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

Digital transmission systems – Digital sections and digital line system – Access networks

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Overview of digital subscriber line (DSL) Recommendations

ITU-T Recommendation G.995.1

(Previously 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. Specifically, this Recommendation contains an overview of the DSL family of Recommendations, and a description of 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. Also illustrations of the data service presentation options using the DSL Recommendations is provided. Finally, a glossary of the terms used in the DSL Recommendations is also included.

Source

ITU-T Recommendation G.995.1 was prepared by ITU-T Study Group 15 (1997-2000) and was approved under the WTSC Resolution No. 1 procedure on the 22nd of June 1999.

FOREWORD

ITU (International Telecommunication Union) is the United Nations Specialized Agency in the field of telecommunications. The ITU Telecommunication Standardization Sector (ITU-T) is a permanent organ of the ITU. The 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 Conference (WTSC), which meets every four years, establishes the topics for study by the ITU-T Study Groups which, in their turn, produce Recommendations on these topics.

The approval of Recommendations by the Members of the ITU-T is covered by the procedure laid down in WTSC Resolution No. 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 term *recognized operating agency (ROA)* includes any individual, company, corporation or governmental organization that operates a public correspondence service. The terms *Administration, ROA* and *public correspondence* are defined in the *Constitution of the ITU (Geneva, 1992).*

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The ITU draws attention to the possibility that the practice or implementation of this Recommendation may involve the use of a claimed Intellectual Property Right. The 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, the 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.

CONTENTS

Recommendation G.995.1

OVERVIEW OF DIGITAL SUBSCRIBER LINE (DSL) RECOMMENDATIONS

(Geneva, 1999)

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.

2 References

The following ITU-T Recommendations and other references contain provisions which, through reference in this text, constitute provisions of this Recommendation. At the time of publication, the editions indicated were valid. All Recommendations and other references are subject to revision; all users of this Recommendation are therefore encouraged to investigate the possibility of applying the most recent edition of the Recommendations and other references listed below. A list of the currently valid ITU-T Recommendations is regularly published.

[1] ITU-T Recommendation G.704 (1998), *Synchronous frame structures used at 1544, 6312, 2048, 8448 and 44 736 kbit/s hierarchical levels.*

[2] ITU-T Recommendation G.961 (1993), *Digital transmission system on metallic local lines for ISDN basic rate access.*

[3] ITU-T Recommendation G.991.1 (1998), *High bit rate Digital Subscriber Line (HDSL) transceivers.*

[4] ITU-T Recommendation G.992.1 (1999), *Asymmetric Digital Subscriber Line (ADSL) transceivers.*

[5] ITU-T Recommendation G.992.2 (1999), *Splitterless Asymmetric Digital Subscriber Line (ADSL) transceivers.*

[6] ITU-T Recommendation G.994.1 (1999), *Handshake procedures for Digital Subscriber Line (DSL) transceivers.*

[7] ITU-T Recommendation G.996.1 (1999), *Test procedures for Digital Subscriber Line (DSL) transceivers*.

[8] ITU-T Recommendation G.997.1 (1999), *Physical layer management for Digital Subscriber Line (DSL) transceivers.*

[9] ITU-T Recommendation I.411 (1993), *ISDN user-network interfaces – Reference configurations*.

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.

The following terminology is used in the DSL Recommendations:

3.2 α: Hypothetical Application (transport protocol) Independent Reference Points/Interfaces.

3.3 β: Hypothetical Application (transport protocol) Independent Reference Points/Interfaces.

3.4 γ-C: xDSL Transport Protocol Reference Point (e.g. ADSL T-R, V-C).

3.5 γ-R: xDSL Transport Protocol Reference Point (e.g. ADSL T-R, V-C).

3.6 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.

3.7 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.

3.8 AS0: The data channel from the ATU-C to the ATU-R.

3.9 Bearer channel: A user data stream of a specified data rate that is transported transparently by an ADSL system.

3.10 Bridged taps: Sections of unterminated twisted-pair cables connected in parallel across the cable under consideration.

3.11 Category I: Basic category of transceivers with no performance-enhancing options, which meet a basic set of performance requirements.

3.12 Category II: Category of transceivers with performance-enhancing options which meet an expanded set of performance requirements.

3.13 Channelization: Allocation of the net data rate to bearer channels.

3.14 Data Frame: A frame of bytes that compose part of the superframe.

3.15 DMT symbol: A set of complex values $\{Z_i\}$ forming the frequency domain inputs to the inverse discrete Fourier transform (IDFT) (see 7.11.2/G.992.1). The DMT symbol is equivalently the set of real valued time samples, $\{x_n\}$, related to the set of $\{Z_i\}$ via the IDFT.

3.16 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).

3.17 Downstream: ATU-C to ATU-R direction.

3.18 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.

3.19 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, sum(B_f) > 0 and sum(B_i) > 0.

3.20 FEC Output Frame: A frame of data presented to the constellation encoder after Reed Solomon encoding.

3.21 Indicator bits: Bits used for OAM purposes; embedded in the synchronization bytes.

3.22 Initiating signal: A signal that initiates a G.994.1 transaction.

3.23 Initiating station: The station that initiates a G.994.1 transaction.

3.24 Loading coils: Inductors placed in series with the cable at regular intervals in order to improve the voiceband response; removed for DSL use.

3.25 LS0: The data channel from the ATU-R to the ATU-C.

3.26 Message: Framed information conveyed via modulated transmission.

3.27 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.

3.28 Responding signal: A signal that is sent in response to an initiating signal.

3.29 Responding station: The station that responds to initiation of a G.994.1 transaction from the remote station.

3.30 Showtime: The state of either ATU-C or ATU-R – reached after all initialization and training is completed – in which user data is transmitted.

3.31 Signal: A collection of one or more carriers from within a given signalling family.

3.32 Signalling family: A group of carriers which are integral multiples of a given carrier spacing frequency.

3.33 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 sum(B_f) > 0 or sum(B_i) > 0.

3.34 Service Node Interface (SNI): SNI is the interface between the Access Network and the Core Network.

3.35 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).

3.36 Sub-carrier: A particular complex valued input, Z_i, to the IDFT (see 7.11.2/G.992.1).

3.37 Superframe: A data entity consisting of 68 Data Frames and one Sync Frame.

3.38 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.

3.39 Sync Byte: A byte of data in the Mux data frame that contains either AOC, eoc or IB bits.

3.40 Sync Frame: A frame of bytes that compose part of the superframe.

3.41 Sync Symbol: A DMT symbol modulated with a constant data pattern.

3.42 Total data rate: Aggregate data rate plus FEC overhead.

3.43 Transaction: A sequence of G.994.1 messages, terminating with either a positive acknowledgement [ACK(1) (except as noted in 10.5)], a negative acknowledgement (NAK), or a time-out.

3.44 Upstream: ATU-R to ATU-C direction.

3.45 Voiceband: 0 to 4 kHz; expanded from the traditional 0.3 to 3.4 kHz to deal with voiceband data services wider than POTS.

3.46 Voiceband services: POTS and all data services that use the voiceband or some part of it.

3.47 xDSL: Any of the various types of digital subscriber lines.

3.48 **XNI**: Access network interface is the interface between the access network and the User Premises.

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
l-p	Low-pass
LTU	Line Termination Unit
M	Mapping
MPS-TC	Management Protocol Specific-Transmission Convergence (layer)
NT1	Network Termination 1
NT2	Network Termination 2
NTU	Network Termination Unit
PHY	Physical Layer
PMS-TC	Physical Media Specific-Transmission Convergence (layer)
POTS	Plain Old Telephone Service

REG	Regenerator
SM	Service Module
SNI	Service Node Interface
STM	Synchronous Transfer Mode
TA	Terminal Adapter
TC	Transmission Convergence
TCM	Time Compression Multiplex
TPS-TC	Transport Protocol Specific-Transmission Convergence (layer)
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: G.992.1, G.992.2, G.991.1, G.996.1, G.994.1, G.997.1 and G.995.1. Recommendations G.991.1, G.992.1, 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. Recommendations G.994.1, G.996.1 and G.997.1 support 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 subclauses 5.1-5.6, the DSL Recommendations have been introduced. In subclause 5.7, the relationship of these Recommendations with each other is described.

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

G.992.1 specifies the physical layer characteristics of the Asymmetric Digital Subscriber Line (ADSL) interface to metallic loops. 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. 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 analog duplex channel, and ADSL line overhead for framing, error control, operations, and maintenance. 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 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 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 of 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, 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 Sublayer 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 of 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 crosstalk from ISDN as defined in Appendix III/G.961.

Recommendation 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 provide for U-interface compatibility and interoperability between transceivers complying to G.992.1 and between those transceivers that include different combinations of options.

5.2 G.992.2: Splitterless Asymmetric Digital Subscriber Line (ADSL) Transceivers

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 G.992.2 apply only to a single asymmetric digital subscriber line which 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. 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 analog duplex channel, and ADSL line overhead for framing, error control, operations, and maintenance. G.992.2 supports a maximum of 1.536 Mbit/s downstream and 512 kbit/s upstream net data rates.

Specifically, 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 Sublayer 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;
– defines loop timing at the ATU-R.

In a separate annex, 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 crosstalk from TCM-ISDN as defined in Appendix III/G.961;
– describes the transmission technique to support the simultaneous transport on a single twisted-pair of ISDN services as defined in Appendices I and II of G.961. Both simplex upstream and downstream bearer channels have been left for future study.

Recommendation G.992.2 defines the following optional capabilities and features:

– transport of a network timing reference.

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

5.3 G.991.1: High bit rate Digital Subscriber Line (HDSL) Transceivers

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. G.991.1 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 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 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.

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.

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 G.991.1 describe examples of a number of telecommunication services that may be supported.

5.4 G.994.1: Handshake Procedures for Digital Subscriber Line (DSL) Transceivers

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 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.

5.5 G.997.1: Physical Layer Management for Digital Subscriber Line (DSL) Transceivers

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 G.992.x-series Recommendations. It specifies Network Management Elements and their content for configuration, fault and performance management.

5.6 G.996.1: Test Procedures for Digital Subscriber Line (DSL) Transceivers

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

5.7 Relationship between the DSL Recommendations

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

The G.992.1, G.992.2 and G.991.1 Recommendations 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, G.991.1 provides symmetric data rates whereas G.992.1 and G.992.2 provide asymmetric data rates in the upstream and the downstream direction. G.991.1 does not allow simultaneous transmission of G.991.1 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. 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 asymmetric. G.992.1 has higher downstream to upstream asymmetry ratio than the G.992.2. From the loop plant coverage perspective, HDSL has shorter loop length compared to the G.992.1 and G.992.2. The length of the 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 line code.

In some respects, 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. G.992.2 has been developed with considerations for possible interoperability with G.992.1. G.992.2 is based on modifications to 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 G.992.2. Some of the differentiating features of the 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 changes the channel characteristics in a significant manner in a splitterless environment.

For service flexibility, central office implementations may choose to include one or more than one DSL scheme as specified in G.992.x-series Recommendations, or elsewhere. Details of these implementations, whether in hardware or software, are beyond the scope of G.995.1.

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 G.994.1 is an integral part of the G.992.1 and G.992.2 Recommendations. G.991.1 does not support the G.994.1. G.994.1 is expected to be used in the future DSL Recommendations and the future revision of the current Recommendations. G.994.1 has no implications for G.997.1 and G.996.1.

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

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 G.992.x-series Recommendations. It specifies Network Management Elements and their content for configuration, fault and performance management. G.997.1 does not preclude the use of eoc as currently defined in G.992.1 and G.992.2. All the network elements may not be relevant to a particular G.992.x Recommendation (e.g. fast data stream management elements for G.992.2).

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

Two generic reference configurations are used to relate the G.99x-series Recommendations. The first reference configuration is based on the reference configuration used for the N-ISDN in Recommendation I.411 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 Recommendation I.411.

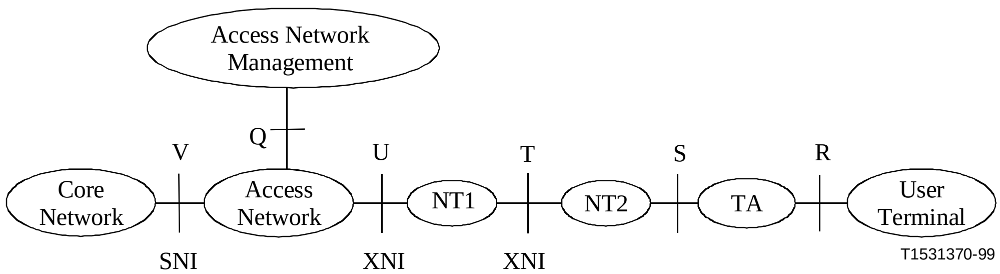


Figure 1/G.995.1 – A reference configuration for a generic G.99x system

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 points interfaces are the subject of 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 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 G.992.1

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

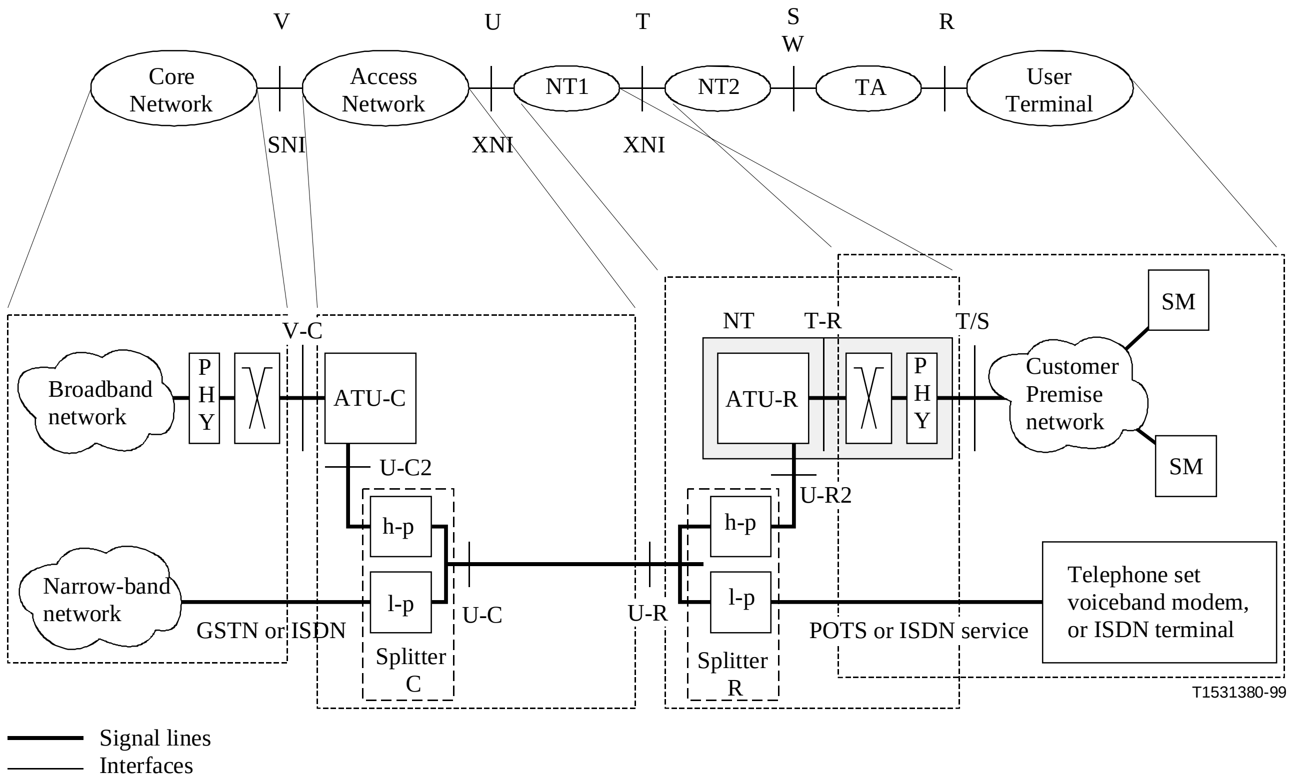


Figure 2/G.995.1 – G.992.1 system reference model and its alignment with the generic reference configuration

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 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 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 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 G.992.2

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

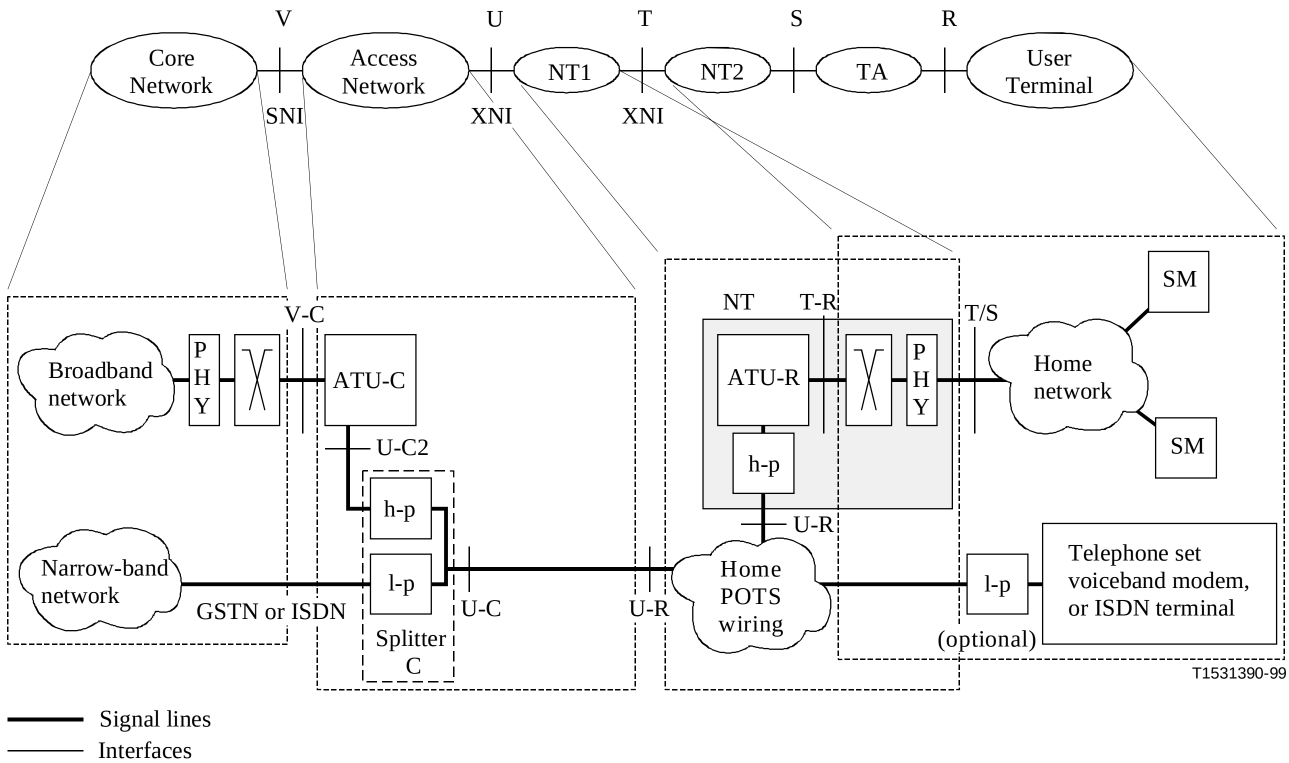
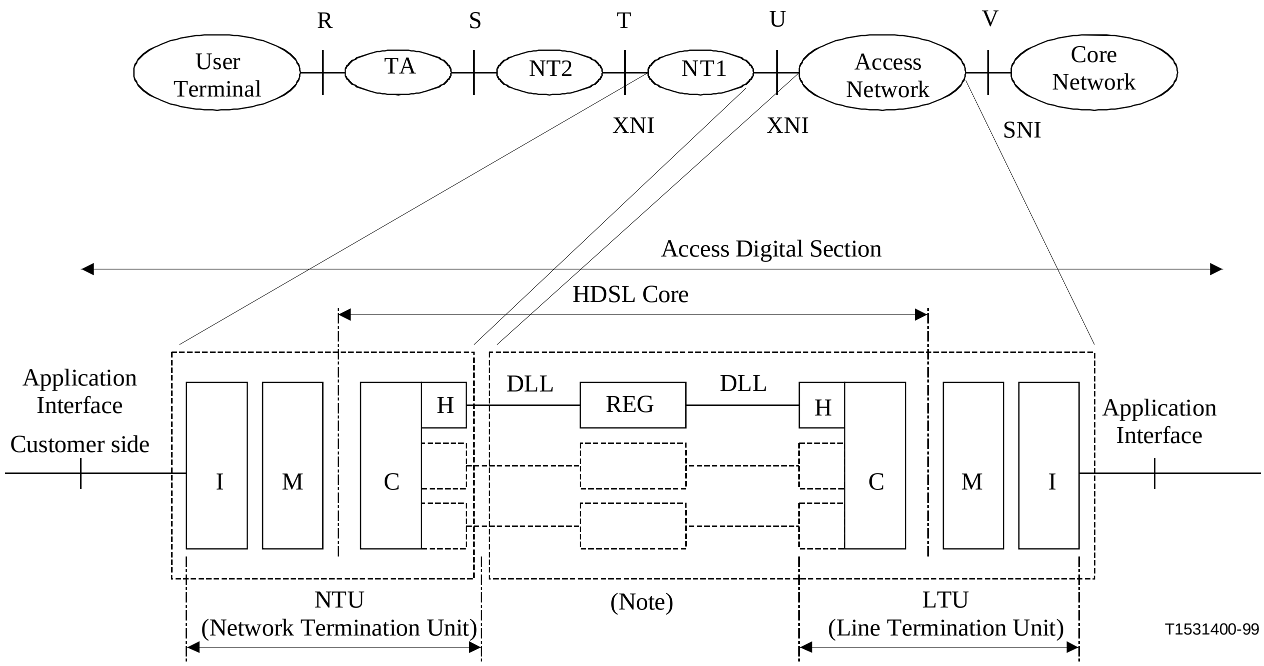


Figure 3/G.995.1 – G.992.2 system reference model and its alignment with the generic reference configuration

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 G.992.1. The U-R2 interface does not exist in G.992.2. The remaining discussion of 6.1.1.1 also applies here.

6.1.1.3 Relation with 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 transceiver data transmission rate
M	Mapping REGs are optional
REG	Regenerator
DLL	Digital Local Line

NOTE – A fully equipped HDSL core consists of one, two or three H, REG and DLL combinations depending on HDSL transceiver data transmission rate. 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 & 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 G.994.1

Figure 5 illustrates the G.994.1 system reference model aligned with the reference configuration shown in Figure 1.

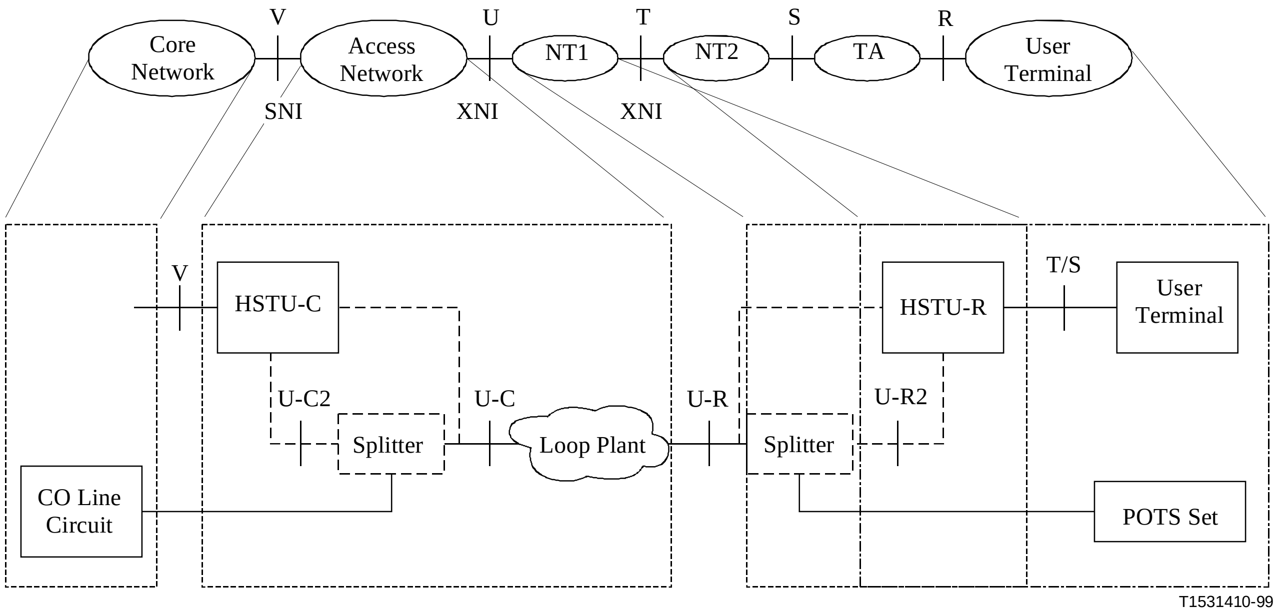


Figure 5/G.995.1 – G.994.1 system reference model and its alignment with the generic reference configuration

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 the G.994.1. The Handshake Transceiver Unit (HSTU) is used to signify that the G.994.1 transceiver function is different from 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.

6.1.1.5 Relation with G.997.1

Figure 6 illustrates the G.997.1 system reference model aligned with the reference configuration shown in Figure 1.

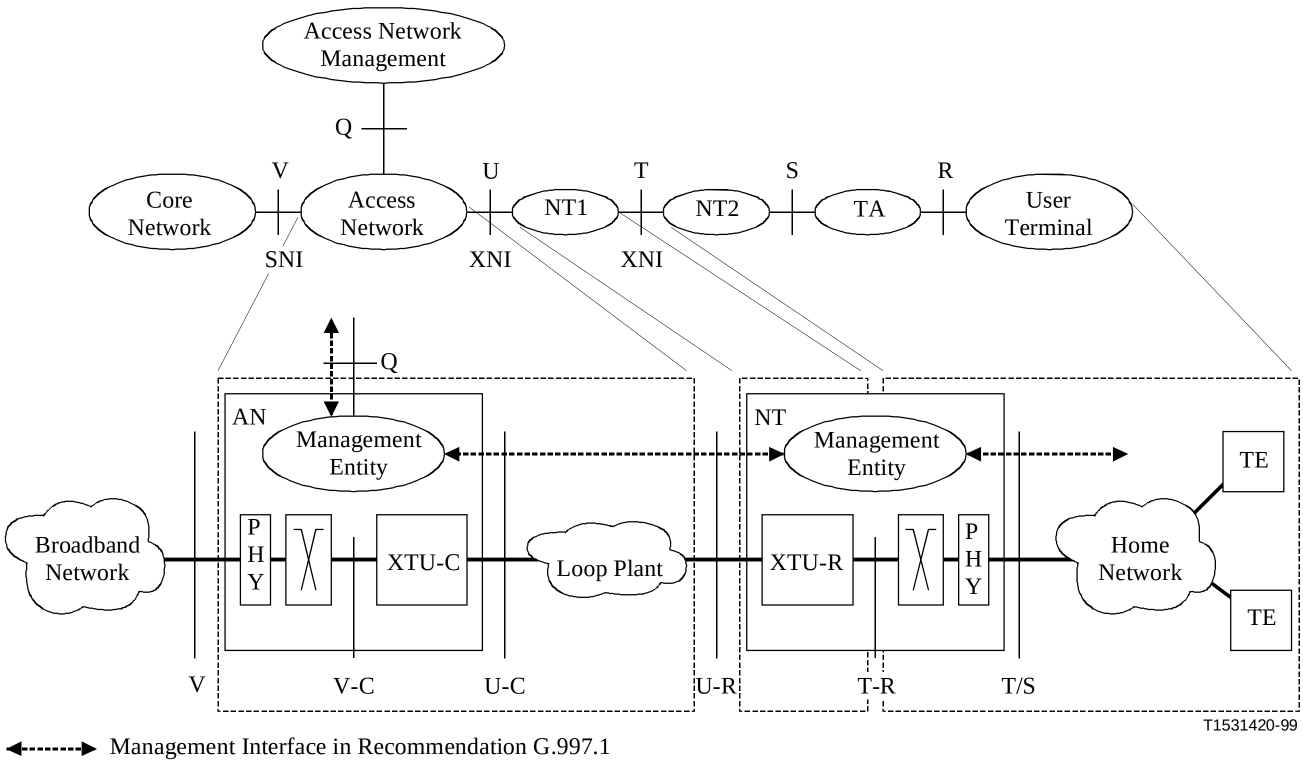


Figure 6/G.995.1 – G.997.1 system reference model and its alignment with the generic reference configuration

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 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.

6.1.1.6 Relation with G.996.1

Figure 7 illustrates the G.996.1 system reference model aligned with the reference configuration shown in Figure 1.

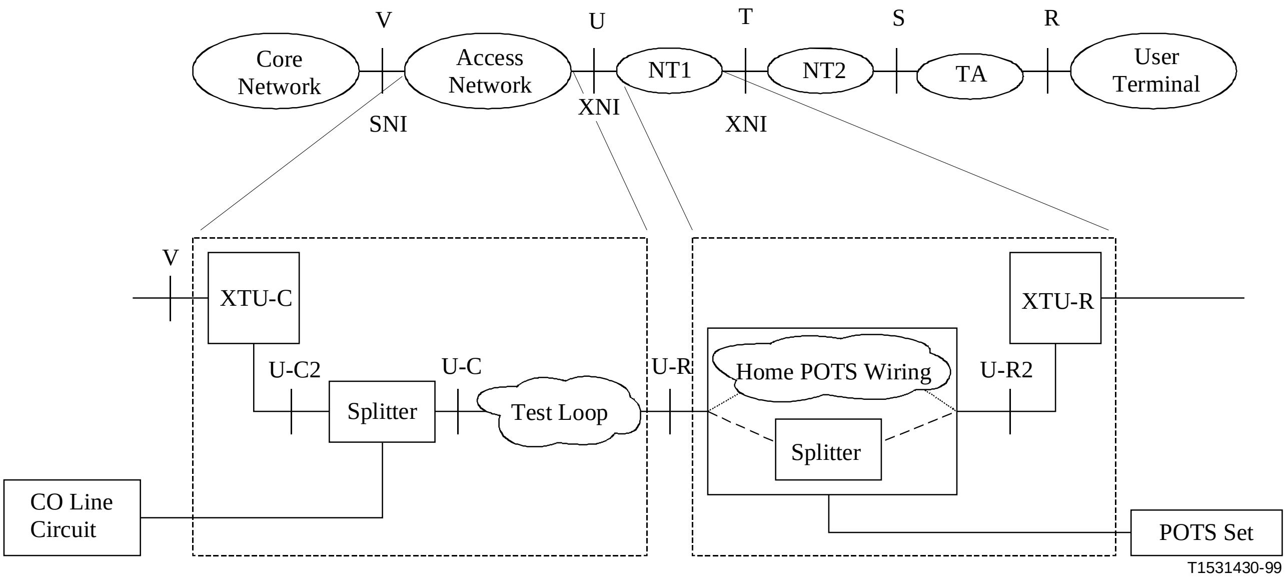


Figure 7/G.995.1 – G.996.1 system reference model and its alignment with the generic reference configuration

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 G.992.1, G.992.2 and also any new future G.99x Recommendation.

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.

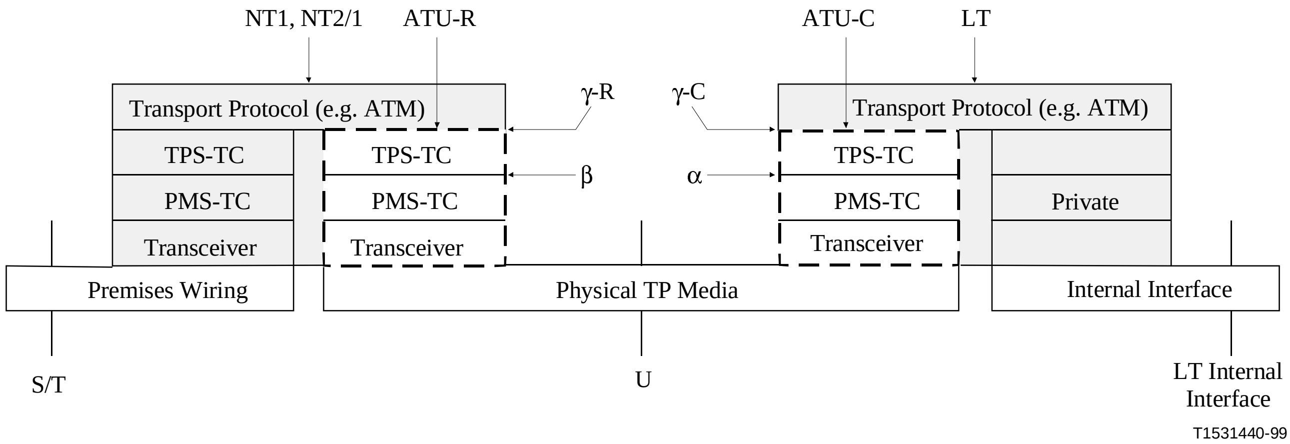
The crosstalk and impulse noise interfering signals are simulations that are derived from a consideration of real loop conditions and measurements. The test procedure is to inject the interference into the test loops and measure the effect on system performance by a bit error test simultaneously run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

When aligned to the reference architecture, only two elements apply to 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 G.99x-series Recommendations

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

Figure 8 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 8/G.995.1 – User plane protocol reference architecture

Both ATU-C and ATU-R are encapsulated in a dashed box and comprise of Transceiver, TPS-TC, and PMS-TC. From the perspective of the OSI layered stack, all of the three may be considered as sublayers 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 9 depicts the user plane protocol layered protocol architecture for both G.992.1 and G.992.2.

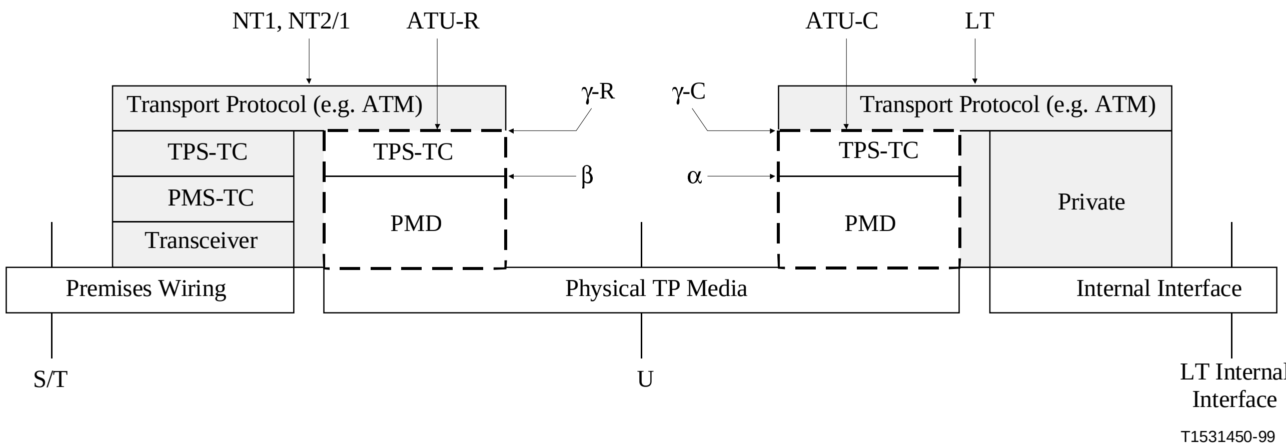


Figure 9/G.995.1 – User plane protocol reference architecture for G.992.1 and G.992.2

Both G.992.1 and G.992.2 do no clearly define the functional separation between the Transceiver and PMS-TC sublayers. As a result, the two sublayers are merged into one and is referred to as the PMD sublayer. The term PMD is used in both G.992.2 and G.992.1.

For G.991.1, that contains two line code specifications, Figure 10 is an appropriate representation of the layered protocol architecture.

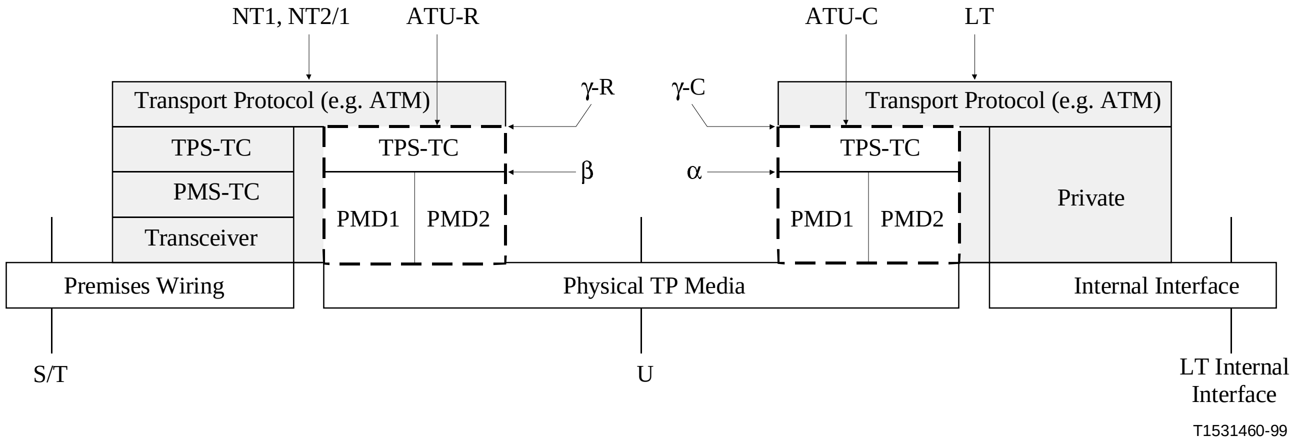


Figure 10/G.995.1 – User plane protocol reference architecture for G.991.1

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

G.994.1 may be viewed from the perspective of user plane layered protocol architecture as shown in Figure 11.

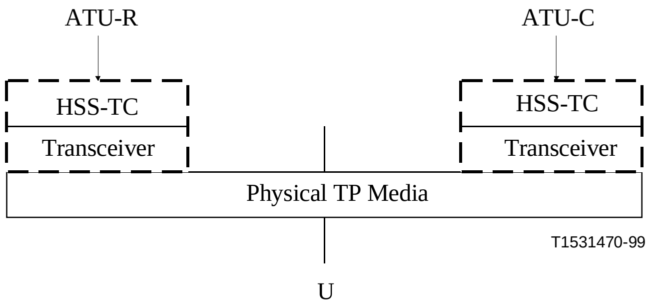


Figure 11/G.995.1 – User plane protocol reference architecture for G.994.1

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

As the handshake procedure takes place before the initialization and showtime of the 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 11 to that in Figure 9 in continuous time.

Figure 12 depicts the management plane protocol reference architecture for G.99x-series Recommendations that may be considered appropriate for G.997.1.

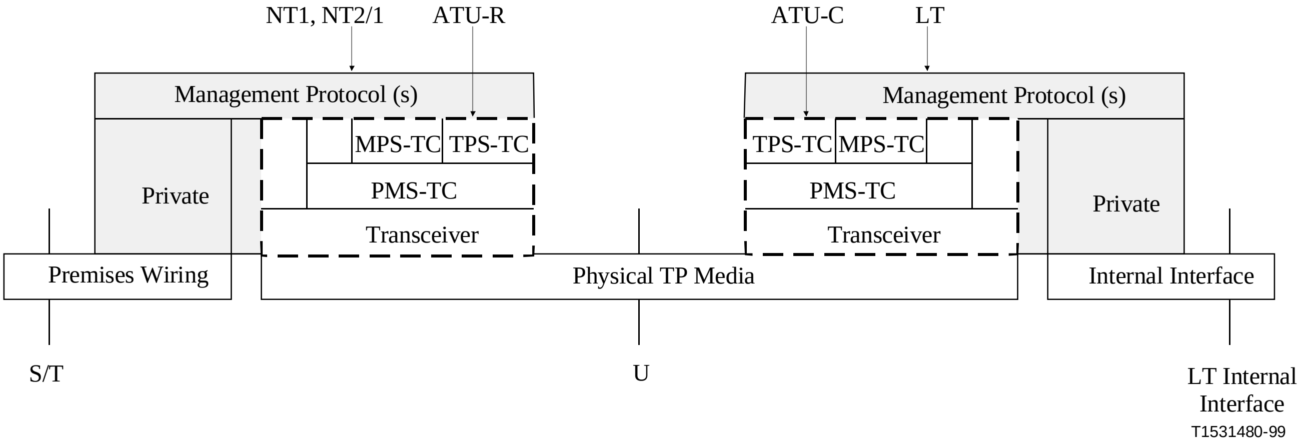


Figure 12/G.995.1 – Management plane protocol reference architecture for G.99x-series Recommendations

In Figure 11, 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 Transceiver 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).

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 13 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 G.992.2 and G.992.1 in relation to an overall broadband system reference model.

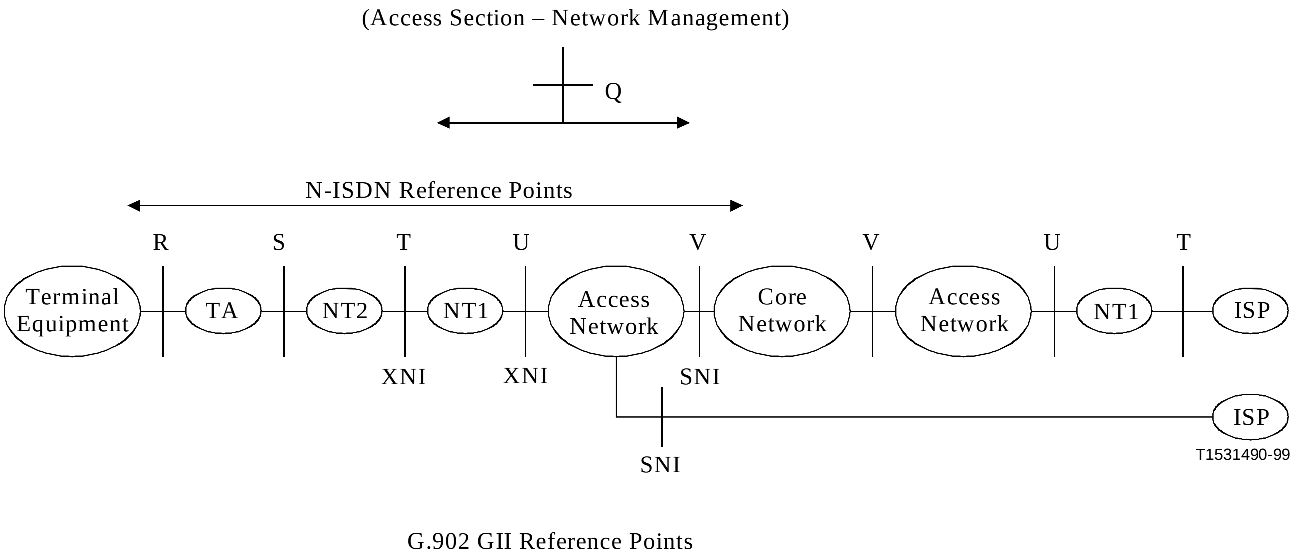


Figure 13/G.995.1 – Illustration of a generic xDSL data Connection

7.2 Illustration of service presentation options

In the following subclause, 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 14.

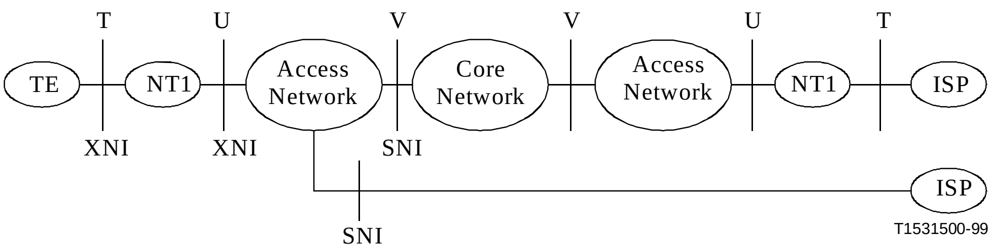


Figure 14/G.995.1 – Data service presentation at the T interface

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 15 depicts a separate NT1 model for G.992.1.

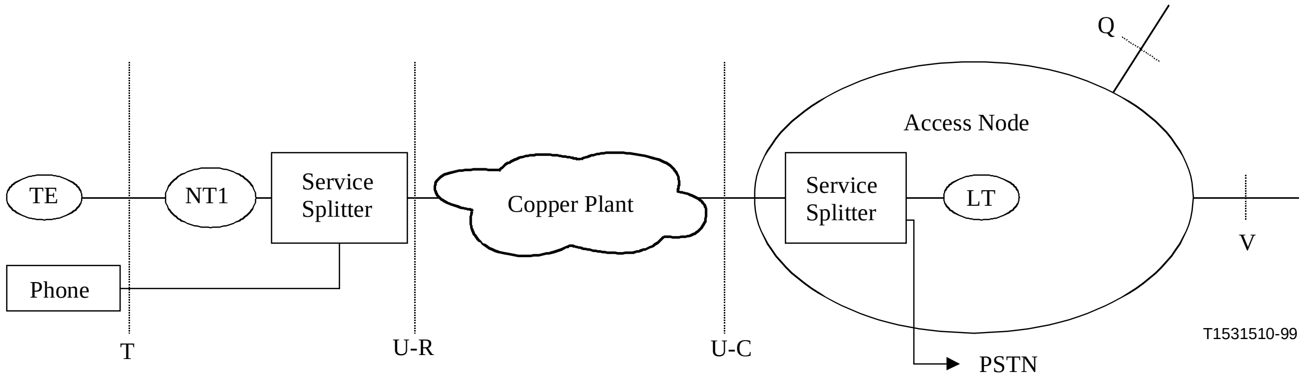


Figure 15/G.995.1 – G.992.1 data service presentation at the T interface

In the case of G.992.2, the above is true except that the Service Splitter between Copper Plant and the NT1 is not present as shown in Figure 16.

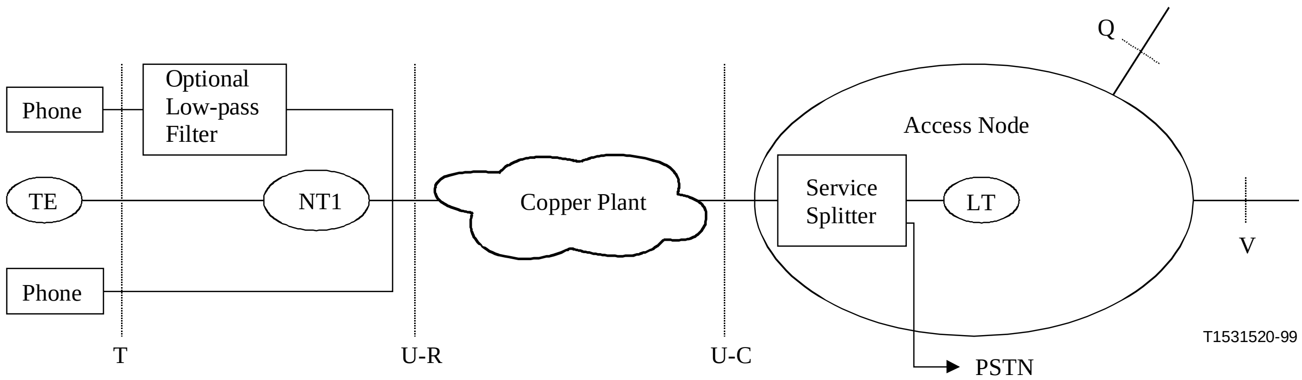


Figure 16/G.995.1 – G.992.2 data service presentation at the T interface

7.2.2 Service Presentation at the U interface

Service Presentation at a U interface is shown in Figure 17.

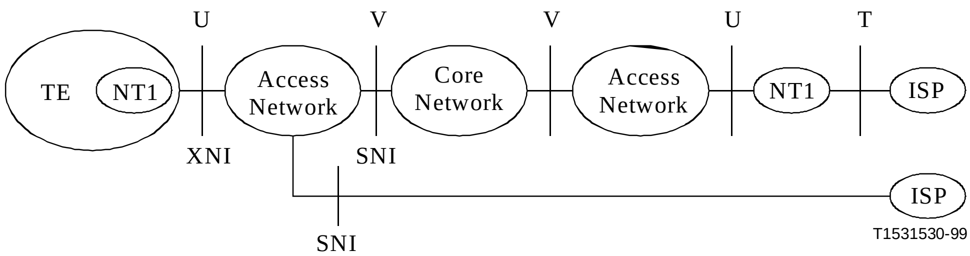


Figure 17/G.995.1 – Data service presentation at the U interface

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 18 depicts an integrated NT1 model for G.992.1.

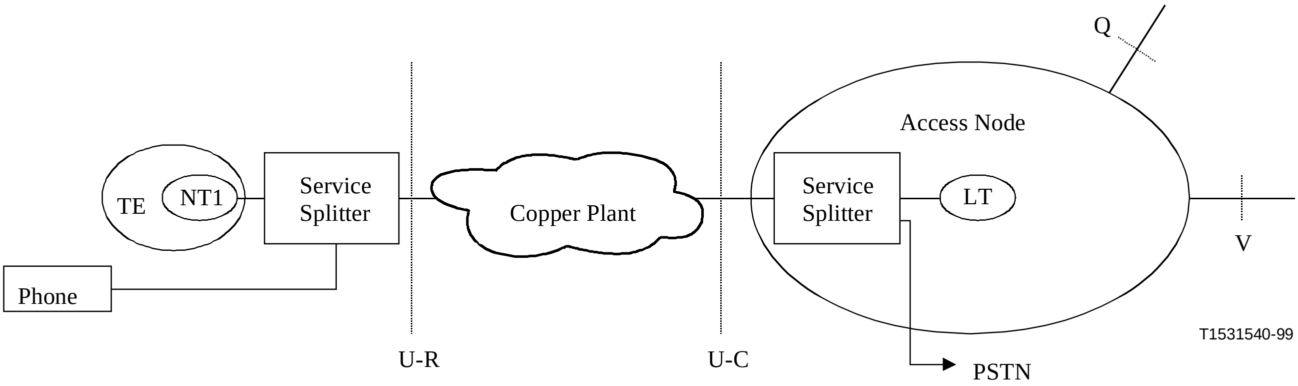


Figure 18/G.995.1 – G.992.1 data service presentation at the U interface

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 19 depicts an integrated NT1 model for G.992.2.

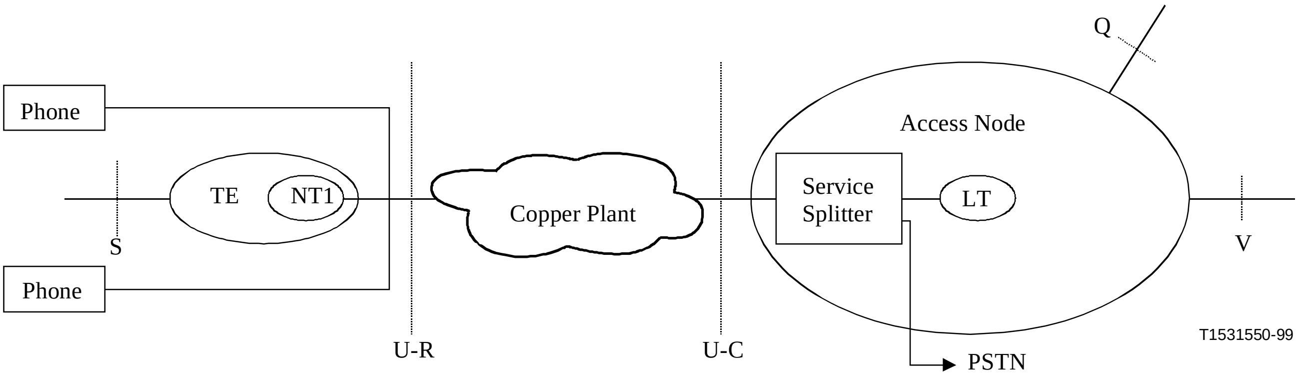


Figure 19/G.995.1 – G.992.2 data service presentation at the U interface

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.

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