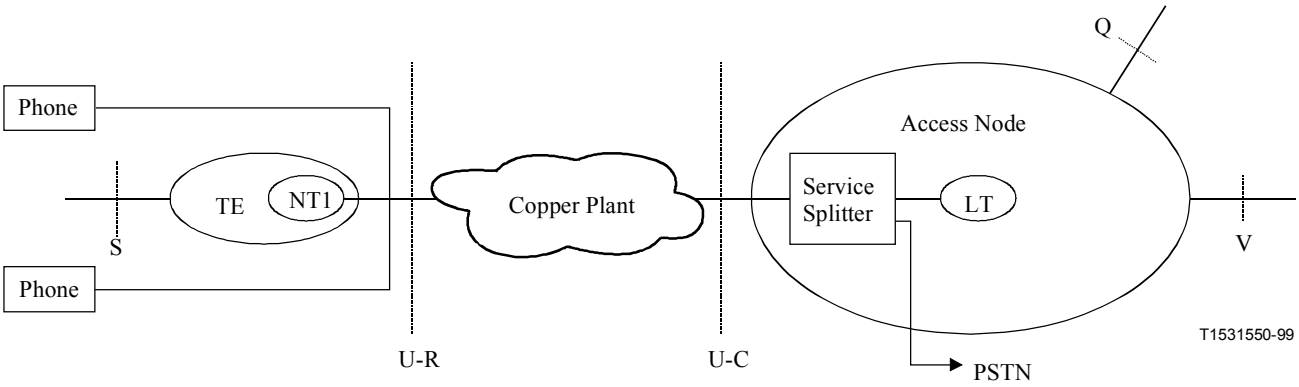


Figure 21/G.995.1 – G.992.2 data service presentation at the U interface

Other data service presentations are also possible but are not shown here for brevity. The options shown here are for illustration purposes only and are not endorsed for implementation.

8 Glossary of Terms in DSL Recommendations

The following terminology is used in the DSL Recommendations:

α	Hypothetical Application (transport protocol) Independent Reference Points/Interfaces.
β	Hypothetical Application (transport protocol) Independent Reference Points/Interfaces.
γ-C	xDSL Transport Protocol Reference Point (e.g. ADSL T-R, V-C).
γ-R	xDSL Transport Protocol Reference Point (e.g. ADSL T-R, V-C).
ADSL system overhead	All overhead needed for system control, including crc, eoc, aoc synchronization bytes, fixed indicator bits for OAM, and FEC; that is, the difference between total data rate and net data rate.
Aggregate data rate	Data rate transmitted by an ADSL system in any one direction; it includes both net data rate and data rate overhead used by the system for crc, eoc, synchronization of the various bearer channels, and fixed indicator bits for OAM; it does not include FEC redundancy.
AS0	The data channel from the ATU-C to the ATU-R.
Bearer channel	A user data stream of a specified data rate that is transported transparently by an ADSL system.
Bridged taps	Sections of unterminated twisted-pair cables connected in parallel across the cable under consideration.
Category I	Basic category of transceivers with no performance-enhancing options, which meet a basic set of performance requirements.
Category II	Category of transceivers with performance-enhancing options which meet an expanded set of performance requirements.
Channelization	Allocation of the net data rate to bearer channels.
Data Frame	A frame of bytes that compose part of the superframe.
DMT symbol	A set of complex values $\{Z_I\}$ forming the frequency domain inputs to the inverse discrete Fourier transform (IDFT). The DMT symbol is equivalently the set of real valued time samples, $\{x_n\}$, related to the set of $\{Z_I\}$ via the IDFT.
Data symbol rate	The net average rate (after allowing for the overhead of the synchronization symbol) at which symbols carrying user data are transmitted (= 4 kbaud).
Downstream	ATU-C to ATU-R direction.
DSL Recommendations	The family of ITU-T Recommendations G.991.1, G.992.1, G.992.2, G.994.1, G.995.1, G.996.1, G.997.1.
Dual latency	Simultaneous transport of multiple data bearer channels in any one direction, in which user data is allocated to both the fast and interleaved paths; that is, $\text{sum}(B_f) > 0$ and $\text{sum}(B_i) > 0$.
FEC Output Frame	A frame of data presented to the constellation encoder after Reed Solomon encoding.
Indicator bits	Bits used for OAM purposes; embedded in the synchronization bytes.
Initiating signal	A signal that initiates a G.994.1 transaction.

Initiating station	The station that initiates a G.994.1 transaction.
Loading coils	Inductors placed in series with the cable at regular intervals in order to improve the voiceband response; removed for DSL use.
LS0	The data channel from the ATU-R to the ATU-C.
Message	Framed information conveyed via modulated transmission.
Net data rate	Data rate that is available for user data in any one direction; for the downstream direction this is the sum of the net simplex and duplex data rates.
Responding signal	Responding signal: A signal that is sent in response to an initiating signal.
Responding station	Responding station: The station that responds to initiation of a G.994.1 transaction from the remote station.
Showtime	The state of either ATU-C or ATU-R – reached after all initialization and training is completed – in which user data is transmitted.
Signal	A collection of one or more carriers from within a given signalling family.
Signalling family	A group of carriers which are integral multiples of a given carrier spacing frequency.
Single latency	Simultaneous transport of one or more bearer channels in any one direction, in which all user data is allocated to either the fast or the interleaved path; that is, either $\text{sum}(B_f) > 0$ or $\text{sum}(B_i) > 0$.
Service Node Interface (SNI)	SNI is the interface between the Access Network and the Core Network.
Splitter	Filter that separates the high frequency signals (ADSL) from the voiceband signals; (frequently called POTS splitter even though the voiceband signals may comprise more than POTS).
Sub-carrier	A particular complex valued input, Z_i, to the IDFT.
Superframe	A data entity consisting of 68 Data Frames and one Sync Frame.
Symbol rate	The rate at which all symbols, including the synchronization symbol, are transmitted ((69/68)*4.0 = 4.0588 kbaud); contrasted with the data symbol rate.
Sync Byte	A byte of data in the Mux data frame that contains either AOC, eoc or IB bits.
Sync Frame	A frame of bytes that compose part of the superframe.
Sync Symbol	A DMT symbol modulated with a constant data pattern.
Total data rate	Aggregate data rate plus FEC overhead.
Transaction	A sequence of G.994.1 messages, terminating with either a positive acknowledgement (ACK(1)), a negative acknowledgement (NAK), or a time-out.
Upstream	ATU-R to ATU-C direction.
Voiceband	0 to 4 kHz; expanded from the traditional 0.3 to 3.4 kHz to deal with voiceband data services wider than POTS.

Voiceband services	POTS and all data services that use the voiceband or some part of it.
xDSL	Any of the various types of digital subscriber lines.
XNI	Access network interface is the interface between the access network and the User Premises.

APPENDIX I

Bibliography

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