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

Access networks – In premises networks

Mitigation of interference between DSL and PLC

Recommendation ITU-T G.9977

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Recommendation ITU-T G.9977

Mitigation of interference between DSL and PLC

Summary

Recommendation ITU-T G.9977 specifies functionality of a mechanism to mitigate interference caused by in-home powerline communication (PLC) devices to an x-type digital subscriber line (xDSL) network termination (implementing transceivers in compliance with ITU-T Recommendations such as ITU-T G.993.2 and ITU-T G.9701). This Recommendation addresses various in-home network types and wiring topologies.

History

Edition	Recommendation	Approval	Study Group	Unique ID*
1.0	ITU-T G.9977	2016-02-26	15	11.1002/1000/12548

* To access the Recommendation, type the URL http://handle.itu.int/ in the address field of your web browser, followed by the Recommendation's unique ID. For example, http://handle.itu.int/11.1002/1000/11830-en.

FOREWORD

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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, implementers are cautioned that this may not represent the latest information and are therefore strongly urged to consult the TSB patent database at http://www.itu.int/ITU-T/ipr/.

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1 Scope

This Recommendation specifies functionality of a mechanism to mitigate interference caused by in-home powerline communication (PLC) devices to an x-type digital subscriber line (xDSL) network termination (implementing transceivers in compliance with ITU-T Recommendations such as [ITU-T G.993.2] and [ITU-T G.9701]). This Recommendation addresses various in-home network types and wiring topologies.

The coordination of both the xDSL access network and in-home PLC network is facilitated by an arbitration function (AF), in order to reduce interference and optimize the performance of both networks and meet the throughput requirements to the end customer across both networks, by appropriately configuring relevant parameters of PLC devices and xDSL network termination (NT) based on a coordination policy that is usually determined and provided by the operator.

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; 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. The reference to a document within this Recommendation does not give it, as a stand-alone document, the status of a Recommendation.

[ITU-T G.993.2] Recommendation ITU-T G.993.2 (2015), *Very high speed digital subscriber line transceivers 2 (VDSL2)*.

[ITU-T G.994.1] Recommendation ITU-T G.994.1 (2012), *Handshake procedures for digital subscriber line transceivers*.

[ITU-T G.997.1] Recommendation ITU-T G.997.1 (2012), *Physical layer management for digital subscriber line transceivers*.

[ITU-T G.997.2] Recommendation ITU-T G.997.2 (2015), *Physical layer management for G.fast transceivers*.

[ITU-T G.998.4] Recommendation ITU-T G.998.4 (2015), *Improved impulse noise protection for digital subscriber line (DSL) transceivers*.

[ITU-T G.9701] Recommendation ITU-T G.9701 (2014), *Fast access to subscriber terminals (G.fast) – Physical layer specification*.

[ITU-T G.9961] Recommendation ITU-T G.9961 (2015), *Unified high-speed wireline-based home networking transceivers – Data link layer specification*.

[ITU-T G.9962] Recommendation ITU-T G.9962 (2014), *Unified high-speed wire-line based home networking transceivers – Management specification*.

[ITU-T G.9979] Recommendation ITU-T G.9979 (2014), *Implementation of the generic mechanism in the IEEE 1905.1a-2014 Standard to include applicable ITU-T Recommendations*.

[IEEE 802.3] IEEE Std 802.3-2008, *IEEE Standard for Information technology – Telecommunications and information exchange between systems – Local and metropolitan area networks--Specific requirements Part 3: Carrier Sense Multiple Access with Collision Detection (CSMA/CD) Access Method and Physical Layer Specifications*.

[IEEE 1905.1] IEEE Std 1905.1-2013, *IEEE Standard for a Convergent Digital Home Network for Heterogeneous Technologies*.

[IEEE 1905.1a] IEEE Std 1905.1a-2014, *IEEE Standard for a Convergent Digital Home Network for Heterogeneous Technologies, Amendment 1, Support of New MAC/PHYs and Enhancements*.

3 Definitions

3.1 Terms defined elsewhere

None.

3.2 Terms defined in this Recommendation

This Recommendation defines the following terms:

3.2.1 arbitration function (AF): Entity that facilitates coordination between the xDSL and PLC systems in order to reduce interference on the basis of coordination policy, by appropriately configuring parameters of the xDSL and PLC devices. The coordination policy is expected to be determined and provided by the operator. In the case where such a policy is not determined or provided by the operator, the AF works according to a predefined default policy.

3.2.2 centralized control mode (CCM): A mode of a PLC network in which devices do not exchange information directly with the AF but via the PLC-NC.

3.2.3 distributed control mode (DCM): A mode of a PLC network in which PLC devices exchange information directly with the AF.

3.2.4 IEEE 1905: Devices implementing the abstraction layer specified in [IEEE 1905.1] and [IEEE 1905.1a]. In this Recommendation, the term IEEE 1905 is used to refer to the technology, the term IEEE 1905.1 is used to refer to the base standard [IEEE 1905.1] and the term [IEEE 1905.1a] is used to refer to the Amendment [IEEE 1905.1a].

3.2.5 power line communication (PLC) devices: Components of a PLC network that are intended to be connected to each other via power line and that communicate with each other using appropriate coding and modulation methods.

3.2.6 PLC network: A set of interconnected PLC devices that communicate with each other. The in-home PLC network uses in-home power line wiring as the transmission medium.

3.2.7 PLC network controller (PLC-NC): In CCM, one of the PLC devices in the PLC network that is assigned to control all other devices in the network.

3.2.8 xDSL access network: A network that comprises customer premises equipment and the exchange (or cabinet or DP) equipment implementing xDSL functionality that is compliant with at least one of the ITU-T Recommendations of the ITU-T G.99x or ITU-T G.970x-series.

3.2.9 xDSL network termination (NT): A customer premises equipment implementing xDSL transceiver and associated functionality that is compliant with at least one of the ITU-T Recommendations of the ITU-T G.99x or ITU-T G.970x-series.

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

ACS	Auto-Configuration Server
AF	Arbitration Function
AL	Abstraction Layer
CCM	Centralized Control Mode
CMDU	Control Message Data Unit
CO	Central Office
CO-MIB	Central Office-Management Information Base
CPE	Customer Premises Equipment
CWMP	CPE WAN Management Protocol
DCM	Distributed Control Mode
DLL	Data Link Layer
DP	Distribution Point
DPU-MIB	Distribution Point Unit Management Information Base
DPM	xDSL and PLC interference Mitigation
DPU	Distribution Point Unit
EMS	Element Management System
LAN	Local Area Network
MAC	Media Access Control
ME	Management Entity
NMS	Network Management System
NT	Network Termination
OLR	On-line Reconfiguration
PHY	Physical Layer
PLC	Powerline Communication
PLC-NC	PLC Network Controller
PSD	Power Spectral Density
QLN	Quiet Line Noise
QoS	Quality of Service
RGW	Residential Gateway
SAVN	Showtime-Adaptive Virtual Noise
SNR	Signal-to-Noise Ratio
SNRM	Signal-to-Noise Ratio Margin
TLV	Type, Length and Value
WAN	Wide Area Network
xDSL	x-type Digital Subscriber Line

5 Conventions

None.

6 Reference models

6.1 Generalized reference model

The generalized reference model addressing the interference mitigation mechanism is presented in Figure 6-1. The arbitration function (AF) facilitates resource allocation between the powerline communication (PLC) network and the xDSL NT. The communication between the PLC and the AF and between the xDSL NT and the AF are defined over logical interfaces Φ_P and Φ_C, respectively, while the operator may control the AF via the logical interface Φ_A. The operator's control on AF, as well as other elements of the customer premises network, is usually implemented via the network management system (NMS). In the case where operator control of the AF is not established for any reason, the AF may use its internal arbitration and coexistence policies to facilitate xDSL-PLC coordination (e.g., the default policies or those downloaded during previous session). This includes the following cases:

– xDSL line is inactive and thus no connection to the NMS is available;

– xDSL line is active, but no connection to the NMS is established or NMS is unavailable.

In these cases the AF should be able to function without operator control.

NOTE – To support the coexistence mechanism during the time when operator control is not available, the AF may (either partially or entirely) reside inside the residential gateway (RGW).

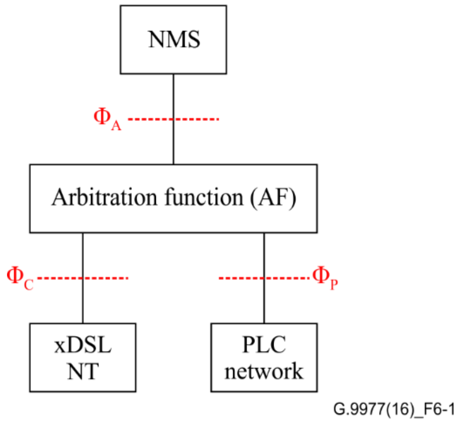

Figure 6-1 – Generalized reference model

An application of the generalized reference model showing more details of the xDSL and the PLC network is presented in Figure 6-2.

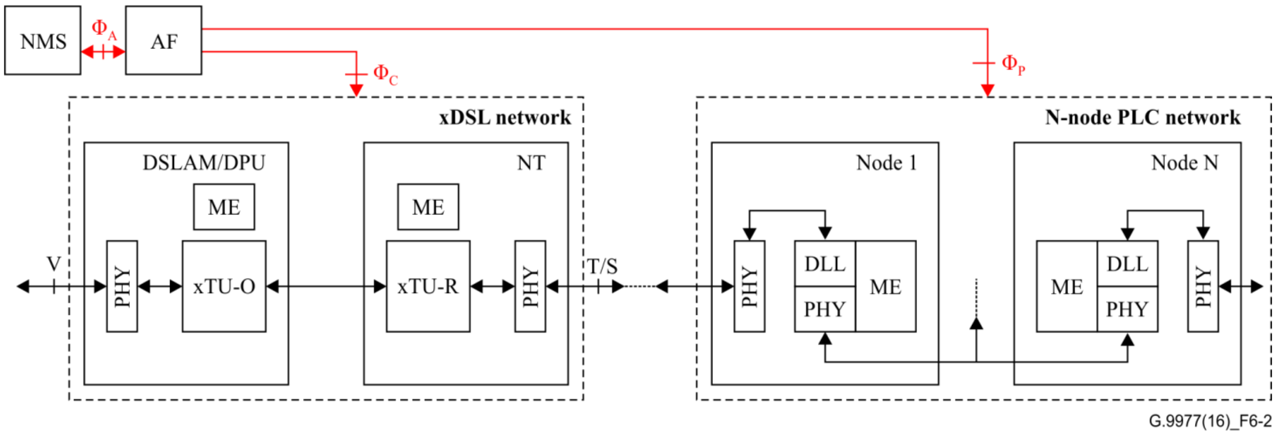

Figure 6-2 – An application of the generalized reference model

The first example of a system functional model corresponding to the reference models in Figure 6-1 and Figure 6-2 is presented in Figure 6-3. It represents the case in which the AF resides entirely in the RGW. To address a generic case of user installation, both the PLC network and the xDSL NT are connected to the RGW using 802.3 local area network (LAN) interfaces (RGW is a stand-alone device that incorporates AF).

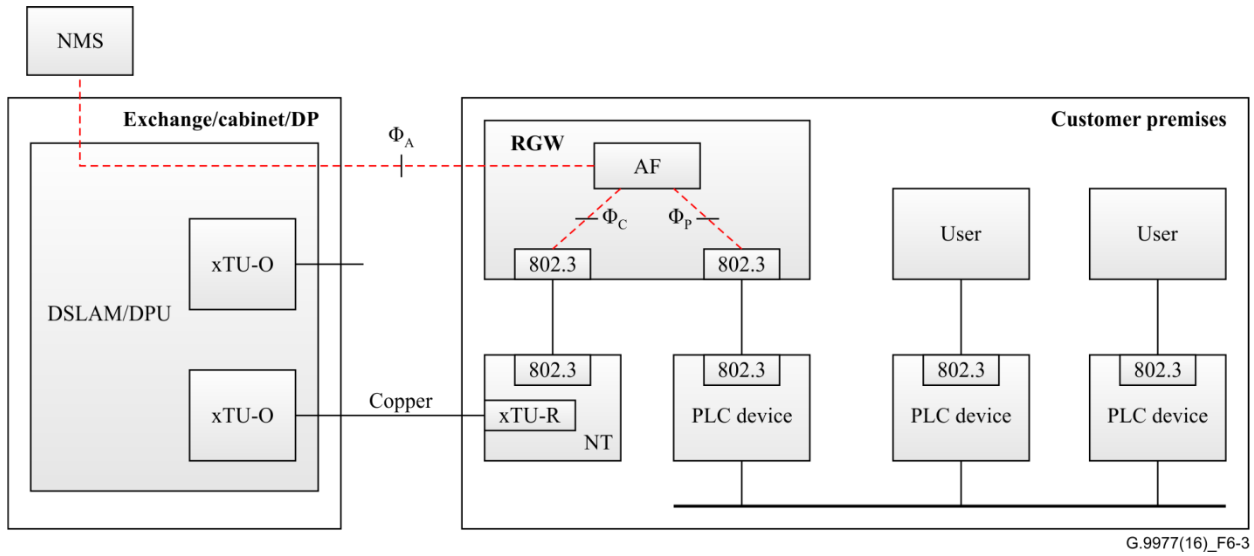

Figure 6-3 – An example of a system functional model for the case when the xDSL access network and PLC network are associated with the same operator network (AF resides inside the RGW)

A second example of a system functional model corresponding to the reference models in Figure 6-1 and Figure 6-2 is presented in Figure 6-4. It represents the case in which the AF resides entirely in the RGW and a PLC device is also part of the RGW. The xDSL NT is connected to the RGW using 802.3 LAN interfaces.

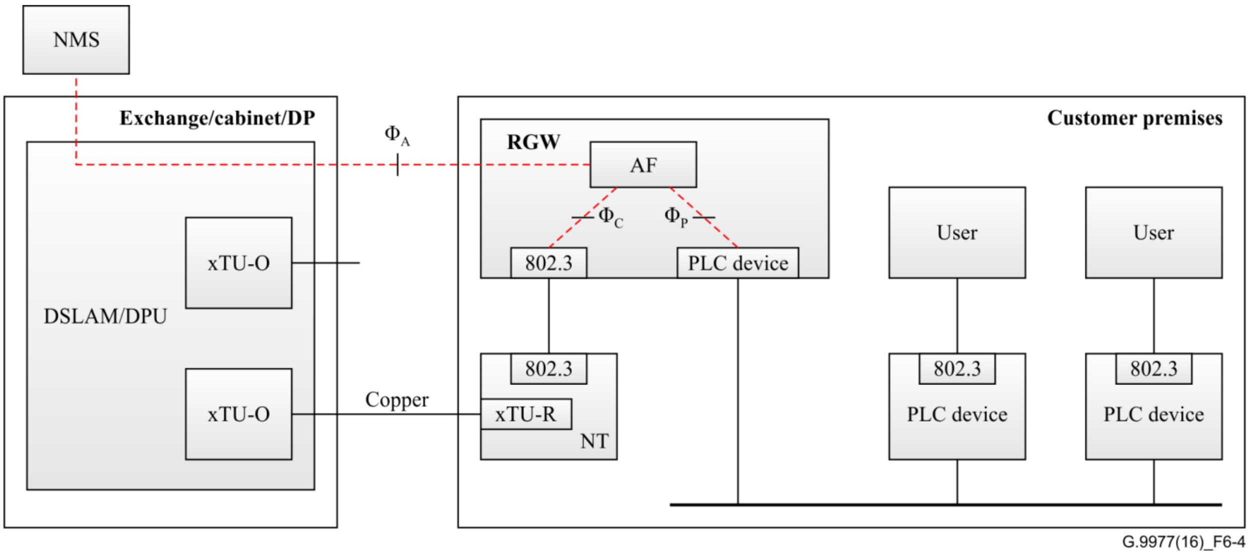

Figure 6-4 – An example of a system functional model for the case when the xDSL access network and PLC network are associated with the same operator network (AF and a PLC device reside inside the RGW)

A third example of a system functional model corresponding to the reference models in Figure 6-1 and Figure 6-2 is presented in Figure 6-5. It represents the case in which the AF resides entirely in the RGW and the xDSL NT is also part of the RGW. The PLC network is connected to the RGW using 802.3 LAN interfaces. In this case, the NT functionalities are integrated into the RGW.

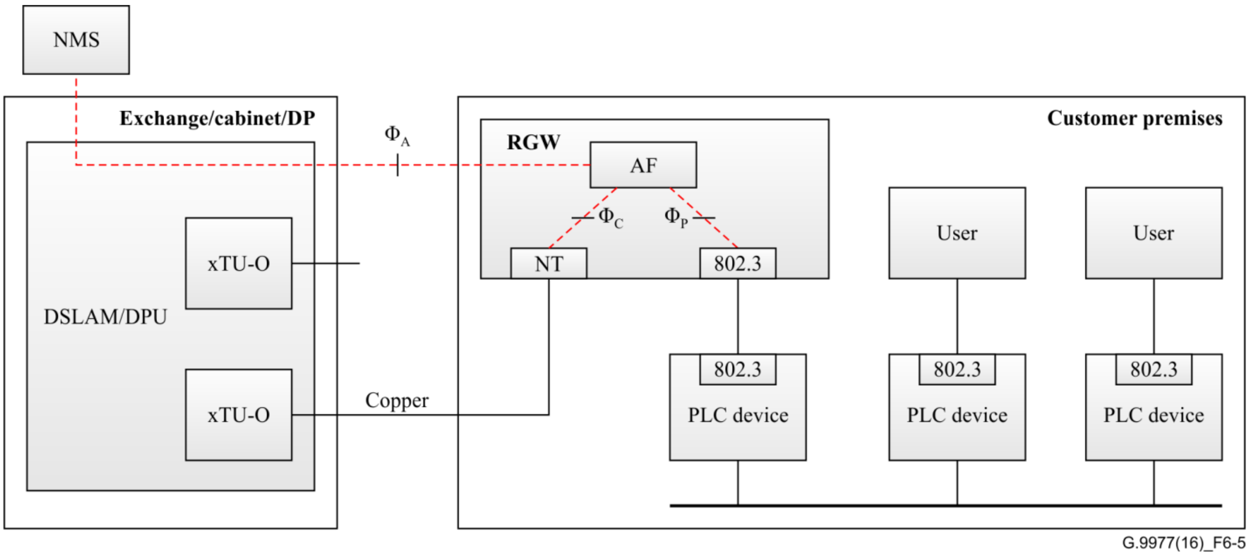

Figure 6-5 – An example of a system functional model for the case when the xDSL access network and PLC network are associated with the same operator network (AF and xDSL NT reside inside the RGW)

A fourth example is the case in which both the xDSL NT and PLC device are implemented as a part of the RGW is presented in Figure 6-6. In this case, the xDSL NT functionalities are integrated into the RGW.

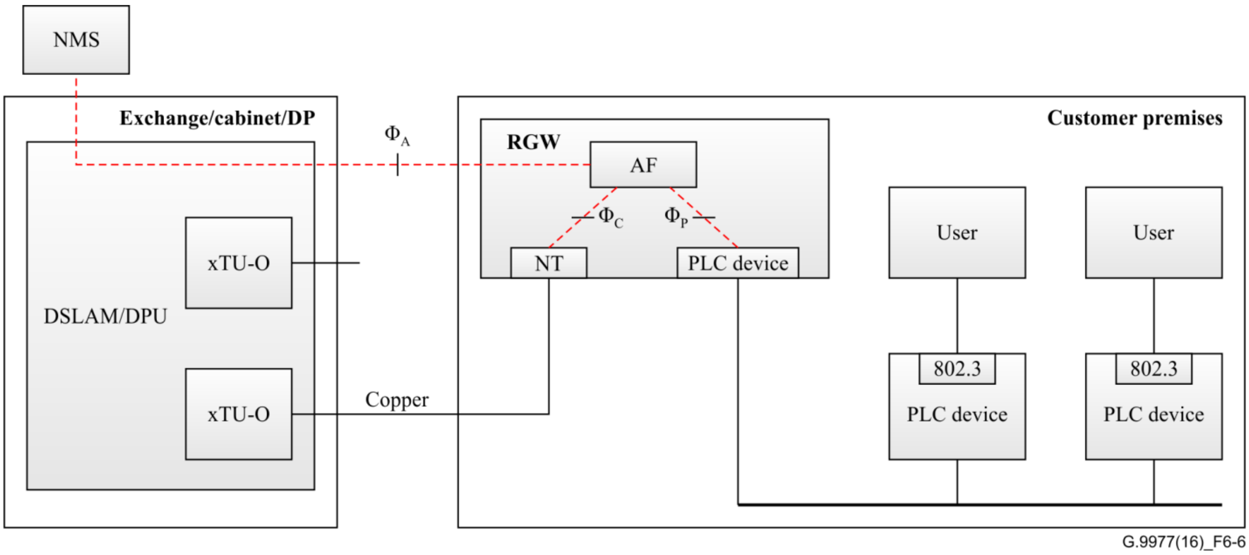

Figure 6-6 – An example of a system functional model for the case when the xDSL access network and PLC network are associated with the same operator network (AF, xDSL NT and a PLC device reside inside the RGW)

A fifth example of a system functional model corresponding to the reference models in Figure 6-1 and Figure 6-2 is presented in Figure 6-7. It represents the case in which the AF resides in the broadband network, remote from the customer premises. The AF implementation may be virtualized, hosted in the cloud, be a part of NMS or element management system (EMS) functionality, etc.

NOTE – A network-located AF may use [ITU-T G.997.1] and [ITU-T G.997.2] for much of the functionality of the Φ_C interface, and may use CPE WAN management protocol (CWMP) [b-BBF TR-069], [b-BBF TR-181] for much of the functionality of the Φ_P interface. For example, for xDSL, SNR(f) may be read across the network using [ITU-T G.997.1] and [ITU-T G.997.2] and the PLC PSD shaping mask (PSM) [ITU-T G.9961] may be configured across the network using CWMP.

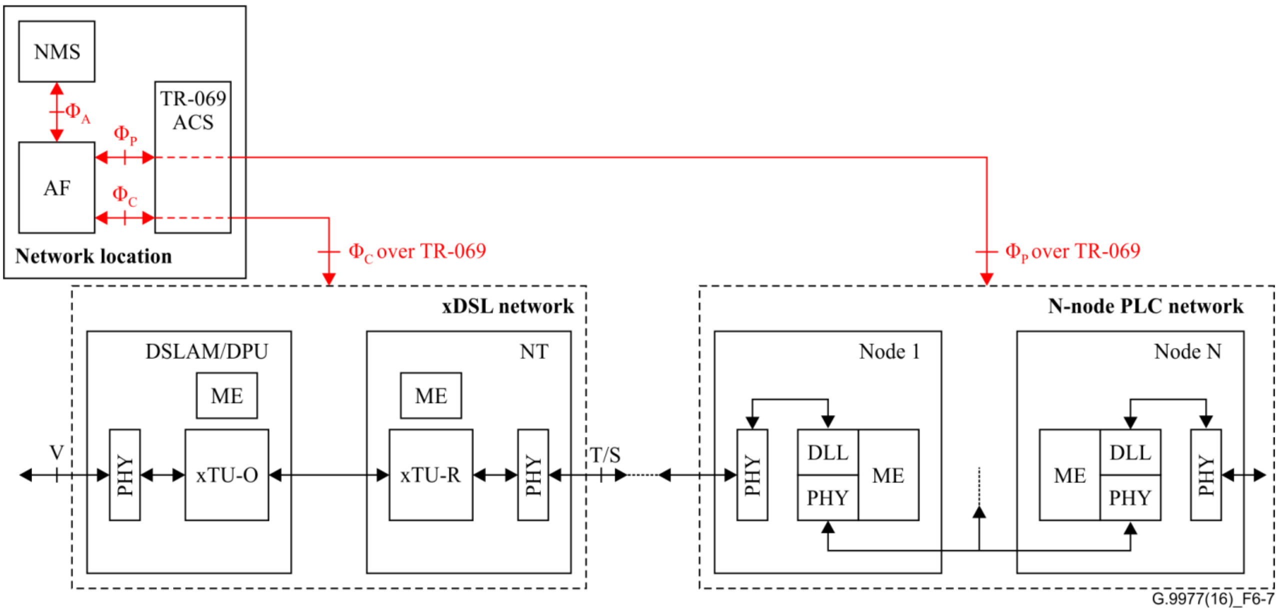

Figure 6-7 – An example of a system functional model for the case when the AF is located in the broadband network

In Figure 6-7 the AF communicates to the xDSL NT and the PLC devices using the TR-069 protocol [b-BBF TR-069]. This is possible when both the xDSL NT and the PLC device(s) support TR-069.

In the distributed mode all the PLC devices need to support TR-069 in this example. In the centralized mode, at least one PLC device needs to support TR-069 [ITU-T G.9962].

The TR-069 protocol is defined such that customer premises equipment (CPE) (i.e., xDSL NT, RGW and PLC devices) communicates with an auto-configuration server (ACS) using corresponding data models [b-BBF TR-181]. The ACS encapsulates AF primitives passed across the Φ_P and Φ_C interfaces, respectively, into corresponding TR-069 data models and passes them transparently, so that the primitives sent from the AF to the ACS are passed to the xDSL NT and the PLC devices, and the primitives sent from the xDSL NT and the PLC devices are passed from the ACS to the AF. In the case where TR-069 connectivity is lost (e.g., due to loss of broadband connectivity), a local AF using a predefined default policy should be invoked. The network-located AF and the ACS could be part of the same system.

6.2 Details of the interfaces

The defined interfaces of the generalized reference model (Φ_C, Φ_P, and Φ_A, Figure 6-1) are logical, which means:

– the interface is defined by sets of primitives to be exchanged (see clause 7.5);

– no L1-layer protocol (physical signals) is specified.

The Φ_C, Φ_P, and Φ_A interface primitives are exchanged by using protocols specified in this Recommendation and messages with transmission formats defined in Annex A.

7 General approach

7.1 Interference mitigation mechanism

7.1.1 Overview

The coexistence mechanism defined in this Recommendation provides mitigation of the PLC interference into xDSL line and mutual optimization of the performance of the xDSL line and PLC network. It facilitates normal initialization and stable steady-state operation of a xDSL line within the quality of service (QoS) requirements defined by the operator, in the presence of PLC and endeavours to provide minimal performance degradation for PLC devices and seamless PLC operation (i.e., no service disruption during xDSL initialization).

The mitigation of PLC interference is accomplished by an AF implementing the following AF device discovery, AF coordination, and AF policy functionalities:

AF device discovery functionality includes the following:

- discovery of the media access control (MAC) addresses of the xDSL NT and PLC devices;
- identification of the type and status of each device;
- monitoring of device presence and status changes.

AF coordination functionality includes the following:

- establish communication with PLC devices and xDSL NT;
- coordinate interference measurement, i.e., trigger measurement modes and retrieve results;
- collect interference data and report it to the AF;
- coordinate start-up procedure of xDSL and PLC devices;
- coordinate parameter reconfiguration of PLC devices and xDSL to mitigate interference based on AF policy.

AF policy functionality includes the following: The AF implements a provided coordination policy from an operator. In the case where such a policy is not provided or available the AF works according to a predefined (default) policy. The coordination policy may be provided via a static definition (e.g., autonomously implemented within the unit embedding the AF) or via a dynamic definition using a remote management protocol (e.g., [b-BBF TR-069]).

Operator control of the AF and the applied coexistence policies prevent conflicting goals that PLC devices and xDSL NT may have, while the overall goal is to optimize the overall performance.

The coexistence mechanism defined in this Recommendation facilitates operation for the following cases:

- when xDSL line is inactive – the PLC devices should be allowed to use all network resources;
- when xDSL line starts initialization – the PLC network and/or devices should facilitate xDSL initialization such that the QoS targets defined by the operator are achieved at the transition to showtime;
- when xDSL line is active – the xDSL line in showtime should maintain the QoS targets set by the operator and should not be disrupted by reconfiguration of the PLC network (e.g., when new PLC devices are added to the network or PLC devices are moved to another location).

7.1.2 Scenarios

This clause provides an overview of the operation of the xDSL access system and PLC network under different coexistence scenarios. The details of the mechanisms that are used are explained in clauses 7.2, 7.3 and 7.4.

7.1.2.1 Scenario #1: PLC is active while xDSL is OFF

In this scenario no broadband service and no management from the operator is available. The PLC network is standalone, operates autonomously and no additional limits on transmit power spectral density (PSD) or other parameters of PLC devices related to coexistence apply.

In order to monitor the status of the PLC network and xDSL NT, the AF shall poll those from time to time using STATUS.request primitives over Φ_P and Φ_C interfaces, respectively (see clause 7.3). The xDSL NT and the applicable PLC devices shall reply with STATUS.confirm primitives, respectively, indicating status updates whenever polled by the AF. If the STATUS.confirm primitives from the xDSL NT are not received, the AF shall monitor discovery messages from the xDSL NT to detect when it turns on.

7.1.2.2 Scenario #2: xDSL line turns active in presence of an active PLC network

NOTE 1 – During initialization, the xDSL NT exchanges special training signals with its peer installed at an exchange, a cabinet, or a distribution point (DP). The xDSL NT is effectively disconnected from the exchange, cabinet, or DP; no broadband service and no management communications are available. In this state the AF can set parameters of the PLC network so that the necessary conditions for the xDSL line to initialize with QoS parameters required by the operator for broadband connection (based on SLA agreement with the customer) are facilitated. At the end of the initialization xDSL line transitions to showtime, allowing the operator to deliver broadband services and remotely manage the RGW, the AF and the PLC network.

The xDSL NT indicates to the AF that it starts initialization by sending a STATUS.ind primitive or indicating start of initialization in STATUS.confirm primitive after receiving a STATUS.request primitive from the AF across Φ_C interface.

Upon reception of the xDSL NT indication of initialization, the AF may send to the PLC network a CONFIGURE.request defining a reduced PSD setting if it expects possible initialization issues, setting the PLC devices in a state in which they do not disturb the initialization process. Upon reception of a CONFIGURE.request primitive, the PLC network shall reply to the AF by sending a primitive CONFIGURE.confirm, which confirms that the requested PSD is applied to all relevant PLC devices.

NOTE 2 – This does not imply that the transmit PSD of all PLC devices have to be reduced from the nominal PSD levels inside the frequency bands assigned for the xDSL downstream transmission. Only those PLC devices that are identified by the AF as potential cause of xDSL NT initialization failure (e.g., newly installed devices or re-positioned devices, or those devices whose PSD was reduced during the previous xDSL session) may be requested to reduce their transmit PSD by an AF-determined value.

Upon reception of CONFIGURE.confirm primitive from the PLC, the AF may send to the xDSL NT a CONFIGURE.request primitive indicating that the xDSL NT may safely start the initialization (including its noise-sensitive part). The xDSL NT shall reply to the AF by sending the CONFIGURE.confirm primitive that acknowledges the request from the AF. After the xDSL line completes the initialization, it transitions to showtime.

NOTE 3 – The ITU-T G.994.1 handshake is robust enough to handle interference from a PLC with nominal transmit PSD levels. Therefore, the xDSL NT may start the ITU-T G.994.1 handshake before it receives a confirmation that PLC applied the reduced PSD limits.

NOTE 4 – If the AF over-restricts the PSD of the PLC devices during xDSL initialization, the xDSL line may initialize with transmission parameters that are established for the case of very low noise interference, which is obviously suboptimal. In addition, some PLC devices may perform insufficiently.

7.1.2.3 Scenario #3: Steady-state operation of xDSL in the presence of a PLC network

After xDSL NT completes initialization and reaches showtime, the broadband link is established and all operators' external management tools (NMS and potentially others) become available to control the AF. Now the AF, possibly under control of the operator, shall coordinate operation of both the xDSL and the PLC and can maximize the overall performance of the customer connection, using AF arbitration policies established by the operator. The measurements of interference between the PLC and the xDSL line is run for all relevant PLC devices to optimize their transmit PSDs, as specified in clause 7.3. Per results of the measurements, the AF reconfigures the PLC devices and the xDSL line parameters with the aim of optimizing performance by minimizing the surplus signal-to-noise ratio (SNR) margin, thereby allowing higher transmit PSDs for some of the PLC devices.

An example of a timeline showing initialization, transition to showtime and operation during showtime is presented in Figure 7-1.

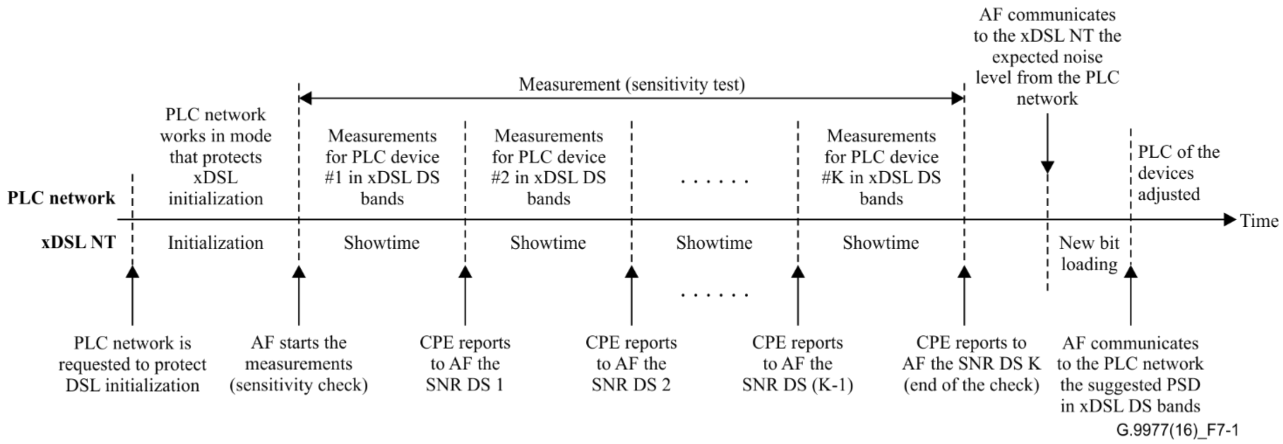

Figure 7-1 – Example of a timeline for xDSL operation in presence of PLC

The xDSL NT indicates transition into showtime to the AF by sending STATUS.ind primitive or by indicating transition into showtime in STATUS.confirm primitive across Φ_C interface. Upon reception of the corresponding STATUS.ind primitive from the xDSL NT, the AF may start the interference measurements between the PLC and the xDSL NT. Further, interference measurements between the PLC and the xDSL NT can be routinely performed during the xDSL NT showtime as specified in clause 7.3.

For a measurement of the impact of PLC device(s) into xDSL, the AF sends a MEASURE-MODE.request primitive indicating that the particular PLC device(s) needs to be measured. The PLC device in distributed control mode (DCM) or the PLC network controller (PLC-NC) in centralized control mode (CCM) replies by a MEASURE-MODE.confirm primitive indicating the availability of the device(s) to be measured. In the case of a positive reply, the requested PLC device starts transmission associated with the measurement with the delay indicated in the MEASURE-MODE.confirm response (see clause 7.3.2). In the case of a negative reply, the AF may retransmit the request.

NOTE 1 – Messages conveying primitives can be sent directly to the PLC device in DCM or to the PLC-NC in CCM. They may also be relayed via other PLC device(s) in the network.

Upon a positive reply from the PLC device, the AF informs the xDSL NT of the measurement by sending the MEASURE.request primitive to the xDSL NT. The xDSL NT replies by sending a MEASURE.confirm primitive and starts the measurement procedure by measuring the SNR (quiet line noise (QLN)) at the receiver.

In order to obtain the measurement result, the AF sends the xDSL NT a RESULTS.request primitive. The xDSL NT replies by sending a RESULTS.confirm primitive that contains the results of the measurement primitive.

After AF obtains the measurement result, the AF may send another MEASURE.request primitive to the xDSL NT to perform another measurement. The total number of measurements in the set depends on the PLC topology and the xDSL type and is determined by the AF. Once sufficient measurement data is obtained from the xDSL NT, the AF requests the PLC device to complete the measurement (see clause 7.3.2).

After one or more measurements the AF may reconfigure the PLC and/or the xDSL NT according to the measurement results. For this, the AF sends to the xDSL NT, or to PLC, or to both, a CONFIGURE.request primitive. The responding entity (xDSL NT or PLC or both) replies by CONFIGURE.confirm primitive and implements the requested re-configuration.

NOTE 2 – The noise generated by the PLC is non-stationary by nature because any particular PLC device may start and stop transmitting at times that are not predictable for the xDSL NT; furthermore, different PLC devices create different interference into the xDSL NT.To mitigate the performance instability caused by non-stationary noise, xDSL NT should apply a substantial SNR margin (SNRM), or showtime-adaptive virtual noise (SAVN), or similar protection methods.

7.1.2.4 Scenario #4: PLC devices initializing in presence of an active xDSL network

The procedures described in scenario #3 allow configuration of the PLC devices and the xDSL line so that the throughput of the overall path is maximized based on operator policies. These policies may lead to a reduced PSD mask applied to some of the PLC devices and/or additional constraints to the xDSL NT.

During the steady-operation of the xDSL line, the topology of the PLC network may change due to new devices being incorporated into the PLC network or existing PLC devices moved from one connection point to another one.

The AF may configure a "default PSD mask" to be applied to these PLC devices, for which a measurement process has not been possible yet using the CONFIGURE.request primitive.

In DCM, this "default PSD mask", if configured, shall be applied to each new PLC device for which interference is expected to be excessive (e.g., in the case where some other PLC devices of the network have been identified by the AF as potential sources of interference and a PSD limitation has been set). Upon reception of a CONFIGURE.request primitive requesting to set a "default PSD mask", the PLC device shall respond with a CONFIGURE.confirm primitive.

In CCM, this "default PSD mask", if configured, shall be applied by the PLC-NC to new PLC devices for which interference is expected to be excessive. Upon reception of a CONFIGURE.request primitive requesting to set a "default PSD mask", the PLC-NC shall respond with a CONFIGURE.confirm primitive. Furthermore, the PLC-NC provides configuration of all other PLC devices and responds to the AF, accordingly (see clause 7.4.2).

During short transient periods (e.g., device registration) new devices may use the PSD allowed by the regional regulation, even in the case where PLC interference is expected. This is tolerable providing that this behaviour lasts for less than 100 ms.

Whenever a new device is admitted to a PLC network, it shall announce its presence to the AF.

Upon discovering a new node in the PLC network, the AF, as described in scenario #2, may send to the PLC network a CONFIGURE.request primitive defining a reduced PSD for the newly joined device if it expects possible interference issues, setting the PLC device parameters so that it mitigates the disturbance to the xDSL link. Prior to that, the new device shall refrain from transmission, if possible, to eliminate potential interference. Furthermore, the AF may launch a measurement procedure for the new device. The results of the measurement procedure may lead to a reconfiguration of the xDSL line and the PLC device as described in scenario #3.

7.2 Device discovery

7.2.1 Overview

The discovery mechanism provides the AF, the xDSL NT and the PLC devices with a procedure to announce themselves and become aware of the existence of devices that are relevant for the coexistence procedure. The discovery mechanism provides the tools that:

- allow the xDSL NT and PLC network devices to announce their presence, address and main properties;
- allow the xDSL NT and PLC network devices to discover the AF;
- allow the AF to routinely monitor the status of the devices relevant for the interference mitigation procedure;
- allow the AF to be informed of new devices added to or leaving the PLC network.

The specified discovery mechanism addresses the operation of the PLC networks in both DCM and CCM.

7.2.2 Discovery of PLC devices

In case of DCM, the PLC devices shall broadcast a topology discovery message to indicate their presence at power on, upon transitions in the network topology and at least every 60 seconds, as defined in clause 8.2.1.1 of [IEEE 1905.1]. This allows the AF to discover PLC devices immediately upon power on or upon transitions in the network topology and monitor their presence in the network.

In case of CCM, the PLC-NC shall broadcast a topology discovery message to indicate its presence once it is active, upon transitions in the network topology and at least every 60 seconds, as defined in clause 8.2.1.1 of [IEEE 1905.1]. This allows the AF to discover the PLC-NC once it is active and other PLC devices once they register with the PLC-NC or upon transitions in the network topology and monitor their presence in the network.

PLC devices incorporating an IEEE 1901 interface for PLC are discovered via IEEE 1905 device information type known as type, length and value (TLV) contained in the topology discovery message, as defined in clause 6.4.5 of [IEEE 1905.1]. PLC devices incorporating any PLC interface not listed in Table 6-12 of [IEEE 1905.1] (e.g., ITU-T G.996x (G.hn) and Homeplug AV2) are discovered by the AF using IEEE 1905.1a generic physical layer (PHY) query/response procedure (see clause 8.2.3 of [IEEE 1905.1a]). In this latter case, the PLC interface is discovered via the generic PHY device information type TLV conveyed in the generic PHY response message received by the AF.

During the discovery procedure, PLC devices indicate whether IEEE 1905 is fully supported or not via DPM device identification (DPM-ID) TLV (see clause 7.2.5).

7.2.2.1 Exchange of status information

Upon reception of a broadcasted STATUS.request primitive, a PLC device shall reply to the AF with a STATUS.confirm primitive across the Φ_P interface, as defined in clause 7.6.5. If the PLC network operates in CCM, only the PLC-NC shall reply.

Whenever the status of a PLC device changes, this device shall inform the AF by sending the STATUS.ind primitive, as defined in clause 7.6.6. If the PLC network operates in CCM, only the PLC-NC shall send to the AF a STATUS.ind primitive on a new device joining or on a departing device, indicating devices that are currently part of the network and those that have been added to the network since the last status report.

Additionally, a device may indicate to the AF the suitability of starting a measurement process through the STATUS change type field of STATUS.ind primitive.

An AF may routinely request for update of the status of a PLC device by sending a STATUS.request primitive over the Φ_P interface, as defined in clause 7.6.4. Upon reception of a STATUS.request primitive, each PLC device shall respond with a STATUS.confirm primitive defined in clause 7.6.5, containing the required information (if the PLC network operates in CCM, only the PLC-NC reports the status of the entire network).

NOTE – PLC devices departing from the network operating in DCM may be identified by the absence of the STATUS.confirm response from the device.

7.2.3 Discovery of xDSL devices

The xDSL NT shall include at least the following IEEE 1905 discovery functionality:

- support of topology discovery message (clauses 6.3.1 and 8.2.1.1 of [IEEE 1905.1], with the value of the abstraction layer (AL) MAC address set equal to the xDSL NT MAC address if no separate AL MAC address is established);
- support of topology query messages (clauses 6.3.2 and 8.2.2.1 of [IEEE 1905.1]);
- support of topology response message (clauses 6.3.3 and 8.2.2.2 of [IEEE 1905.1], with indication of 0 bridging capabilities, 0 neighbour device TLVs; it shall use PowerOff TLV to indicate the power state of the xDSL interface).

NOTE – The list above defines the minimum required IEEE 1905 capabilities. If an xDSL NT implementation fully supports IEEE 1905, other relevant capabilities may be implemented as well.

If the xDSL NT indicates support of [IEEE 1905] in the topology discovery message and topology response message (see clause 7.2.5), the xDSL interface will be identified via generic PHY query/response messages and generic PHY device information type TLV defined in clause 8.2.3 of [IEEE 1905.1a] and otherwise, the xDSL NT properties will be discovered during the exchange of status information defined in clause 7.2.3.1. The generic PHY XML description document (clause 8.4 of [IEEE 1905.1a]) for xDSL interfaces is defined in clauses 7 and 8 of [ITU-T G.9979].

7.2.3.1 Exchange of status information

Upon reception of a broadcasted STATUS.request primitive, the xDSL NT shall reply to the AF with a STATUS.confirm primitive across the Φ_C interface, as defined in clause 7.6.2.

Whenever status of the xDSL NT has changed, it shall inform the AF on the new status by sending a STATUS.ind primitive, as described in clause 7.6.3. This message contains the new status of the xDSL NT and associated parameters since the last status report.

An AF may routinely request for update of the status of the xDSL NT by sending a STATUS.request primitive over the Φ_C interface, as defined in clause 7.6.1. The xDSL NT shall respond with a STATUS.confirm primitive defined in clause 7.6.2, containing the required information.

NOTE – Absence of a STATUS.confirm response is considered by the AF as "no xDSL NT compliant to this Recommendation is present".

7.2.4 Discovery of AF function

The xDSL NT and PLC network devices discover the AF by the corresponding indication in the DPM-ID TLV (DeviceInfoField) communicated in the topology query messages (see clause 7.2.5, Table 7-1). The MAC address of the AF is identified as it is carried by the SA field of the L2 protocol format of the topology query message (see Annex A).

7.2.4.1 Exchange the status information

AF may routinely announce itself by broadcasting the STATUS.request primitive defined in clause 7.6.1 to the xDSL NT, or as defined in clause 7.6.4 to PLC-NC or to all PLC devices, or both.

7.2.5 ITU-T DPM device identification

Devices implementing this Recommendation shall send an additional vendor specific DPM device identification (DPM-ID) TLV in the topology discovery, topology query, topology response and generic PHY response messages to indicate implementation of this Recommendation and/or [IEEE 1905]. The format of DPM-ID TLV is presented in Table 7-1.

Table 7-1 – DPM device identification (DPM-ID) TLV

Field	Length	Value range	Description
TLV-Type	1 byte	$0B_{16}$	Vendor specific TLV
TLV-Length	2 bytes	0006_{16} – $FFFF_{16}$	Total number of bytes in TLV-Value field
TLV-Value	3 bytes	$0019A7_{16}$	ITU-T OUI (the 24-bit globally unique IEEE-SA assigned value for ITU-T)
	1 byte	01_{16}	ITU-T TLV subtype DPM-ID corresponding to ITU-T G.9977. It shall be fixed to the value 01_{16}.
	2 bytes	0000_{16}	OPCODE
	1 byte	00_{16} – FF_{16}	Support of IEEE 1905: 00_{16}: IEEE 1905 is not supported 01_{16}: IEEE 1905 is supported 02_{16} – FF_{16}: Reserved by ITU-T
	Variable	See Table 7-3	DeviceEntry corresponding to the device sending the TLV (see Table 7-3)

In the case of CCM, the PLC-NC may include an additional vendor specific device status (DS) TLV in the topology response and generic PHY response messages that allows it to indicate the MAC addresses corresponding to the devices of the PLC network it is controlling. The TLV is presented in Table 7-2 and the DeviceEntry field format is presented in Table 7-3.

Table 7-2 – Device status (DS) TLV

Field	Length	Value range	Description
TLV-Type	1 byte	$0B_{16}$	Vendor specific TLV
TLV-Length	2 bytes	0006_{16} – $FFFF_{16}$	Total number of bytes in TLV-Value field
TLV-Value	3 bytes	$0019A7_{16}$	ITU-T OUI (the 24-bit globally unique IEEE-SA assigned value for ITU-T)

Table 7-2 – Device status (DS) TLV

Field	Length	Value range	Description
	1 byte	01_{16}	ITU-T TLV subtype DPM-ID corresponding to ITU-T G.9977. It shall be fixed to the value 01_{16}.
	2 bytes	0001_{16}	OPCODE
	1 byte	Variable	Number (N) of devices that are in the PLC network
	8 bytes	Variable	Entry corresponding to the first device of the PLC network being reported. It shall be formatted as shown in Table 7-3.
	…	…	…
	8 bytes	Variable	Entry corresponding to the N-th device of the PLC network being reported. It shall be formatted as shown in Table 7-3.

Table 7-3 – DeviceEntry field format

Payload field	Octet number	Field size (in bytes)	Description
MACAddress	1-6	6	MAC address of the device being reported
DeviceInfoField	7-8	2	Bit map representing information related to the device being reported. Bit 0 corresponds to the LSB. Bit 0: If set to one, it indicates that the device being reported has been incorporated into the PLC network since the last report. Zero otherwise Bit 1: If set to one, it indicates that the device is a PLC-NC. Zero otherwise Bit 2: If set to one, it indicates that the device is in sleep mode and is not able to transmit. Bit 3: If set to one, it indicates that the device is an AF. Zero otherwise. Bit 4: If set to one, it indicates that the device is an ITU-T G.993.2 NT. Zero otherwise. Bit 5: If set to one, it indicates that the device is an ITU-T G.9701 NT. Zero otherwise. Bit 6: If set to one, it indicates that the device supports linear interpolation of PSD. Zero otherwise.
Maximum Number of PSD Bands	9	1	Maximum number of PSD bands that the device supports in the range from 8 to 32
Minimum PSD Band Size	10-13	4	Minimum width for PSD band configuration the device supports in Hz, represented as an unsigned integer
NOTE – Other values are reserved by ITU-T.			

7.3 Device measurement

7.3.1 Overview

The AF coordinates the measurement of the interference between xDSL and PLC network devices. To do this, the AF may request corresponding time windows. As a result of these measurement procedures, the AF can obtain measurement data and use it to facilitate coexistence between xDSL NT and PLC network devices and optimize end-to-end throughput. The defined measurement mechanism provides the tools that:

- allow the AF to initiate a measurement procedure that evaluates the impact of transmission of each PLC device on the xDSL access system;
- allow the AF to retrieve the measurement data (measurement results) from xDSL NT.

A measurement procedure that evaluates the impact of xDSL transmission on the PLC devices is for further study.

7.3.2 Measurement of impact from PLC devices into xDSL

Whenever the AF identifies that a measurement of the impact of PLC network devices on xDSL NT is necessary, it shall send a MEASURE-MODE.request primitive over the Φ_P interface, as defined in clause 7.6.11, indicating to particular PLC device(s) that need to be measured during a measurement period (T_1) specified in the MEASURE-MODE.request primitive.

Upon reception of the MEASURE-MODE.request primitive, the PLC device in DCM or the PLC-NC in CCM shall respond with a MEASURE-MODE.confirm primitive as defined in clause 7.6.12, indicating either the availability of the device(s) to be measured to perform the measurement or its request to postpone the measurement. The device (PLC-NC in case of CCM) also indicates the delay to start the measurement period after transmission of MEASURE-MODE.confirm primitive.

The AF may request one or more PLC devices to stop transmitting during the measurement period (i.e., the device stays silent except for the transmission of mandatory PLC signals like ACK, MAP, Beacon, etc.). Also, the AF may request one or more PLC devices to transmit continuously during the measurement period. In this case the requested PLC device shall maximize its transmission time (a best effort to increase the time of continuous transmission) and transmit a signal that is representative of the signal that would be transmitted during normal operation (e.g., the signals used for channel estimation or transmitting information). These signals shall be transmitted at the maximum transmit PSD level at which the PLC device expects to transmit when communicating with other devices in the domain, but the maximum transmit PSD level shall incorporate PSD changes applied upon request of the AF (as indicated in the latest CONFIGURE.request primitive defined in clause 7.6.7).

In CCM, the AF shall send a MEASURE-MODE.request primitive only to the PLC-NC indicating the specific PLC devices that the AF requests to stop transmitting and the ones that the AF requests to transmit continuously during the measurement period. If the PLC-NC device responds by indicating its availability and the availability of the requested PLC devices to perform measurement, it shall make its best effort to allocate resources so that the transmission status meets the AF requirements indicated in the MEASURE-MODE.request primitive (i.e., allocate transmit opportunities, require continuous transmission from applicable devices and require applicable devices to be silent as requested by the AF).

In DCM, the AF shall send a MEASURE-MODE.request primitive to each PLC device the AF requests to stop transmitting or to transmit continuously. If the PLC device responds indicating availability to perform measurement, it shall make best effort to meet the AF requirements indicated in the MEASURE-MODE.request primitive (i.e., either transmit continuously or stay silent as requested by the AF).

When the AF receives a MEASURE-MODE.confirm primitive with STATUS = accepted (i.e., the requested device accepted the measurement request) it shall inform the xDSL NT that the measurement process is going to start (indicating the delay) by sending the MEASURE.request primitive via the Φ_C interface, as defined in clause 7.6.13. This primitive indicates to the xDSL NT the duration of the measurement and the delay to start. The xDSL NT shall respond to the AF with a MEASURE.confirm primitive (see clause 7.6.14).

NOTE – A PLC device or xDSL NT may request to perform a measurement process at a particular time by sending the AF an optional STATUS.ind primitive (see clause 7.6.6) with STATUS Change type set to 05_{16}, indicating its availability.

The AF shall request the xDSL NT for the results of the measurement via the RESULTS.request primitive as defined in clause 7.6.17. The xDSL NT shall respond to the AF with a RESULTS.confirm primitive as defined in clause 7.16.18. The primitive includes information about the status of the measurement and the measurement data (if the measurement has been completed).

The AF may request the xDSL NT to repeat the measurement with the aim of obtaining more comprehensive knowledge of the interference from PLC device(s) into xDSL NT. Once sufficient measurement data is obtained, the AF shall request the PLC device to complete the measurement by sending a COMPLETION.request primitive defined in clause 7.6.15 (via the Φ_P interface). Upon reception of this primitive, the PLC device(s) shall respond with COMPLETION.confirm primitive defined in clause 7.6.16 and terminate the measurement.

If PLC network operates in CCM, the AF shall exchange the mentioned primitives over the Φ_P interface with the PLC-NC only, and the PLC-NC shall convey them to the corresponding PLC device(s) in the network. The messages communicated between the PLC-NC and the PLC device(s) for this purpose are beyond the scope of this Recommendation.

7.4 Device configuration

7.4.1 Overview

The device configuration procedure allows changing transmission parameters of PLC network devices and xDSL line (xDSL NT) necessary to facilitate coexistence between the PLC network and the xDSL and optimize the overall end-to-end service delivery to the customer. The procedure is managed by the AF and performed under control of the operator.

The configuration procedure provides the tools that:

- allow re-configuration of selected transmission parameters of the PLC network devices;
- allow re-configuration of selected transmission parameters of the xDSL line (xDSL NT);
- facilitates a capability for both PLC devices and xDSL NT to negotiate configuration with the AF in case a compromise is necessary.

7.4.2 Configuration of PLC devices

The configuration procedure is intended to modify the transmit PSD or update a PSD limit of a particular PLC device in up to 32 frequency bands, each defined by a start frequency and a stop frequency, in a format of PSD descriptor defined in Table 7-12.1. The modification of the PSD can be used to perform a sensitivity test, while applying another PSD limit can be used to prevent excessive PSD during the entire operation of the PLC network. For devices that support linear interpolation of PSD (see Table 7-3), the relevant value of transmit PSD modification (trim) or a PSD limit on all intermediate frequencies of the band shall be computed using linear interpolation over linear frequency scale. For devices that do not support linear interpolation of PSD, it shall be modified (trimmed) using a step-shaped PSD.

To start configuration, the AF sends across the Φ_P interface a CONFIGURE.request primitive as defined in clause 7.6.7, containing a PSD descriptor of any valid type.

Upon reception of the CONFIGURE.request primitive, a PLC device shall reply within 2 seconds with a CONFIGURE.confirm primitive defined in clause 7.6.8, which indicates that the requested update of the transmit PSD is either confirmed or rejected. A PLC device may reject the proposed configuration if it is expected to result in disruption of transmission in the PLC network or cause some other type of critical degradation. In the case of rejection, the PLC device shall offer an alternative PSD modification (e.g., on a request to reduce PSD by a certain value, the PLC device may reply by a proposal of a smaller PSD reduction).

Prior to replying the CONFIGURE.request primitive, the PLC device shall implement the required configuration, either the requested one, or the alternative one, if implementation of the requested one is not possible due to reasons mentioned above. The AF may require a next configuration after a time period that is not less than 2 seconds.

If the PLC network operates in CCM, the AF is allowed to exchange the mentioned primitives over the Φ_P interface with the PLC-NC only and the PLC-NC shall convey them to the corresponding PLC device(s) in the network. The messages communicated between the PLC-NC and the PLC device(s) for this purpose are beyond the scope of this Recommendation.

7.4.3 Configuration of xDSL

The configuration procedure is capable of modifying parameters of the xDSL line with the goal of accommodating stronger crosstalk from the PLC. The configuration (or re-configuration) should be used when interference from one or more PLC devices cannot be sufficiently reduced by adjusting the transmit PSD of these devices, as described in clause 7.4.2, or for overall optimization of the end-to-end throughput. The re-configuration is achieved by modification of some xDSL parameters selected by the xDSL management entity (ME) at the network side. The modified configuration parameters shall be chosen so that they remain within the allowed range defined in the xDSL central office management information base (CO-MIB) [ITU-T G.997.1], [ITU-T G.997.2] or distribution point unit management information base (DPU-MIB) [ITU-T G.997.2].

To start configuration, the AF sends across the Φ_C interface a CONFIGURE.request primitive as defined in clause 7.6.9, containing the measurement data reported by the xDSL NT (SNR or QLN measurement) associated with a particular measurement scenario that AF considers as an input for xDSL re-configuration. The content and format of the reported data is defined in Table 7-14.

Upon reception of the CONFIGURE.request primitive, the xDSL NT shall reply within 2 seconds with a CONFIGURE.confirm primitive defined in clause 7.6.10, which indicates that the request for reconfiguration of xDSL is either confirmed or rejected. The xDSL NT shall reject the configuration if it results in values of one or more of xDSL configuration parameters that violate the allowed range of configuration parameters received during initialization defined in the CO/DPU-MIB.

NOTE – If reaching coexistence within the current range of CO/PDU-MIB parameters is impossible (i.e., the PLC network has already exhausted its means of reducing interference), the offered xDSL service may not meet the QoS requirements. In response, the operator may offer an alternative suitable range of CO/DPU-MIB parameters. The associated actions are beyond the scope of this Recommendation.

In the case where the xDSL reconfiguration necessary to meet the required increase of the downstream SNRM violates the current CO/DPU MIB parameters, the xDSL NT may perform an alternative (partial) reconfiguration, implementing the best effort possible without violating the CO/DPU MIB. If allowed by the policy, a new MIB configuration may be requested through the Φ_A interface to achieve the downstream SNRM.

The xDSL implements the required re-configuration by using standard procedures defined for the particular xDSL, such as on-line reconfiguration (OLR), SAVN update, etc. See [ITU-T G.993.2], [ITU-T G.9701] and [ITU-T G.998.4]. More specifically, the xDSL shall take into account the measured SNR and/or the measured QLN data provided by the AF into its bit-loading calculation by treating the interference as additional noise generated by the PLC device. This may help in stabilizing the xDSL link in the presence of the time-varying interference from the PLC device. After completion of the reconfiguration, the xDSL NT shall indicate to the AF the completion of the re-configuration by sending a STATUS.ind primitive via the Φ_C interface. The AF shall not request next xDSL reconfiguration within 15 seconds of the current re-configuration.

7.5 Primitives supporting coexistence protocol

The list of primitives that facilitate coordination between xDSL NT and PLC network for the logical interfaces Φ_P, Φ_C, and Φ_A is presented in Table 7-4.

Table 7-4 – Primitives at interfaces Φ_C, Φ_P and Φ_A

Primitive	Direction	Description
Φ_C		
STATUS.request	AF → NT	Requests an update of the status of the xDSL link and the xDSL NT
STATUS.confirm	NT → AF	Delivers an update on the xDSL link and xDSL NT status
STATUS.ind	NT → AF	Informs on changes to the xDSL NT status (ON, OFF, etc.) and the status of the xDSL link
MEASURE.request	AF → NT	Requests to start measurements to facilitate the interference measurement from PLC to xDSL
MEASURE.confirm	NT→ AF	Informs that SNR measurement request was received
RESULTS.request	AF → NT	Request an update of measurements results including: SNR QLN (if applicable)
RESULTS.confirm	NT → AF	Reports SNR/QLN measurement results to the AF
CONFIGURE.request	AF → NT	Request to re-configure the xDSL line
CONFIGURE.confirm	NT → AF	Confirms the re-configuration of the xDSL line
Φ_P		
STATUS.request	AF → PLC	Requests an update of the status of the PLC network relevant information: Number of PLC devices PLC network topology
STATUS.confirm	PLC → AF	Delivers an update of the PLC network status
STATUS.ind	PLC → AF	Informs on a change of the PLC network status (new device joining, device turns to a sleep mode, etc.)
MEASURE-MODE.request	AF → PLC	Requests to launch a procedure to measure the interference from PLC to xDSL
MEASURE-MODE.confirm	PLC → AF	Informs the AF whether the request is granted or not; if granted, the PLC shall start the measurement procedure
COMPLETION.request	AF → PLC	Requests information about completion of the previous Measurement procedure
COMPLETION.confirm	PLC → AF	Informs the status of the measurement period and the transmission duty cycle

Table 7-4 – Primitives at interfaces Φ_C, Φ_P and Φ_A

Primitive	Direction	Description
Φ_C		
CONFIGURE.request	AF → PLC	Requests a re-configuration of a PLC network device (e.g., modify its transmit PSD)
CONFIGURE.confirm	PLC → AF	Confirms the re-configuration of the PLC network device
Φ_A (Note)		
STATUS.request	NMS → AF	Requests an update of the status of the AF at the RGW: PLC status xDSL NT status RGW topology Policies
STATUS.confirm	AF → NMS	Update on the AF status
STATUS.ind	AF → NMS	Informs of an update in the AF status
CONFIGURE.request	NMS → AF	Requests to configure or re-configure the AF, including Active/Inactive Policies
CONFIGURE.confirm	AF → NMS	Confirms the re-configuration of the AF
NOTE – The primitives at the Φ_A interface defined in this table are for further study.		

7.6 Description of primitives

The primitive exchange across the Φ_P, Φ_C and Φ_A interfaces shall have the following properties:

- the exchange contains a set of request – response pairs of primitives (except for indication primitives);
- each primitive may carry more than one parameter;
- the type of the primitive is determined by the OPCODE that indicates the interface across which this primitive is exchanged, whether the primitive is a request, or a response, or an indication and specific parameter(s) carried by this primitive.

The entity initiating the primitive transaction (e.g., AF or PLC device or xDSL NT) shall send a request (a .request primitive) and wait for a response (a .confirm primitive). If no response is received during the defined timeout, depending on the type of the request, the request primitive may be either retransmitted or abandoned. A timeout of two seconds should be used if no specific timeout is defined for a particular primitive exchange. A mandatory requirement is for further study.

The list of request primitives and corresponding response primitives and indication primitives is shown in Table 7-5. An indication (an .ind primitive) is considered as a request with no response required. If after an indication is sent, no expected activity is detected within 10 seconds, it may imply that the indication is lost. In this case, the indication shall be sent again with any updates. A response (a .confirm primitive) may include no parameters associated (simple acknowledgement).

Whenever the entities exchange primitives across the Φ_P, Φ_C or Φ_A interfaces over Layer 2, the primitives shall be mapped into messages using protocol formats defined in clause A.1.1. Each message communicates primitives which are mapped to a TLV along with its 2-byte OPCODE.

Table 7-5 – Request and response primitives

Primitive type (OPCODE bits [15:8]; for OPCODE bits [7:0] see (Note 1))	Primitive type name	Primitives	Application
Φ_C interface			
00001000	Status	STATUS.request STATUS.confirm STATUS.ind	Update of the status of the xDSL NT
00001001	Configure	CONFIGURE.request CONFIGURE.confirm	Reconfiguration of the xDSL NT
00001100	Measure	MEASURE.request MEASURE.confirm	Facilitate a measurement of the interference from PLC device(s) into xDSL
00001010	Results	RESULTS.request RESULTS.confirm	Update of measurement results (SNR) performed by the xDSL NT
Φ_P interface			
00001000	Status	STATUS.request STATUS.confirm STATUS.ind	Update of the status of the PLC network
00001001	Configure	CONFIGURE.request CONFIGURE.confirm	Reconfiguration of the PLC device(s) (modify transmit PSD)
00001011	Measure	MEASURE-MODE.request MEASURE-MODE.confirm	Facilitate a measurement of the interference from PLC device(s) into xDSL
00001100	Completion	COMPLETION.request COMPLETION.confirm	Provide feedback about the completion of the measurement and the duty cycle from PLC device(s) to AF
Φ_A interface (Note 2)			
00001000	Status	STATUS.request STATUS.confirm STATUS.ind	Update of the status of the AF, xDSL NT, and PLC network
00001001	Configure	CONFIGURE.request CONFIGURE.confirm	Reconfiguration of the AF (new arbitration policies)
NOTE 1 – The bits [7:0] of the 2-byte OPCODE field of the primitive shall use the following format: – bits [0:1] – identify the AF interface: 00 for Φ_P, 11 for Φ_C, 01 for Φ_A, and 10 – reserved by ITU-T; – bits [2:3] – identify whether the primitive is a command or a response with the following coding: 11 = request, 10 = indication, 01 = confirmation, 00 = reserved by ITU-T; – bits [4:6] – indicate the type of the primitive communicated: 000 = STATUS, 001 = CONFIGURE, 010 = MEASURE, 011 = RESULTS, 100 = MEASURE-MODE, 101 = COMPLETION, 110 and 111 = reserved by ITU-T; – bit [7] – reserved by ITU-T and shall be set to 0. NOTE 2 – The primitives at the Φ_A interface defined in this table are for further study.			

7.6.1 STATUS.request primitive (Φ_C interface)

The STATUS.request primitive is used by the AF to request the current status of the xDSL NT. The xDSL NT shall reply to it by sending STATUS.confirm primitive (see clause 7.6.2). The first 2 bytes of the STATUS.request primitive (OPCODE) shall be as defined in Table 7-5. The payload of the TLV-Value field (m-bytes) is presented in Table 7-6.

Table 7-6 – Parameters of the STATUS.request primitive

Parameter name	Octet number	Field size (in bytes)	Description
STATUS REQ	N/A	0	The TLV-Value Parameter of this primitive is empty

7.6.2 STATUS.confirm primitive (Φ_C interface)

The STATUS.confirm primitive is used by the xDSL NT to report the current status of the xDSL access network on request from the AF (STATUS.request). The first 2 bytes of the STATUS.request primitive (OPCODE) shall be as defined in Table 7-5. The payload of the TLV-Value field (m-bytes) is presented in Table 7-7.

Table 7-7 – Parameters of the STATUS.confirm primitive

Parameter name	Octet number	Field size (in bytes)	Description
xDSL access network STATUS	3	1	00_{16} – Inactive 01_{16} – Initialization 02_{16} – Re-initialization 10_{16} – Showtime, QoS met 11_{16} – Showtime, QoS violation 03_{16} – Deactivation (Note)
NOTE – Other values are reserved by ITU-T.			

7.6.3 STATUS.ind primitive (Φ_C interface)

The STATUS.ind primitive is used by the xDSL NT to indicate a change in the status of the xDSL access network to the AF (idle, initialization, showtime, disconnect, etc.). The first 2 bytes of the STATUS.ind primitive (OPCODE) shall be as defined in Table 7-5. The payload of the TLV-Value field (m-bytes) is presented in Table 7-8.

Table 7-8 – Parameters of the STATUS.ind primitive

Parameter name	Octet number	Field size (in bytes)	Description
Previous xDSL access network STATUS	3	1	00_{16} – Inactive 01_{16} – Initialization 02_{16} – Re-initialization 10_{16} – Showtime, QoS met 11_{16} – Showtime, QoS violation 03_{16} – Deactivation (Note)
Current xDSL access network STATUS	4	1	00_{16} – Inactive 01_{16} – Initialization 02_{16} – Re-initialization 10_{16} – Showtime, QoS met 11_{16} – Showtime, QoS violation 03_{16} – Deactivation (Note)
NOTE – Other values are reserved by ITU-T.			

7.6.4 STATUS.request primitive (Φ_P interface)

The STATUS.request primitive is used by the AF to request the current status of the PLC network. The requested PLC device in case of DCM or the PLC-NC in case of CCM shall reply to it by sending STATUS.confirm primitive (see clause 7.6.5). The first 2 bytes of the STATUS.request primitive (OPCODE) shall be as defined in Table 7-5. The payload of the TLV-Value field (m-bytes) is presented in Table 7-9.

For PLC network operating in CCM, the destination address value in the header of L2 message carrying this primitive (see Table A.1) shall be the MAC address associated with the domain master, which is the PLC-NC of the network and keeps an updated status of the PLC network.

Table 7-9 – Parameters of the STATUS.request primitive

Parameter name	Octet number	Field size (in bytes)	Description
STATUS Request Type	3	1	Type of the status request. 00_{16}: Full report. In CCM, the PLC-NC reports the status of all the devices in the PLC network. In DCM, the receiver of this primitive reports the status related to the device. 01_{16}: Partial report. In CCM, the PLC-NC reports the status of all the devices included in this request. This value is not applicable in DCM. (Note)
Number of devices	4	1	Unsigned integer representing the number of PLC devices (j) for which a status is requested. This field only exists if STATUS Request Type is set to 01_{16}.

Table 7-9 – Parameters of the STATUS.request primitive

Parameter name	Octet number	Field size (in bytes)	Description
MACAddress[0]	5-10	6	MAC address of the first PLC device for which a status is requested. This field only exists if STATUS Request Type is set to 01_{16}.
…	…	…	…
MACAddress[j-1]	5+(j-1)*6 – 10+(j-1)*6	6	MAC address of the last PLC device for which a status is requested. This field only exists if STATUS Request Type is set to 01_{16}.
NOTE – Other values are reserved by ITU-T.			

7.6.5 STATUS.confirm primitive (Φ_P interface)

The STATUS.confirm primitive is used by the PLC network to reply with the current status of the PLC network on request of the AF (STATUS.request). The first 2 bytes of the STATUS.request primitive (OPCODE) shall be as defined in Table 7-5. The payload of the TLV-Value field (m-bytes) is presented in Table 7-10 and the format of the Device status sub-field is shown in Table 7-10.1.

Table 7-10 – Parameters of the STATUS.confirm primitive

Parameter name	Octet number	Field size (in bytes)	Description
Number of devices	3	1	The number of devices for which the information is reported represented as an unsigned integer in the range from 1 to 255. The first entry in the list of status of the PLC devices corresponds to the device that sends the report.
Status of Device 1	variable	variable	A sub-field that defines the status of Device #1 of the PLC network. This sub-field shall follow the format described by Table 7-10.1.
…………	…….	……	
Status of Device M	variable	variable	A sub-field that defines the status of Device #M of the PLC network, where M is the total number of devices. The format of this sub-field is defined in Table 7-10.1.

Table 7-10.1 – Parameters of the Device status sub-field

Parameter name	Octet number	Field size (in bytes)	Description
Length	1	2	Length in bytes of the PLC device status sub-field represented as an unsigned integer
MACAddress	3	6	MAC address of the reported device
PowerState	9	1	00_{16}: Reported device is in a normal power state 01_{16}: Reported device is in a low power state 02_{16}: Reported device is OFF (Note)
DeviceType	10	1	00_{16}: Reported device is a PLC-NC 01_{16}: Reported device is not a PLC-NC (Note)
LowFrequency	11	1	Unsigned integer representing the lowest frequency (in units of 1 MHz) the reported device is using for transmissions
HighFrequency	12	1	Unsigned integer representing the highest frequency (in units of 1 MHz) the reported device is using for transmissions
PSDType	13	1	00_{16} – Standard PSD (no PSD cutback associated with xDSL coexistence) 01_{16} – Modified PSD defined in the "PSD descriptor" field (to facilitate xDSL coexistence) (Note)
PSDType Configuration ID	14	2	A 2-byte integer associated with the latest configuration applied, assigned by the AF (see Table 7-12, Configuration ID). This field shall be set to zero and ignored by the receiver if PSDType field is 00_{16}.
Last measurement ID	16	2	Measurement ID of the last MEASURE-MODE.request received and responded with MEASURE-MODE.confirm. The initial value for this field is zero (when no previous MEASURE-MODE request has been processed).
Number of bands	18	1	The number of bands used in the PSD descriptor in the range between 0 and 32, represented as an unsigned integer. The value of zero indicates no PSD change and the PSD descriptor shall not be included.
PSD descriptor	19 – t+18	t	A *t*-byte sub-field describing the PSD of the PLC device (see Table 7-12.1)
NOTE – Other values are reserved by ITU-T.			

7.6.6 STATUS.ind primitive (Φ_P interface)

The STATUS.ind primitive is used by the PLC network to indicate a change in its current status (that may require action from the AF). The first 2 bytes of the STATUS.ind primitive (OPCODE) shall be as defined in Table 7-5. The payload of the TLV-Value field (m-bytes) is presented in Table 7-11.

Table 7-11 – Parameters of the STATUS.ind primitive

Parameter name	Octet number	Field size (in bytes)	Description
STATUS change type	3	1	01_{16} – One or more devices added to the PLC network 02_{16} – One or more devices left the PLC network 03_{16} – One or more PLC devices turned to low power state 04_{16} – One or more PLC devices came back from low power state 05_{16} – PLC network/device is ready for a measurement procedure (Note)
Number of devices	4	1	Number of PLC devices (N) for which the status changed
MAC device 1	5	6	MAC address of the first PLC device for which the status changed
……….	……….	……….	……….
MAC device N	5+6*(N-1)	6	MAC address of the last PLC device for which the status changed
NOTE – Other values are reserved by ITU-T.			

7.6.7 CONFIGURE.request primitive (Φ_P interface)

The CONFIGURE.request primitive is used by the AF to request modification of the parameters of PLC devices. The PLC shall reply to it by sending CONFIGURE.confirm primitive (see clause 7.6.8). The first 2 bytes of the CONFIGURE.request primitive (OPCODE) shall be as defined in Table 7-5. The payload of the TLV-Value field (m-bytes) is presented in Table 7-12.

Table 7-12 – Parameters of the CONFIGURE.request primitive

Parameter name	Octet number	Field size (in bytes)	Description
Configuration ID	3-4	2	A 2-byte unsigned integer associated with the requested configuration, assigned by the AF (Note 1)
PSDType	5	1	00_{16} – Standard PSD (no PSD cutback associated with xDSL coexistence) 01_{16} – Modified PSD defined in the "PSD descriptor" field (to facilitate xDSL coexistence) (Note 2)
Configuration type	6	1	00_{16} – PSD modification request is to change the transmit PSD at which the device operates 01_{16} – PSD modification request is only for measurement purpose (Note 3) (Note 2)
Number of bands	7	1	The number of bands (*N*) used in the PSD descriptor in the range between 0 and 32, represented as an unsigned integer. The value of

Table 7-12 – Parameters of the CONFIGURE.request primitive

Parameter name	Octet number	Field size (in bytes)	Description
			zero indicates no PSD change and the PSD descriptor shall not be included.
PSD update type	8	1	Indicates the type of PSD update: 00_{16} – update of the PSD limit mask 01_{16} – update of the TX PSD (step up or down comparing to the currently used PSD) (Note 2)
PSD descriptor	8 – (t+7)	t	A *t*-byte sub-field describing the PSD of the PLC device (see Table 7-12.1)
Number of devices	Variable	1	Number of PLC devices (V) for which the PSD descriptor in this primitive is applicable
MAC device 1	Variable	6	MAC address of the first PLC device for which the PSD descriptor is applicable
……….	……….	……….	……….
MAC device V	Variable	6	MAC address of the last PLC device for which the PSD descriptor is applicable
NOTE 1 – The value of Configuration ID shall be incremented for every subsequent configuration request. When it reaches 2^{16}, it wraps around to zero. NOTE 2 – Other values are reserved by ITU-T. NOTE 3 – The AF can change the transmit PSD using the CONFIGURE.request primitive regardless of the Configuration type set in the previous instance of the CONFIGURE.request primitive.			

The format of the sub-field describing the PSD is defined in Table 7-12.1 and the format of the band PSD descriptor is shown in Table 7-12.2.

Table 7-12.1 – Format of *t*-byte PSD descriptor

Parameter name	Octet number	Field size (in bytes)	Description
Band 1	1-10	10	Band 1 PSD descriptor (see Table 7-12.2)
Band 2	11-20	10	Band 2 PSD descriptor (see Table 7-12.2)
……….	……….	……….	……….
Band #N	[10*(N-1)+1] - [10*N]	10	Band N PSD descriptor (N ≤ 32) (see Table 7-12.2)

Table 7-12.2 – Format of band PSD descriptor

Parameter name	Octet number	Field size (in bytes)	Description
START_FREQ	1-4	4	Start frequency in Hz, represented as an unsigned integer
START_PSD	5	1	The value of PSD or PSD step: in units of 1 dB, represented as twos-complimentary integer (Note 1), (Note 2)
END_FREQ	6-9	4	End frequency in Hz, represented as an unsigned integer
END_PSD	10	1	The value of PSD or PSD step: in units of 1 dB, represented as twos-complimentary integer (Note 1), (Note 2)
NOTE 1 – Depending on the PSD update type, the following representation shall be used: – update of PSD limit, in the range between −85 dBm/Hz to −50 dBm/Hz; – update of the TX PSD (PSD step), in the range between −35 dB to 35 dB. NOTE 2 – For devices that support linear interpolation of PSD (see Table 7-3), PSD values are linearly interpolated over frequency between START_FREQ and END_FREQ (in dB scale). For devices that do not support linear interpolation of PSD, PSD values shall be constant over frequency between START_FREQ and END_FREQ (in dB scale).			

7.6.8 CONFIGURE.confirm primitive (Φ_P interface)

The CONFIGURE.confirm primitive is used by the PLC to reply on CONFIGURE.request primitive. The first 2 bytes of the CONFIGURE.confirm primitive (OPCODE) shall be as defined in Table 7-5. The payload of the TLV-Value field (m-bytes) is presented in Table 7-13.

Table 7-13 – Parameters of the CONFIGURE.confirm primitive

Parameter name	Octet number	Field size (in bytes)	Description
Configuration ID	3-4	2	A 2-byte integer associated with the confirmed configuration (indicated in the CONFIGURE.request)
STATUS	5	1	00_{16} – Request completed 01_{16} – Request rejected and alternative change proposed in the "PSD descriptor" field 02_{16} – Request rejected due to invalid parameters (Note)
Number of bands	6	1	The number of bands (*N*) used in the PSD descriptor in the range between 1 and 16, represented as an unsigned integer. This field shall be set to 00_{16} if STATUS = 00_{16} or 02_{16} and shall be different from 00_{16} if STATUS = 01_{16}. The value of zero indicates no PSD change and the PSD descriptor shall not be included.
PSD descriptor	7 – (t+6)	t	A *t*-byte sub-field describing the PSD of the PLC device (see Table 7-12.1)
NOTE – Other values are reserved by ITU-T.			

7.6.9 CONFIGURE.request primitive (Φ_C interface)

The CONFIGURE.request primitive is used by the AF to request modification of the xDSL line parameters based on the reported measurement data. The xDSL NT shall reply to it by sending CONFIGURE.confirm primitive (see clause 7.6.10). The first 2 bytes of the CONFIGURE.request primitive (OPCODE) shall be as defined in Table 7-5. The payload of the TLV-Value field (m-bytes) is presented in Table 7-14.

Table 7-14 – Parameters of the CONFIGURE.request primitive

Parameter name	Octet number	Field size (in bytes)	Description
Configuration ID	3-4	2	A 2-byte integer associated with the requested configuration, assigned by the AF (Note 1)
Measurement data type	5	1	00_{16} – SNR measurement 01_{16} – QLN measurement 02_{16} – the xDSL may initialize, no measurement data provided (Note 2)
Measurement data	6 – (5+s)	s	This field contains the reported measurement data (upon the latest measurement request) in the format defined in the field SNR/QLN descriptor of the RESULTS.confirm primitive (see clause 7.6.18, Table 7-23.1). This field is not present when measurement data type equals 02_{16}.
NOTE 1 – The value of Configuration ID shall be incremented for every subsequent configuration request. When it reaches 2^{16}, it wraps around to zero. NOTE 2 – Other values are reserved by ITU-T.			

7.6.10 CONFIGURE.confirm primitive (Φ_C interface)

The CONFIGURE.confirm primitive is used by the xDSL NT to reply to a CONFIGURE.request primitive. It either confirms or rejects making modifications of the xDSL link parameters based on the measurement data provided by the AF. The first 2 bytes of the CONFIGURE.confirm primitive (OPCODE) shall be as defined in Table 7-5. The payload of the TLV-Value field (m-bytes) is presented in Table 7-15.

Table 7-15 – Parameters of the CONFIGURE.confirm primitive

Parameter name	Octet number	Field size (in bytes)	Description
Configuration ID	3-4	2	A 2-byte integer associated with the confirmed configuration (indicated in the CONFIGURE.request)
STATUS	5	1	00_{16} – The requested reconfiguration based on the measurement data provided by the AF is accepted 01_{16} – The requested reconfiguration based on the measurement data provided by the AF is rejected (Note)
NOTE – Other values are reserved by ITU-T.			

7.6.11 MEASURE-MODE.request primitive (Φ_P interface)

The MEASURE-MODE.request primitive is used by the AF to request a PLC device to start the measurement procedure. The PLC device shall reply to it by sending MEASURE-MODE.confirm primitive (see clause 7.6.12). The first 2 bytes of the MEASURE-MODE.request primitive (OPCODE) shall be as defined in Table 7-5. The payload of the TLV-Value field (m-bytes) is presented in Table 7-16.

Table 7-16 – Parameters of the MEASURE-MODE.request primitive

Parameter name	Octet number	Field size (in bytes)	Description
Measurement ID	3-4	2	A 2-byte integer associated with the requested measurement, assigned by the AF (Note)
Measurement time	5-8	4	The measurement time (T_1) expressed in ms and represented as an unsigned integer. During this time period the PLC device shall transmit or remain silent as requested (see clause 7.3.2).
N transmit	9	1	Number of PLC devices that make best effort to transmit all the time during the measurement time
MAC device 1	10	6	MAC address of the first PLC device in the transmission list
……….	……….	……….	……….
MAC device N	10+6*(N-1)	6	MAC address of the last PLC device in the transmission list
M silence	10+6*N	1	Number of PLC devices that stop transmitting during the measurement time (see clause 7.3.2)
MAC device 1	11+6*N	6	MAC address of the first PLC device in the silence list
……….	……….	……….	……….
MAC device M	11+6*N+6*(M-1)	6	MAC address of the last PLC device in the silence list
NOTE – The value of Measurement ID shall be incremented for every subsequent measurement request. When it reaches 2^{16}, it wraps around to zero.			

7.6.12 MEASURE-MODE.confirm primitive (Φ_P interface)

The MEASURE-MODE.confirm primitive is used by the PLC to reply on the MEASURE-MODE.request primitive and thus confirm that the addressed PLC device starts the measurement procedure. The PLC device may defer the request with a reason code. The first 2 bytes of the MEASURE-MODE.confirm primitive (OPCODE) shall be as defined in Table 7-5. The payload of the TLV-Value field (m-bytes) is presented in Table 7-17.

Table 7-17 – Parameters of the MEASURE-MODE.confirm primitive

Parameter name	Octet number	Field size (in bytes)	Description
Measurement ID	3-4	2	A 2-byte integer associated with the requested measurement (indicated in the MEASURE-MODE.request)
STATUS	5	1	00_{16} – Accepted, and all PLC devices requested by the AF to transmit will start to make best effort to transmit all the time and all PLC devices requested by the AF to stay silent will be silent in DELAY milliseconds (see clause 7.3.2) 01_{16} – Rejected (Note 1)
DELAY	6-7	2	This field is the delay in milliseconds (represented as an unsigned integer) after sending this primitive. The measurement procedure actually starts after this time has elapsed. In case of CCM, the value of this field is generated by the PLC-NC.
Number of devices	8	1	Number of PLC devices (R) for which the request was rejected
MAC device 1	9	6	MAC address of the first PLC device for which the request is rejected
Rejection reason	15	1	01_{16} – Busy 02_{16} – Rejected: measurement time too short 03_{16} – Rejected: measurement time too long (Note 1)
Recommended measurement time	16-19	4	Recommended measurement time (Note 2): Maximum valid time in case rejection is for too short (Rejection reason = 02_{16}) Minimum valid time in case rejection is for too long (Rejection reason = 03_{16})
……….	……….	……….	……….
MAC device R	variable	6	MAC address of the last PLC device for which the request was rejected
Rejection reason	variable	1	01_{16} – Busy 02_{16} – Rejected: measurement time too short 03_{16} – Rejected: measurement time too long (Note 1)
Recommended measurement time	variable	4	Recommended measurement time (Note 2): Maximum valid time in case rejection is for too short (Rejection reason = 02_{16}) Minimum valid time in case rejection is for too long (Rejection reason = 03_{16})
NOTE 1 – Other values are reserved by ITU-T. NOTE 2 – In case Rejection reason is "Busy", this field shall indicate the recommended measurement time.			

7.6.13 MEASURE.request primitive (Φ_C interface)

The MEASURE.request primitive is used by the AF to request the xDSL NT to start the measurement procedure. The xDSL NT shall reply to it by sending MEASURE.confirm primitive (see clause 7.6.14). The first 2 bytes of the MEASURE.request primitive (OPCODE) shall be as defined in Table 7-5. The payload of the TLV-Value field (m-bytes) is presented in Table 7-18.

Table 7-18 – Parameters of the MEASURE.request primitive

Parameter name	Octet number	Field size (in bytes)	Description
Measurement ID	3-4	2	A 2-byte integer associated with the requested measurement, assigned by the AF (Note)
Measurement delay	5-6	2	The measurement start time relative to the instant the MEASURE.request primitive is sent, expressed in ms units and represented as an unsigned integer
Measurement time	7-8	2	The measurement time expressed in ms and represented as an unsigned integer (T_1). During this time period the xDSL NT shall measure and store the SNR or QLN that includes the impact of the PLC device.
NOTE – The value of Measurement ID shall be incremented for every subsequent measurement request. When it reaches 2^{16}, it wraps around to zero.			

7.6.14 MEASURE.confirm primitive (Φ_C interface)

The MEASURE.confirm primitive is used by the xDSL NT to reply on MEASURE.request primitive and thus confirm the start of the measurement procedure. The xDSL NT cannot reject the MEASURE.request if in showtime. The first 2 bytes of the MEASURE.confirm primitive (OPCODE) shall be as defined in Table 7-5. The payload of the TLV-Value field (m-bytes) is presented in Table 7-19.

Table 7-19 – Parameters of the MEASURE.confirm primitive

Parameter name	Octet number	Field size (in bytes)	Description
Measurement ID	3-4	2	A 2-byte integer associated with the requested measurement (indicated in the MEASURE.request)
STATUS	5	1	00_{16} – 02_{16} – Accepted; the measurement procedure will start at the requested time and for requested duration – 00_{16} – xDSL NT is in L0 state (showtime) – 01_{16} – xDSL NT is in L2.1 state (showtime) – 02_{16} – xDSL NT is in L2.2 state (showtime) 03_{16} – 04_{16} – Rejected: SNR measurement is not available – 03_{16} – xDSL NT is in initialization – 04_{16} – xDSL NT is idle (L3 state) (Note)
NOTE – Other values are reserved by ITU-T.			

7.6.15 COMPLETION.request primitive (Φ_P interface)

The COMPLETION.request primitive is used by the AF to request to a PLC device to confirm completion of the measurement previously requested. The PLC device shall reply to it by sending COMPLETION.confirm primitive (see clause 7.6.16). The first 2 bytes of the COMPLETION.request primitive (OPCODE) shall be as defined in Table 7-5. The rest of the TLV-Value field (m-bytes) is presented in Table 7-20.

Table 7-20 – Parameters of the COMPLETION.request primitive

Parameter name	Octet number	Field size (in bytes)	Description
Measurement ID	3-4	2	A 2-byte integer associated with the requested measurement shall be identical to the one used for the corresponding MEASURE-MODE.request (see clause 7.6.11)
Number of devices	5	1	Number of PLC devices (N) for which MEASURE-MODE.request was sent
MAC device 1	6	6	MAC address of the first PLC device in the list
……….	……….	……….	……….
MAC device N	6*N	6	MAC address of the last PLC device in the list

7.6.16 COMPLETION.confirm primitive (Φ_P interface)

The COMPLETION.confirm primitive is used by the PLC device to provide feedback and confirm the completion of a previously requested measurement. The first 2 bytes of the COMPLETION.confirm primitive (OPCODE) shall be as defined in Table 7-5. The rest of the TLV-Value field (m-bytes) is presented in Table 7-21.

Table 7-21 – Parameters of the COMPLETION.confirm primitive

Parameter name	Octet number	Field size (in bytes)	Description
Measurement ID	3-4	2	A 2-byte integer associated with the confirmed measurement (indicated in COMPLETION.request)
STATUS	5	1	00_{16}: measurement completed 01_{16}: measurement not completed yet (Note)
Number of devices	6	1	Number of PLC devices for which COMPLETION.request was sent
MAC device 1	7	6	MAC address of the first PLC device in the list
DUTY_CYCLE of device 1	13	1	Percentage of time that the PLC device corresponding to MAC device 1 has been transmitting during the measurement
……….	……….	……….	……….
MAC device N	variable	6	MAC address of PLC device N in the list
DUTY_CYCLE of device N	variable	1	Percentage of time that the PLC device corresponding to MAC device N has been transmitting during the measurement
NOTE – Other values are reserved by ITU-T.			

7.6.17 RESULTS.request primitive (Φ_C interface)

The RESULTS.request primitive is used by the AF to request the xDSL NT to send the measurement results. The xDSL NT shall reply to it by sending RESULTS.confirm primitive (see clause 7.6.18). The first 2 bytes of the RESULTS.request primitive (OPCODE) shall be as defined in Table 7-5. The rest of the TLV-Value field (m-bytes) is presented in Table 7-22.

In case the xDSL system uses frequency division duplexing, such as VDSL2 [ITU-T G.993.2], the AF should use a separate RESULTS.request primitive for every relevant downstream band.

Table 7-22 – Parameters of the RESULTS.request primitive

Parameter name	Octet number	Field size (in bytes)	Description
Measurement ID	3-4	2	A 2-byte integer associated with the requested measurement shall be identical to the one used for the corresponding MEASURE.request (see clause 7.6.13)
Group size	5	1	The tone group size (*G*) used for SNR/QLN report with valid values consistent with relevant xDSL Recommendation
START_Index	6-7	2	The group index associated with the lowest frequency of the requested SNR/QLN report represented as unsigned integer
END_Index	8-9	2	The group index associated with the highest frequency of the requested SNR/QLN report represented as unsigned integer

7.6.18 RESULTS.confirm primitive (Φ_C interface)

The RESULTS.confirm primitive is used by the xDSL NT to provide the measurement results. The first 2 bytes of the RESULTS.confirm primitive (OPCODE) shall be as defined in Table 7-5. The rest of the TLV-Value field (m-bytes) is presented in Table 7-23.

Table 7-23 – Parameters of the RESULTS.confirm primitive

Parameter name	Octet number	Field size (in bytes)	Description
Measurement ID	3-4	2	A 2-byte integer associated with the confirmed measurement (indicated by MEASURE.request)
STATUS	5	1	00_{16} – measurement completed 01_{16} – measurement failed (Note)
MODE	6	1	00_{16} – reported data represents SNR 01_{16} – reported data represents QLN (Note)
DURATION	7-10	4	Total measurement duration in milliseconds units (represented as an unsigned integer)
SNR/QLN descriptor	11 – (d+10)	d	A sub-field representing the SNR/QLN descriptor (see Table 7-23.1)
NOTE – Other values are reserved by ITU-T.			

Table 7-23.1 – Format of SNR/QLN descriptor

Parameter name	Octet number	Field size (in bytes)	Description
Group #1	1	1	The SNR/QLN value for Group #1 (Note)
Group #2	2	1	The SNR/QLN value for Group #2 (Note)
……….	……….	……….	……….
Group #N	N	1	The SNR/QLN value for Group #N (Note)
NOTE – The format of the SNR/QLN values, including use of special values, shall be as defined in the associated xDSL Recommendations [ITU-T G.993.2], [ITU-T G.9701], etc. One of the special values indicates the groups for which SNR/QLN values are unavailable.			

Annex A

Transmission formats for message exchange

(This annex forms an integral part of this Recommendation.)

A.1 Transmission formats

Layer 2 transmission format is defined (see clause A.1.1). Other transmission formats are for further study.

A.1.1 Layer 2 transmission format

The L2 protocol format at both Φ_C and Φ_P interfaces shall use the IEEE 1905 compatible format which makes use of IEEE Std 802.3-2008 MAC frame format at layer 2 (L2) of the protocol stack, as presented in Figure 3-1 of [IEEE 802.3].

Table A.1 – L2 protocol format

Field	Length	Value range	Description
Destination address	6 bytes	Any EUI-48 value	MAC address of the receiving device (xDSL NT, or a PLC device, or the AF)
Source address	6 bytes	Any EUI-48 value	MAC address of the source device (xDSL NT, or a PLC device, or the AF)
EtherType	2 bytes	0x893A	EtherType field defines the type of MAC protocol (IEEE 1905 in this case)
CMDU payload	46-1500 bytes	See Table A.2	CMDU payload, including one or more messages. The format of the payload is defined in Table A.2
FCS	4 bytes	Any 4-byte value	Frame check sequence field computed as defined in clause 3.2.9 of [IEEE 802.3]

The control message data unit (CMDU) is intended to carry primitives associated with the coexistence mechanism defined in this specification (over the Φ_C, Φ_P and Φ_A interfaces). The format of the CMDU is presented in Table A.2 and consists of the header and the payload.

The primitives carried by the CMDU are formatted as TLV; the CMDU payload contains:

- the TLV-field that carries a single TLV or a number of concatenated TLVs;
- the End TLV field that indicates the end of the CMDU payload (see Table A.2).

The rest of the CMDU fields defined in Table A.2 represent the CMDU header (8 bytes in total).

If a primitive to be transmitted in the CMDU contains more than 1500 bytes, it shall be communicated using multiple CMDUs, while every CMDU carries a fragment of the primitive. The fragmentation rule is defined in [IEEE 1905.1]; the header of the CMDU indicates the fragment number and total number of fragments.

The CMDU format is defined in Table A.2 and is consistent with the IEEE 1905 CMDU format as defined in Table 6-3 of [IEEE 1905.1].

Table A.2 – CMDU format

Field	Length	Value range	Description
Message version	2 bytes	N/A	Set to zero on transmission
Message type	2 bytes	0004_{16}	All messages related to this Recommendation shall be of the same Type = 0004_{16} ([IEEE 1905.1], vendor specific)
Message ID	2 bytes	0000_{16} – $FFFF_{16}$	An ID assigned for each message; the receiver uses the ID to process messages in the order they were sent. If it is a response message, the value MUST be set to the same value as that of the received request message; otherwise, set to a new value.
Fragment ID	1 byte	00_{16} – 40_{16}	Identifies the fragment of a message with the given message ID. Message can be divided by up to 64 fragments. The value starts from 0 for the first fragment and monotonically increases by 1 for the successive fragments. If the message is not fragmented, the value MUST be set to 00_8.
Last fragment indicator	1 byte	00_{16} – 01_{16}	The LSB indicates whether the frame is the last fragment. 1 – Last fragment 0 – Not last fragment If the message is not fragmented, the value MUST be set to 1. Bits 1-7 are reserved. Set to zero on transmission. Ignore upon reception.
TLVs	35-1489 bytes	See Table A.3	One or more concatenated TLV-formatted data elements (primitives). Each TLV has a format shown in Table A.3.
End TLV	3 bytes	000000_{16}	Indicates the end of the TLV message

The format of the TLVs to be used for communication of the messages in this Recommendation is defined in Table A.3. The defined TLV format is consistent with the ITU-T vendor specific TLV, as defined in clause 11 of [ITU-T G.9979] and with the IEEE 1905 vendor specific TLV as defined in Table 6-7 of [IEEE 1905.1]. All TLVs defined to convey the primitives in this Recommendation are identified by the vendor specific TLV-type = $0B_{16}$. The TLV-length field carries a 2-byte unsigned integer indicating the length of the TLV-value field in bytes. The TLV-value field consists of four sub-fields:

– a 3-byte sub-field with the ITU-T OUI;
– a 1-byte sub-field with the ITU-T subtype. It shall be fixed to the value 00_{16};
– the last two sub-fields correspond to the ITU-T TLV payload, see clause 11 of [ITU-T G.9979], containing a 2-byte ITU-T G.9977 OPCODE and a m-byte field containing the ITU-T G.9977 message body, as defined in clause 7.6.

Table A.3 – TLV format

Field	Length	Value range	Description
TLV-Type	1 byte	$0B_{16}$	Vendor specific TLV
TLV-Length	2 bytes	0006_{16} – $FFFF_{16}$	Total number of bytes in TLV-Value field (Note 1)
TLV-Value	3 bytes	$0019A7_{16}$	ITU-T OUI (the 24-bit globally unique IEEE-SA assigned value for ITU-T)
	1 byte	00_{16}	ITU-T TLV subtype corresponding to ITU-T G.9977 messages. It shall be fixed to the value 00_{16}.
	2 bytes	0000_{16} – $FFFF_{16}$	The primitive type (OPCODE); the particular OPCODE types are defined in Table 7-5 (Note 2)
	m bytes	N/A	Parameters of the primitive as defined in corresponding tables of clause 7.6 (Note 2)
NOTE 1 – the value of the length field shall be in the range 32-1486 bytes. NOTE 2 – The OPCODE and parameters (m+2 bytes) of the TLV-Value field correspond to the message content (n bytes) of the ITU-T vendor specific message as defined in Table 11-1 of [ITU-T G.9979].			

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