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

Access networks – Metallic access networks

Transceiver and system specifications for backhaul applications based on G.fast (G.fastback)

Recommendation ITU-T G.9702

ITU-T

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Recommendation ITU-T G.9702

Transceiver and system specifications for backhaul applications based on G.fast (G.fastback)

Summary

Recommendation ITU-T G.9702 specifies means to support a distribution point unit – fast backhaul (DPU-FB), which uses the G.fast technology for both the backhaul connections (back lines) and the connections to the G.fast NTs (front lines) in an environment where crosstalk cancelling between the wire-pairs of the back lines and wire-pairs of the front lines is required in addition to the FEXT cancellation provided by G.fast.

This Recommendation is written as a delta Recommendation relative to Recommendation ITU-T G.9701. For the clauses that have been changed, this Recommendation contains complete replacement text (unless explicitly indicated). For the clauses that have not been changed, this Recommendation contains only the clause heading, with reference to Recommendation ITU-T G.9701.

History

Edition	Recommendation	Approval	Study Group	Unique ID*
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Backhaul, fastback, fast backhaul, G.fast.

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FOREWORD

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Recommendation ITU-T G.9702

Transceiver and system specifications for backhaul applications based on G.fast (G.fastback)

1 Scope

This Recommendation describes the modifications to [ITU-T G.9701] that are needed to support distribution point unit – fast backhaul (DPU-FB). DPU-FB uses G.fast technology for both the backhaul connections (back lines) and the connections to the G.fast NTs (front lines) in an environment where crosstalk cancelling between the wire-pairs of the back lines and front lines is required in addition to the FEXT cancellation provided by G.fast.

All transceivers connected to the back lines and front lines shall be fully compliant with [ITU-T G.9701].

This Recommendation specifies modifications that apply to the transceivers connected to both ends of the back lines as well as the required synchronizations between the transceivers of the DPU-FB.

More specifically, this Recommendation includes the following:

- Requirements on the synchronization between the ITU-T G.9701 framing of the back lines and front lines.
- Allocation of sync symbol positions for the derivation of the crosstalk channel between the wire pairs of the back lines and the front lines.
- Modifications to the initialization of the transceivers of the back line to support joining of back lines into active front lines.
- Requirements on the use of transceivers between the DPU and DPU-FB to support G.fastback backhaul in the presence of underlying services such as POTS, ADSL2 and VDSL2 on the same twisted pair.

G.fastback lines are likely to be between 100 m and 200 m long and use up to 12 wire-pairs in a bonded group.

The number of customers served by a DPU is expected to be up to 20.

Data rate and reach from a DPU to a customer is expected to be that of ITU-T G.9701 transceivers using either profile 106a, 106b or 212a.

The DPU-FB may be reverse powered (see Annex A of [ITU-T G.997.2]).

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 (2019), *Very high speed digital subscriber line transceivers 2 (VDSL2).*

[ITU-T G.994.1] Recommendation ITU-T G.994.1 (2021), *Handshake procedures for digital subscriber line transceivers*.

[ITU-T G.997.2] Recommendation ITU-T G.997.2 (2019), *Physical layer management for ITU-T G.9701 transceivers.*

[ITU-T G.998.2] Recommendation ITU-T G.998.2 (2018), *Ethernet-based multi-pair bonding*.

[ITU-T G.9701] Recommendation ITU-T G.9701 (2019), *Fast access to subscriber terminals (G.fast) – Physical layer specification*.

3 Definitions

3.1 Terms defined elsewhere

Unless otherwise noted, the definitions in [ITU-T G.9701] shall apply.

3.2 Terms defined in this Recommendation

This Recommendation defines the following terms:

3.2.1 back line: A line between a DPU-FB and a DPU.

3.2.2 front line: A line between a DPU-FB and a CPE.

4 Abbreviations and acronyms

This Recommendation uses the abbreviations and acronyms defined in [ITU-T G.9701]. In addition, this Recommendation uses the following abbreviations and acronyms:

DPU-FB Distribution Point Unit – Fast Backhaul

FBTU Fast Backhaul Transceiver Unit

FBTU-O FBTU at the customer facing U-interface of a DPU-FB

FBTU-R FBTU at the network facing U-interface of a DPU-FB

F_C Cut-off Frequency

5 Reference models and system requirements

5.1 System reference models

This Recommendation covers the interface specification between an FTU-O and FBTU-R, as applied at the UB reference point, and the interface specification between an FBTU-O and FTU-R, as applied at the U reference point.

The functional reference model of FTTdp deployment including a DPU-FB is illustrated in Figure 5-1. The FTU-O is located inside the distribution point unit (DPU) at the network side of the wire-pair (UB-O reference point). The FBTU-R and FBTU-O are located inside the Fastback DPU (DPU-FB). The FTU-R is located inside the network termination (NT) at the customer premises side of the wire-pair (U-R reference point). Implementations complying with this Recommendation are typically deployed in a fibre-to-the-distribution point (FTTdp) scenario, to extend the loop reach by deploying a DPU-FB between the DPU and the NT.

The interface between the DPU and the DPU-FB consists of ITU-T G.998.2 bonded ITU-T G.9701 interfaces (shown as BOND in Figure 5-1), with some differences defined in this Recommendation. The lines connecting the DPU-FB to the DPU are further referred to as the back lines. The interface between the DPU-FB and each individual NT is defined in [ITU-T G.9701] with some differences defined in this Recommendation. The lines connecting the DPU-FB to the NT are further referred to as the front lines.

The upstream traffic from all DPUs is aggregated by the optical distribution network (ODN) and higher order node (HON) up to the V reference point. The downstream traffic at the V reference point is distributed towards multiple DPUs by HON and ODN. The aggregation and distribution functions of ODN and HON are out of the scope of this Recommendation. Different aggregation examples are united under HON, ODN and DPU, as shown in Figure 5-1.

Each DPU is located at a distribution point and contains one or more FTU-Os, with one or more FTU-Os connected to an FBTU-R located in the DPU-FB. The NT contains an FTU-R, which is a peer of the FBTU-O located in the DPU-FB.

The management of the DPU and the DPU-FB is performed by the network management system (NMS), passing management information to the DPU's management entity (ME-O) and the DPU-FB's management entity (FBME-O) over the Q reference point. The NMS may also monitor each FTU-R via the related NT's ME-R via the G reference point. The connection between the ME-O and the FBME-R is established over management channels provided by the FTU-Os and FBTU-Rs via the back line wire-pairs. The connection between the FBME-O and the ME-R is established over management channels provided by the FBTU-Os and FTU-Rs via the front line wire-pairs.

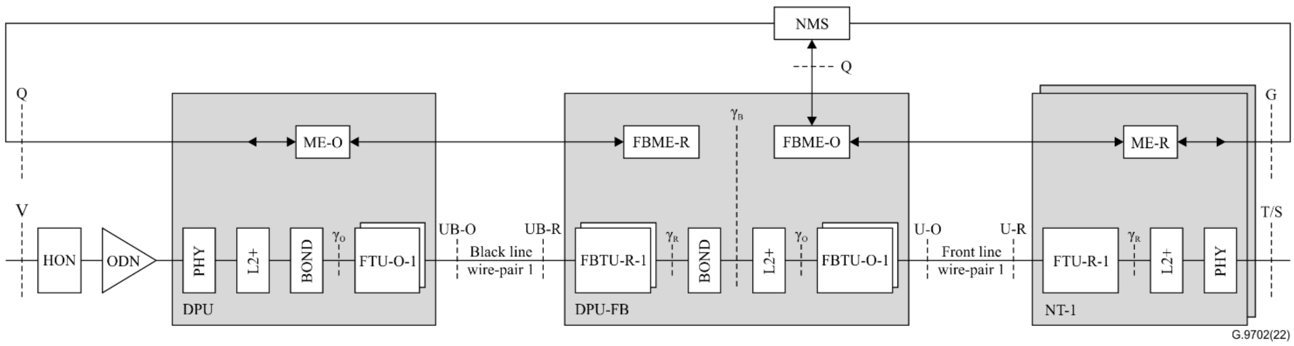

Figure 5-1 – Functional reference model of FTTdp deployment with copper backhaul

The reference model of the information flows within the DPU and the functionality of the FTU-Os in the DPU is described in clause 5.1 of [ITU-T G.9701].

The reference model of the information flows within NT-*n* and the functionality of the FTU-R-*n* in the NT-*n* is described in clause 5.1 of [ITU-T G.9701].

Figure 5-2 provides an overview of the reference model with the logical information flows within the DPU-FB containing NB FBTU-Rs and NF FBTU-Os. The fundamental principle of the system is synchronous and coordinated transmission and reception of signals from all NB wire-pairs connected to the DPU, and of all NF wire-pairs connected to the NTs. Thus, both the back line signals and the front line signals may be represented as a vector where each component is the signal on one of the multiple lines.

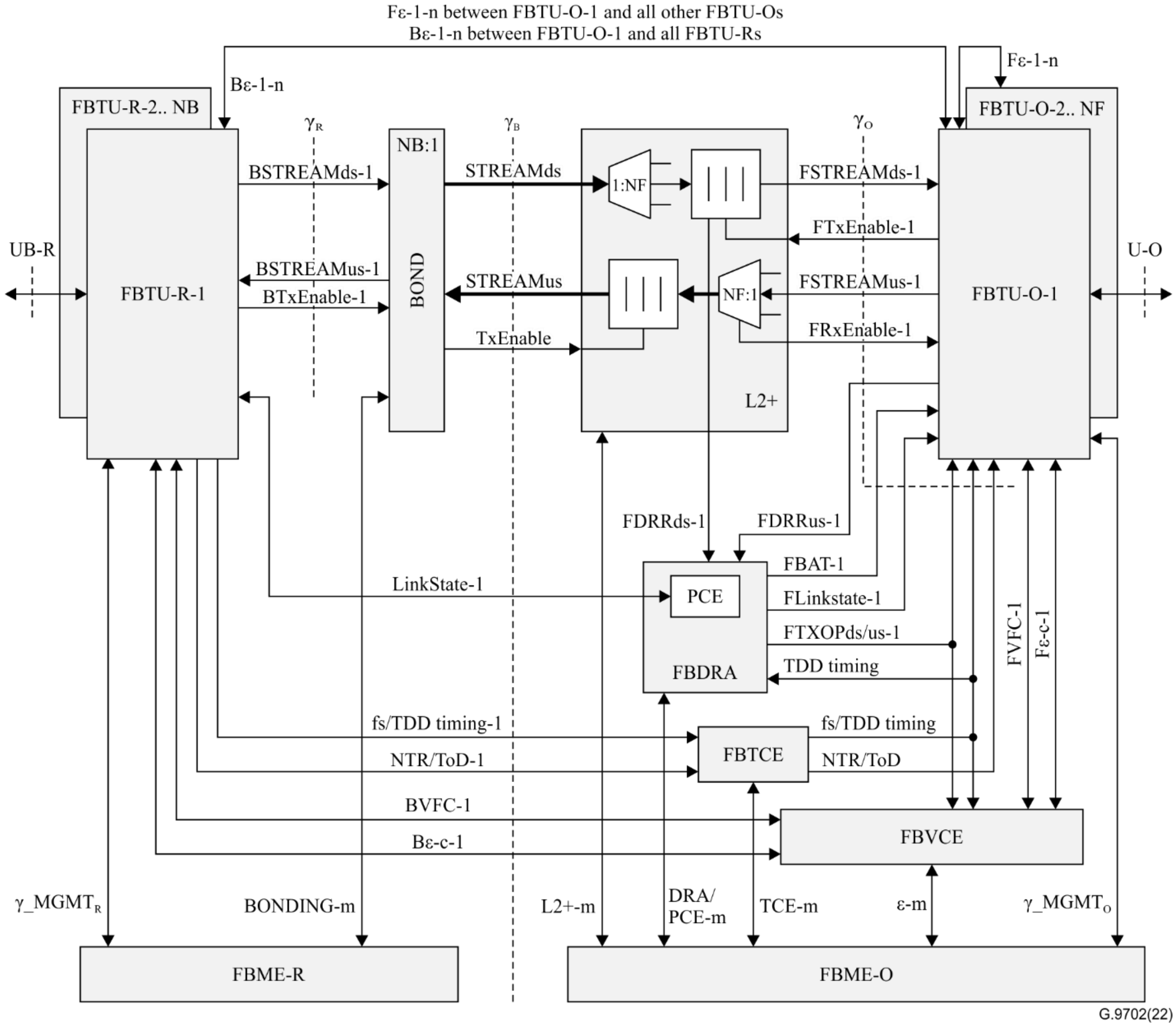

Figure 5-2 – Reference model of the DPU-FB
(shown for line 1 of NB back lines and for line 1 of NF front lines)

The NF front lines and the NB back lines are part of a single vectored group. For each of the NF FBTU-Os in the vectored group, the data plane information flow over the γ_O reference point is represented by a single downstream data stream (STREAMds-*n*) and a single upstream data stream (STREAMus-*n*), where '*n*' is an identifier for a specific FBTU-O (FBTU-O-*n*) and associated wire-pair. The FBTU-O may use flow control (TX Enable-*n*) on the downstream data stream. The L2+ entity may use flow control (RX Enable-*n*) on the upstream data stream. Inside the DPU-FB, the FBME-O conveys the management information (over the γ_MGMT$_O$ interface) to each of the FBTU-Os.

The functionalities of the DPU-FB also include:

- Timing control entity (FBTCE);
- Vectoring control entity (FBVCE);
- Dynamic resource allocation (FBDRA) that also includes power control entity (PCE).

The FBTCE coordinates the transmission and reception with synchronous time-division duplexing (STDD) over the vectored group. The FBTCE derives the TDD timing applied to the front lines from the TDD timing as applied on the back lines by the TCE in the DPU. At the UB-R and U-O reference point, downstream symbols transmitted by all NB FTU-Os, upstream symbols transmitted by all NB FBTU-Rs, downstream sync symbols transmitted by all NF FBTU-Os, and upstream sync symbols transmitted by all NF FTU-Rs are aligned over all wire-pairs in the vectored group. The coordination is shown in Figure 5-2 as the same TDD timing (as received by the FBTU-Rs on the back lines) being passed from the FBTCE to all NF FBTU-Os.

The FBTCE receives the transceiver sample clock f_s and network frequency/timing from the FBTU-Rs. The FBTCE passes the transceiver sample clock f_s, network timing reference (NTR) and time-of-day (ToD) to all NF FBTU-Os. Inside the DPU-FB, the FBME-O conveys the management information (over an interface here called TCE-m) to the FBTCE.

The FBVCE coordinates the crosstalk cancellation over the vectored group. This coordination is made possible through communication from each FBTU-O to all other FBTU-Os and FBTU-Rs and from each FBTU-R to all FBTU-Os; for example:

– Fε-1-*n* identifies the interface between an FBTU-O online 1 (here called FBTU-O-1) and all other FBTU-Os on lines *n* (here called FBTU-O-*n*, *n* = 2…*NF*) and;
– Bε-1-*n* identifies the interface between an FBTU-O online 1 (here called FBTU-O-1) and all FBTU-Rs on lines *n* (here called FBTU-R-*n*, *n* = 1…*NB*).

Coordination data (e.g., precoder data for vectoring) are exchanged between FBTU-O-*n*1 and FBTU-O-*n*2 over an interface here called Fε-*n*1-*n*2, and between FBTU-O-*n*1 and FBTU-R-*n*2 over an interface called Bε-*n*1-*n*2. Each FBVCE controls a single DPU-FB, and controls FBTU-O-*n* (connected to front line *n*) over an interface here called Fε-c-*n* (e.g., to set precoder coefficients for vectoring). The information contained in the vectoring feedback channel (FVFC-*n*) enables the VCE to estimate the FEXT and determine the precoder coefficients. The vectoring feedback information is conveyed from the FTU-R to the FBVCE over the U-interface to the FBTU-O and then over the FVFC to the VCE. Inside the DPU-FB, the FBME-O conveys the management information (over an interface here called ε-m) to the FBVCE. Each FBVCE also controls each FBTU-R-*n* (connected to back line *n*) over an interface here called Bε-c-*n* (e.g., to set upstream probe sequences for vectoring). The information contained in the vectoring feedback channel (BVFC-*n* and FVFC-*n*) enables the FBVCE to estimate the NEXT.

The FBDRA (including the PCE) coordinates the downstream and upstream transmission opportunities over the front lines of the vectored group. Its functionality is the same as described for the DRA in clause 5.1 of [ITU-T G.9701]. In addition, the PCE controls the desired link state for the FBTU-Rs (e.g., for intentional temporary shutdown of some bonded lines; see clause 9 of [ITU-T G.998.2]). Inside the DPU-FB, the FBME-O conveys the management information (over an interface here called DRA-m) to the FBDRA.

5.2 Application reference models

Implementations complying with this Recommendation are typically deployed in a FTTdp scenario. FTTdp deployment and FTTdp key aspects (as self-install and reverse powering) are described in clause 5.2 of [ITU-T G.9701]. The optical distribution network that feeds the distribution point units (DPUs) may be based on point-to-multipoint (e.g., PON) or point-to-point (e.g., GbE) technologies. The copper distribution network that feeds the fastback distribution point units (DPU-FBs) is based on bonded G.fast (see [ITU-T G.998.2] and [ITU-T G.9701]).

The basic application reference model for FTTdp with POTS shown in Figure 5-4 of [ITU-T G.9701] and the related signal flows shown in Table 5-1 of [ITU-T G.9701] remain valid for this Recommendation, with the U-O reference point applying at the DPU-FB (as shown in Figure 5-1) instead of the DPU (as shown in Figure 5-1 of [ITU-T G.9701]), and the FTU-O and service splitter residing in the DPU-FB.

The basic application reference model for FTTdp with reverse powering and POTS shown in Figure 5-5 of [ITU-T G.9701] and the related signal flows shown in Table 5-2 remain valid for this Recommendation, with the U-O reference point applying at the DPU-FB (as shown in Figure 5-1) instead of the DPU (as shown in Figure 5-1 of [ITU-T G.9701]), and the FXO POTS adapter, PSU and PE residing in the DPU-FB.

The basic application reference model for FTTdp with reverse powering and derived POTS shown in Figure 5-6 of [ITU-T G.9701] and the related signal flows shown in Table 5-3 remain valid for this Recommendation, with the U-O reference point applying at the DPU-FB (as shown in Figure 5-1) instead of the DPU (as shown in Figure 5-1 of [ITU-T G.9701]), and the FTU-O, PSU and PE residing in the DPU-FB.

The basic application reference model for FTTdp with reverse powering and derived POTS not sharing the in-premises wiring with [ITU-T G.9701] shown in Figure 5-7 of [ITU-T G.9701] and the related signal flows shown in Table 5-4 remain valid for this Recommendation, with the U-O reference point applying at the DPU-FB (as shown in Figure 5-1) instead of the DPU (as shown in Figure 5-1 of [ITU-T G.9701]), and the FTU-O, PSU and PE residing in the DPU-FB.

The electrical reference model for FTTdp with reverse powering and (derived) POTS shown in Figure 5-8 of [ITU-T G.9701] remains valid for this Recommendation, with the U-O reference point applying at the DPU-FB (as shown in Figure 5-1) instead of the DPU (as shown in Figure 5-1 of [ITU-T G.9701]), and the FTU-O, POTS adapter-E and PE residing in the DPU-FB.

5.3 FTU protocol reference model

The FTU protocol reference model defined in clause 5.3 of [ITU-T G.9701] describes the FTU-O and the FTU-R, and concerns the FTU protocol sub-layers that are all below the γ reference point. The reference model includes data and management planes addressing the TPS-TC, PMS-TC and PMD sub-layers.

The FTU protocol reference model defined in clause 5.3 of [ITU-T G.9701] remains valid for this Recommendation, with this reference model applied both at the UB reference point (between FTU-O and FBTU-R) and the U reference point (between the FBTU-O and the FTU-R).

The functionality of the TPS-TC, PMS-TC and PMD sub-layers is defined, respectively, in clauses 8, 9 and 10 of [ITU-T G.9701], with differences defined in this Recommendation.

The data plane protocol reference model of the ITU-T G.9702 link is shown in Figure 5-3.

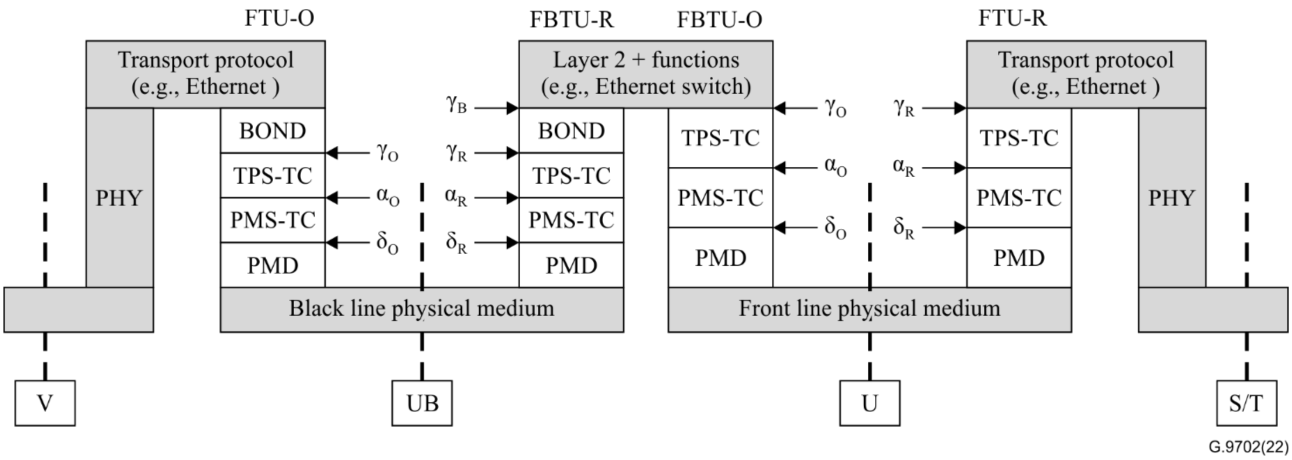

Figure 5-3 – Data plane protocol reference model

5.4 FTU functional model

The FTU functional model presented in Figure 5-11 of [ITU-T G.9701] includes functional blocks and interfaces of the FTU-O and FTU-R, and illustrates the most basic functionality of an FTU.

The FTU functional model presented in Figure 5-11 of [ITU-T G.9701] remains valid for this Recommendation, with this functional model applied to the FTU-O, FBTU-R, FBTU-O and the FTU-R.

The PMD and PMS-TC functions are defined in the main body of [ITU-T G.9701], with differences defined in this Recommendation. The packet-based TPS-TC (PTM-TC) function is defined in clause 8.3 of [ITU-T G.9701]. Other types of TPS-TC are for further study. Functions above the γ reference point are beyond the scope of this Recommendation, except the NTR and ToD functions of the TCE, which are defined in clauses 8.4 and 8.5 of [ITU-T G.9701], respectively.

The principal functions of the PMD are the same as in [ITU-T G.9701]. In this Recommendation, due to the DPU-FB being in between the DPU and the NT (see Figure 5-1), the symbol timing of the FTU-R is synchronized to the symbol timing of the DPU-FB, which in turn is synchronized to the central clock of the DPU.

5.5 INP system requirements

The equipment between the V and T reference points (i.e., the access section including HON, DPU, DPU-FB and NT1, see Figure 5-1) shall have the capability to support impulse noise protection (INP) against SHINE impulses of up to 10 ms at all supported bit rates without loss of user data.

In order to support this system requirement, each transceiver shall be compliant with the INP requirements defined in clause 9.8 of [ITU-T G.9701].

6 Profiles

See clause 6 of [ITU-T G.9701].

FBTU-R and FBTU-O shall support at least one profile listed in clause 6.1 of [ITU-T G.9701]. The selected profiles of the FBTU-Os and FBTU-Rs of the same DPU-FB may differ from each other. However, the DPU-FB shall provide means to cancel crosstalk between any front line and any back line over the widest frequency spectrum determined by the profiles selected by those two lines.

NOTE – In particular, if a back line uses a 106 MHz profile and a front line uses a 212 MHz profile, the crosstalk in the frequency spectrum between 106 MHz and 212 MHz generated by the front line into the back line is cancelled and the crosstalk generated by the IDFT image above 106 MHz of the back line into the front line is cancelled.

The rules of handling profiles and profile compliance shall be as defined in clause 6.2 of [ITU-T G.9701].

7 Transmission medium interface characteristics

See clause 7 of [ITU-T G.9701].

8 Transport protocol specific transmission convergence (TPS-TC) function

See clause 8 of [ITU-T G.9701], as well as the following clause 8.1.4.

8.1.4 γ_B reference point

The γ_B reference point is internal to the DPU-FB and defined between the BOND and the L2+ functional blocks (see reference models in Figures 5-1 and 5-2). The γ_B reference point corresponds to the MII in the protocol stack representation in Figure 1 of [ITU-T G.998.2]. The order in which the data packets are transmitted is determined by the L2+ media access control mechanism in the DPU (for downstream) and DPU-FB (for upstream), which is beyond the scope of this Recommendation.

The interface at the γ_B reference point is logical and is defined through primitives in the data plane and the control plane. The primitives at the γ_B reference point are media-independent, and within the scope of this Recommendation, applied to bonded ITU-T G.9701 backhaul between the DPU-FB and the DPU. The content of the data packet is application specific. The primitives that control the flow of data packets across the γ_B reference point are summarized in Table 8-1. The TX primitives in Table 8-1 control packet transfer from the upper layers to the bonding function, while RX primitives control packet transfer from the bonding function to the upper layers.

Table 8-1 – Flow control primitives at the γ_B reference point

Primitive	Direction	Description
TX Start Flag	Upper layer → BOND	Indicates the first byte of the packet transmitted towards the BOND function
TX Stop Flag		Indicates the last byte of the packet transmitted towards the BOND function
TX Clock		Transmit data clock reference
TX Enable	BOND → Upper layer	Flow control primitive indicating that the BOND function is ready to receive the next packet from the upper layer (Note)
RX Start Flag		Indicates the first byte of the packet transmitted by the BOND function towards the upper layer
RX Stop Flag		Indicates the last byte of the packet transmitted by the BOND function towards the upper layer
RX Clock	Upper layer → BOND	Receive data clock reference
NOTE – If the TX Enable primitive is turned off during the transfer of a data packet, the upper layer shall complete the transfer of this data packet.		

The data flow primitives defining transmit and receive data transferred across the γ_B reference point are summarized in Table 8-2.

Table 8-2 – Data flow primitives across the γ_B reference point

Primitive	Direction	Description
STREAMds	BOND $\rightarrow$ L2+	Downstream data
STREAMus	BOND $\leftarrow$ L2+	Upstream data

The timing related primitives at the γ_B reference point are presented in Table 8-3. The primitives also indicate whether ToD and NTR are enabled and the synchronization option to be used. The primitives are sourced by each FTBU-R. How the FBTCE derives a single set of primitives towards the FTU-Os is beyond the scope of this Recommendation.

Table 8-3 – Timing related primitives at the γ_B reference point

Primitive	Direction	Description
f_s-*n*	FBTU-R-*n* → FBTCE	Transceiver sample clock (synchronized to the primary transceiver sample clock at the DPU)
TDD_timing-*n*	FBTU-R-*n* → FBTCE	TDD timing (synchronized to the primary TDD timing at the DPU)
NTR_sc_clock-*n*	FBTU-R-*n* → FBTCE	Recovered NTR clock at the DPU-FB (synchronized to the primary NTR at the V reference point)
ToD_sc_value-*n*	FBTU-R-*n* → FBTCE	Recovered value of ToD at the DPU-FB associated with the ToD_sc_edge
ToD_sc_edge-*n*	FBTU-R-*n* → FBTCE	The instant of time associated with ToD_sc_value at the DPU-FB
ToD_sc_clock-*n*	FBTU-R-*n* → FBTCE	Recovered ToD clock at the NT (synchronized to the primary ToD at the V reference point)

The vectoring related primitives at the γ_B reference point are presented in Table 8-4. These primitives support the FBVCE in the cancellation of NEXT at the DPU-FB.

The NTR_sc_clock primitive is used to generate the NTR source for the FBTU-O (NTR_mc primitive) which is used for FTU-R NTR frequency synchronization, as defined in clause 8.4.1.1 of [ITU-T G.9701]. The specific method of generating the NTR_mc primitive using NTR_sc_clock-*n* primitives collected from the DPU-FB FBTU-Rs is vendor discretionary.

The ToD_sc_value, ToD_sc_edge and ToD_sc clock primitives are used to generate the ToD source for the FBTU-O (ToD_mc_value, ToD_mc_edge, ToD_mc primitives) are used for the FTU-R ToD synchronization, as defined in clause 8.5.1 of [ITU-T G.9701]. The specific method of generating the FBTU-O ToD source primitives using the ToD_sc_value-*n*, ToD_sc_edge-*n* and ToD_sc clock-*n* primitives collected from the DPU-FB FBTU-Rs is vendor discretionary.

Table 8-4 – Vectoring related primitives at the γ_B reference point

Primitive	Direction	Description
BVFC-*n*	FBTU-R-*n* ↔ FBVCE	Data and configuration for the vectoring feedback channel related to the back lines
Bε-C-*n*	FBTU-R-*n* ↔ FBVCE	Control channel related to the back lines (e.g., to configure upstream probe sequences for NEXT measurement)

The power control related primitives at the γ_B reference point are presented in Table 8-5. These primitives support the PCE in saving power.

Table 8-5 – Power control related primitives at the γ_B reference point

Primitive	Direction	Description
LinkState.request-*n*	FBDRA/PCE → FBTU-R-*n*	Request to transition to the desired Link State (e.g., for intentional temporary shutdown of some bonded lines, see [ITU-T G.998.2] clause 9)
LinkState.confirm-*n*	FBTU-R-*n* → FBDRA/PCE	Confirmation that the transition to the desired Link State has succeeded or failed

9 Physical media specific transmission convergence (PMS-TC) sub-layer

See clause 9 of [ITU-T G.9701].

10 Physical media dependent (PMD) function

See clause 10 of [ITU-T G.9701], except as follows:

10.2.1.5.2 Gain adjuster (replaces clause 10.2.1.5.2 of [ITU-T G.9701])

The gain adjuster g_i is intended for the adjustment of the transmit power of each subcarrier, which may be used for PSD adjustments, to adjust the signal-to-noise ratio (SNR) margin for some or all subcarriers, or turn the subcarrier off to prevent unnecessary crosstalk.

The g_i values in dB shall be defined as the $20 \times \log 10(g_i)$. The values of g_i for all MEDLEY subcarriers shall be assigned during the initialization, as described in clause 12.3.3 of [ITU-T G.9701] and stored in the bits-and-gains table specified in clause 10.2.1.2 of [ITU-T G.9701] (b_i and g_i values).

The g_i settings (in the bits-and-gains table) shall comply with the following requirements:

– If $b_i > 0$, then g_i shall be one (linear scale) in the downstream direction and [−30, 0] (dB) range in the upstream direction.

– If $b_i = 0$, then g_i shall be either equal to zero (linear scale) or in the same range as for $b_i > 0$.

– During initialization the value of g_i is one (linear scale) in both upstream and downstream (initialization PSD shaping is determined by the tss_i).

– During the showtime, the upstream g_i values may also be updated via an OLR procedure described in clause 11.2.2.5.

For subcarriers not in the MEDLEY set, the valid range of g_i is the same as for subcarriers in MEDLEY set (see Table 10-5, clause 10.2.1.5.4 of (ITU-T G.9701]).

In showtime, the g_I values on upstream sync symbols of the FBTU-R for odd values of BL_CNT_{SF} (see clause 10.8.1) are determined by the VCE at the DPU-FB. The valid values are the same as for upstream data symbols. The g_i values on those sync symbols may be different from those of the data symbols.

10.3.2.5.2 Time identification control parameters (replaces clause 10.3.2.5.2 of [ITU-T G.9701])

Any FTU-R supporting ITU-T G.9702 and any FBTU-R shall send the VFRBs on sync symbols with even CNT_SF values only, using the rule defined in this clause.

An FTU-R not supporting ITU-T G.9702 sends the VFRB on all sync symbols as specified in clause 10.3.2.5.2 of [ITU-T G.9701] while the VCE at the DPU-FB shall select the relevant VFRBs for the downstream FEXT estimation of the front line, i.e., on even CNT_{SF}.

In a case in which the FTU-R or FTBU-R reports the VFRB only on sync symbols with even values of CNT_{SF}, the FTU-R/FBTU-R shall send the first VFRB on the first sync symbol with an even CNT_{SF} value following the reception of the request to update the VFRB control parameters. Then it shall send a VFRB on every $2 \times q$-th subsequent sync symbol position $z - 1$ times. After z VFRBs have been sent (which takes $2 \times q \times z$ superframes), the next VFRB shall be reported for the next $(2 \times q + 2)$-th sync symbol position, after which the following $z - 1$ VFRBs shall be reported every $2 \times q$-th sync symbol position, etc. until the next request to update VFRB control parameters.

With the rule defined above, the VFRB are sent on sync symbol positions associated with even CNT_{SF_n} values only, computed with the following recursive rule starting from $n = 0$:

$$CNT_{SF_n} = CNT_{SF_0} \text{ if } n = 0$$

$$CNT_{SF_n} = (CNT_{SF_{n-1}} + 2q) \text{ MOD } 2^{16} \text{ if } n \text{ MOD } z \neq 0$$

$$CNT_{SF_n} = (CNT_{SF_{n-1}} + 2q + 2) \text{ MOD } 2^{16} \text{ if } n \text{ MOD } z = 0$$

where CNT_{SF_0} is the superframe count value of the first sent VFRB.

Valid values for the time identification control parameters are defined in Table 10-12 of [ITU-T G.9701]. For every vectored band of the reported VBB, the starting subcarrier is the one with the smallest index within the vectored band.

The VFRB shift period z equals zero is a special value defined in clause 10.3.2.5.2 of [ITU-T G.9701]. The VFRB period value of $q = 0$ is a special value defined in clause 10.3.2.5.2 of [ITU-T G.9701].

For example, the reports are sent on the following superframe counts with $CNT_{SF_0} = 0$ if the reporting is done only on even CNT_{SF}:

$q = 4$, $z = 0$, then CNT_{SF} = 0, 8, 16, 24, 32, 40, 48, 56, …

$q = 4$ and $z = 4$, then CNT_{SF} = 0, 8, 16, 24, 34, 42, 50, 58, 68, 76, …

10.8.1 Synchronization of superframe counts (new to this Recommendation)

The front line superframe count of a DPU-FB (FL_CNT_{SF}) shall be synchronized with the back line superframe count (BL_CNT_{SF}) sourced by the DPU, so that the sync symbols of superframes with even values of BL_CNT_{SF} are aligned in time with sync symbols of superframes with odd values of FL_CNT_{SF}.

NOTE – Since the CNT_{SF} count of the FBTU-R is forced to be the same as at the DPU, the CNT_{SF} of the DPU-FB can be synchronized with the DPU CNT_{SF}, so that $FL\_CNT_{SF} = BL\_CNT_{SF} + 1$. Use of this option is vendor discretionary.

10.9 Probe sequences (new in this Recommendation)

The VCE of the DPU shall set to 0 all probe sequence elements modulating the downstream sync symbols of the back line in superframes with odd values of CNT_{SF}. At its own discretion, the VCE of the DPU may assign the probe sequence elements modulating upstream or downstream sync symbols of the back line in superframes with even values of CNT_{SF}.

Further, the VCE of the DPU-FB connected to this back line shall set to 0 all probe sequence elements modulating the downstream sync symbols of the front line in superframes with odd values of FL_CNT_{SF}. At its own discretion, the VCE of the DPU-FB may assign:

– the probe sequence elements modulating upstream or downstream sync symbols of the front line in superframes with even values of FL_CNT_{SF};

– the probe sequence elements modulating upstream sync symbols of the back line or front line in superframes with odd values of BL_CNT_{SF};

– the probe sequence elements modulating upstream sync symbols of the front line in superframes with odd values of FL_CNT_{SF}.

NOTE 1 – To avoid interference through FEXT of the elements modulating upstream sync symbols of the front line in superframes with odd values of FL_CNT_{SF} and the elements modulating upstream sync symbols of the back line in superframes with even values of BL_CNT_{SF}, the elements of the front line on those upstream sync symbols should be selected carefully, e.g., set to 0.

If FBTU-O of a DPU-FB serves to feed the back line of another DPU-FB, called for certainty DPU-FB1, the probe sequence elements modulating upstream sync symbols of the front line in superframes with odd values of FL_CNT_{SF} shall be set by the VCE of the DPU-FB1. The DPU-FB1, in turn, the DPU-FB1 shall assign probe sequences to its front lines and to the upstream of the back line as it is defined above for the DPU-FB connected to the back lines served by the DPU.

NOTE 2 – Element 0 of probe sequence means that no signal is transmitted on that sync symbol.

11 Operation and maintenance (OAM)

See clause 11 of [ITU-T G.9701], as well as the following new clause 11.4.7.

11.4.7 G.fastback parameters (new in this Recommendation)

11.4.7.1 FTU-O G.fastback enabling parameter

The control parameter fastback_enable indicates if G.fastback is enabled or disabled at the FTU-O. If it is enabled, the FTU-O initializes only with an FBTU-R, i.e., only if CLR indicates support for G.fastback. It shall be set to 1 if G.fastback is enabled and 0 otherwise. The control parameter fastback_enable shall be derived from the configuration parameter FASTBACK_ENABLE of the DPU MIB.

If fastback_enable is set to 1 and the NPAR(2) bit G.fastback is not set to ONE in the CLR, the handshake procedure shall terminate with 'no mode selected'.

12 Link activation methods and procedures

The initialization of the front lines, i.e., between the FBTU-O and FTU-R, shall be as specified in clause 12 of [ITU-T G.9701].

The initialization of the back lines, i.e., between the FTU-O and FBTU-R, shall be as specified in clause 12 of [ITU-T G.9701] with the supplements specified in the sub-clauses below.

12.1.5 Interaction between FBTU-R and FBTU-O states

The DPU-FB derives sample timing and TDD frame timing from the back lines to be applied to the front line through the fs/TDD timing primitive received by the FBTCE (see clause 5.1). The fs/TDD timing primitive is generated if and only if at least one FBTU-R is in R-SHOWTIME state or in the process of fast retrain.

The FBTU-O shall transition from O-SILENT to O-INIT/HS state only if the fs/TDD timing primitive is generated.

If the fs/TDD timing primitive disappears:

– all FBTU-Os in O-SHOWTIME state shall go to O-SILENT state (upon an o:L3_request from the FBME-O) and stay in O-SILENT;

– all FBTU-Os in O-INIT/TRAIN state shall abort initialization and go back to O-SILENT state;

– all FBTU-Os in O-INIT/HS state shall abort Handshake and go back to O-SILENT state.

Then, all FBTU-Os shall stay in O-SILENT state, waiting for the generation of the fs/TDD timing primitive. The corresponding o:L0_request is generated by the FBME-O.

NOTE – If no FBTU-R is in R-SHOWTIME state and one or more of FTBU-Rs are in the process of fast retrain, the clock recovered by the FBTU-R may drift during the beginning of the fast retrain. This drift is transferred to the FBTU-O. If the drift is substantial, the FBTU-Os could leave the O-SHOWTIME state during the fast retrain of the FBTU-Rs and transition to O-SILENT.

12.1.6 Link activation for back lines shared with [ITU-T G.993.2]

G.fastback back lines may initialize in the presence of other DSL services, such as ADSL2plus or VDSL2, operating on the same twisted pair. This use case is enabled through the use of splitters at the DPU and DPU-FB locations to isolate the spectrum between G.fastback back lines and other DSL services. The G.fastback back lines use a high frequency spectrum whereas the other services occupy the lower spectrum below a cut-off frequency (F_C) defined to maintain compatibility with existing DSL services present on the line.

G.fastback back lines use a different handshake carrier set to the other DSL services sharing the same twisted pair to avoid conflicts during initialization and in order that the G.fastback carrier set frequencies be within the pass band of the splitter.

The FTU-O and FBTU-R may use a different carrier set to the FBTU-O and FTU-R.

The FTU-O and FBTU-R may use carrier set F43f to initialize the back lines. The carrier set operates from 18009 kHz to 19147.5 kHz and is compatible with DSL services using spectrum up to 17.664 MHz.

The FBTU-R may transmit other carrier sets in parallel with F43f but only carriers above the F_C will pass the service splitter northbound of the DPU-FB. If multiple carrier sets are received at the FTU-O the FTU-O decides which carrier set to use.

12.3.2.1.1 CL messages (supplements clause 12.3.2.1.1 of [ITU-T G.9701])

The FTU-O shall include inside the CL message the additional sPar(2) bit (Table 11.70 of [ITU-T G.994.1]) defined in Table 12-1. Table 12-2 shows the definitions and coding for the additional FTU-O CL nPar(3) fields.

Table 12-1 – Additional FTU-O CL message sPar(2) bit definitions

ITU-T G.994.1 sPar(2) bit	Definition of sPar(2) bit
ITU-T G.9702	Shall be set to ONE if the FTU-O supports G.fastback and the control parameter *fastback_enable* is set to ONE. Otherwise, it shall be set to ZERO.

Table 12-2 – FTU-O CL message nPar(3) bit definitions

ITU-T G.994.1 sPar(2) bit	Definition of nPar(3) bits
ITU-T G.9702	Number of consecutive Z-states during R-P-VECTOR 1. This 4-bit field shall be set to 0.

12.3.2.1.2 MS messages (supplements clause 12.3.2.1.2 of [ITU-T G.9701])

The FTU-O shall include inside the MS message the additional sPar(2) bit (Table 11.70 of [ITU-T G.994.1]) defined in Table 12-3. Table 12-4 shows the definitions and coding for the additional FTU-O MS nPar(3) fields.

Table 12-3 – FTU-O MS message sPar(2) bit definitions

ITU-T G.994.1 sPar(2) bit	Definition of sPar(2) bit
ITU-T G.9702	Set to ONE if and only if this bit is set to ONE in both the last previous CLR message and the last previous CL message. If set to ONE, both the FTU-O and the FBTU-R shall use G.fastback.

Table 12-4 – FTU-O MS message nPar(3) bit definitions

ITU-T G.994.1 sPar(2) bit	Definition of nPar(3) bits
ITU-T G.9702	Number of consecutive Z-states during R-P-VECTOR 1. This 4-bit field shall be set to 0.

12.3.2.2.1 CLR messages (supplements clause 12.3.2.2.1 of [ITU-T G.9701])

The FBTU-R shall include inside the MS message the additional sPar(2) bit (Table 11.70 of [ITU-T G.994.1]) defined in Table 12-5. Table 12-16 shows the definitions and coding for the additional FBTU-R CLR nPar(3) fields.

Table 12-5 – FBTU-R CLR message sPar(2) bit definitions

ITU-T G.994.1 sPar(2) bit	Definition of sPar(2) bit
ITU-T G.9702	Always set to ONE.

Table 12-6 – FBTU-R CLR message nPar(3) bit definitions

ITU-T G.994.1 sPar(2) bit	Definition of nPar(3) bits
ITU-T G.9702	Number of consecutive Z-states during R-P-VECTOR 1. This 4-bit field indicates the minimum number of quiet symbols transmitted consecutively on the upstream sync symbol positions with odd values of CNT_{SF} that the FTU-O needs to detect before leaving R-VECTOR 1 stage. The 4-bit value *n* represents 4n + 4 quiet symbols (Z-states). The valid numbers of quiet symbols are from 4 to 64 in steps of 4.

12.3.2.2.2 MS messages (supplements clause 12.3.2.2.2 of [ITU-T G.9701])

The FBTU-R shall include inside the MS message the additional sPar(2) bit (Table 11.70 of [ITU-T G.994.1]) defined in Table 12-7. Table 12-8 shows the definitions and coding for the additional FBTU-R MS nPar(3) fields.

Table 12-7 – FBTU-R MS message sPar(2) bit definitions

ITU-T G.994.1 sPar(2) bit	Definition of sPar(2) bit
ITU-T G.9702	Set to ONE if and only if this bit is set to ONE in both the last previous CLR message and the last previous CL message. If set to ONE, both the FTU-O and the FBTU-R shall use G.fastback.

Table 12-8 – FBTU-R MS message nPar(3) bit definitions

ITU-T G.994.1 sPar(2) bit	Definition of nPar(3) bits
ITU-T G.9702	Number of consecutive Z-states during R-P-VECTOR 1. This 4-bit field shall be set to 0.

12.3.3.1.4 R-VECTOR 1 stage (supplements clause 12.3.3.1.4 of [ITU-T G.9701])

During the transmission of R-P-VECTOR 1, the probe sequence allocated on the upstream sync symbol position corresponding to odd BL_CNT_{SF} value may be used by the VCE at the DPU-FB to estimate the crosstalk channels between the back lines and front lines (see clause 10.9). When the VCE at the DPU-FB has completed the joining, the VCE at the DPU-FB modifies the probe sequence to transmit quiet symbols on all those upstream sync symbols positions. After detecting quiet symbols in a number of those consecutive upstream sync symbol positions greater than or equal to the value indicated by the FBTU-R during handshake, the FTU-O completes this stage by sending O-P-SYNCHRO 1.

12.3.3.3.4.1 O-P-CHANNEL-DISCOVERY 1 (supplements 12.3.3.3.4.1 of [ITU-T G.9701])

The O-P-SYNCHRO 1 signal shall be transmitted only after the FTU-O has detected, during the transmission of R-P-VECTOR 1, quiet symbols in a number of consecutive upstream sync symbol positions with odd values of BL_CNT_{SF} greater than or equal to the value specified in the NPar(3) field "Number of consecutive Z-state during R-P-VECTOR 1" of the last CLR.

NOTE – The requirement to detect quiet symbols before leaving the R-VECTOR 1 stage provides a control on the duration of R-P-VECTOR 1 by the VCE at the DPU-FB. Indeed, the VCE at the DPU-FB may modify the probe sequence on upstream sync symbol with odd CNT_{SF} when the joining of the back line into the front line is completed.

13 Online reconfiguration (OLR)

See clause 13 of [ITU-T G.9701].

14 Electrical requirements

See clause 14 of [ITU-T G.9701].

Annex A to Annex C

(Annexes A to C have been intentionally left blank.)

Annex D

Operation with dynamic time assignment in a crosstalk environment

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

Use of dynamic time assignment (DTA) according to Annex D of [ITU-T G.9701] is for further study.

Annex E to Annex Q

(Annexes E to Q have been intentionally left blank.)

Annex R

Showtime reconfiguration

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

See Annex R of [ITU-T G.9701].

Annex S

NT software upgrade

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

See Annex S of [ITU-T G.9701].

Annex S is only applicable to the front line. It is not applicable to the back line.

Annex T

Dynamic time assignment (DTA) – higher-layer control aspects

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

Support of cDTA according to Annex T of [ITU-T G.9701] is for further study.

Annex U

(Annex U has been intentionally left blank.)

Annex V

Targeted generalized vectoring with non-active ITU-T G.9701 supporting lines (TGVN)

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

See Annex V of [ITU-T G.9701].

Annex W

(Annex W has been intentionally left blank.)

Annex X

Operation without multiline coordination intended for a crosstalk-free environment

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

X.1 Scope

This annex specifies the operation of G.fastback transceivers serving front lines in a crosstalk-free environment established by using coaxial cables between the DPU-FB and the CPE. In a crosstalk-free environment, vectoring is not used and synchronization between lines is not needed.

The annex is not applicable for twisted-pair (TP) cables.

Unless otherwise specifically stated in this annex, all definitions and requirements specified in the main body of this Recommendation are applicable for transceivers compliant with this annex.

X.2 Definitions

See clause X.2 of [ITU-T G.9701].

X.3 Abbreviations and acronyms

See clause X.3 of [ITU-T G.9701].

X.4 Reference model(s)

The reference model of a DPU-FB intended to operate its front lines in a crosstalk-free environment is consistent with the one in Figure 5-2, except that it has no Fε-c-1 or Fε-1-*n* signal exchanges. However, the VCE is still present to support test parameters (see clause 11.4.1.2 of [ITU-T G.9701]).

X.5 Profiles

For operation over coaxial cables in a crosstalk-free environment, the FBTU-O shall comply with at least one profile specified in Table X.1 of [ITU-T G.9701].

FBTU-R may support any profile listed in clause 6.1 of [ITU-T G.9701]. The selected profiles of the FBTU-Os and FBTU-Rs of the same DPU-FB will differ from each other. However, the DPU-FB shall provide means to cancel crosstalk, if any, between any front line and any back line over the widest frequency spectrum determined by the profiles selected by those two lines.

The rules for handling profiles and profile compliance shall be as specified in clause 6.2 of [ITU-T G.9701].

X.6 Independent dynamic time assignment (iDTA)

iDTA is not supported by this Recommendation.

X.7 Initialization messages

X.7.1 ITU-T G.994.1 Handshake phase

See clause X.7.1 of [ITU-T G.9701].

X.7.2 Channel analysis and exchange phase

X.7.2.1 O-MSG 1

See clause X.7.2.1 of [ITU-T G.9701].

The field iDTA_enabled of the Annex X parameter field in O-MSG1 shall be set to 00_{16} (disabled).

X.7.2.2 R-MSG 2

See clause X.7.2.2 of [ITU-T G.9701].

X.8 Discontinuous operation

See clause X.8 of [ITU-T G.9701].

X.9 Online reconfiguration

See clause X.9 of [ITU-T G.9701].

X.10 Initialization

See clause X.10 of [ITU-T G.9701].

X.11 Low power states

NOTE – There are no exceptions to the main body of [ITU-T G.9701] related to low power states.

X.12 Adaptation to the coaxial cable medium

See clause X.12 of [ITU-T G.9701].

The basic application reference model for coaxial cable medium shown in Figure X.4 of [ITU-T G.9701] remains valid for this Recommendation, with the U-O reference point applying at the DPU-FB (as shown in Figure 5-1) instead of the DPU (as shown in Figure 5-1 of [ITU-T G.9701]), and the FTU-O residing in the DPU-FB.

Annex Y

Upstream dynamic resource reports

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

See Annex Y of [ITU-T G.9701].

Annex Z

Cross-layer traffic monitoring functions and link state control

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

See Annex Z of [ITU-T G.9701].

Appendix I

Wiring topologies and reference loops

(This appendix does not form an integral part of this Recommendation.)

See Appendix I of [ITU-T G.9701]. The wiring topologies and reference loops contained therein are only applicable to the front line.

Appendix II

Example OLR use cases

(This appendix does not form an integral part of this Recommendation.)

See Appendix II of [ITU-T G.9701].

Appendix III

Motivation of MTBE accelerated test

(This appendix does not form an integral part of this Recommendation.)

See Appendix III of [ITU-T G.9701].

Appendix IV

Targeted generalized vectoring with active ITU-T G.9701 supporting lines (TGVA)

(This appendix does not form an integral part of this Recommendation.)

See Appendix IV of [ITU-T G.9701].

Appendix V

Retransmission buffer size and the achievable bit-rate

(This appendix does not form an integral part of this Recommendation.)

See Appendix V of [ITU-T G.9701].

Appendix VI

Example applications of discontinuous operation

(This appendix does not form an integral part of this Recommendation.)

See Appendix VI of [ITU-T G.9701].

Appendix VII

Calculation of loop attenuation (LATN)

(This appendix does not form an integral part of this Recommendation.)

See Appendix VII of [ITU-T G.9701].

Appendix VIII

Impulse noise monitoring – detection and interpretation of impulse noise using clusters of corrupted DTUs

(This appendix does not form an integral part of this Recommendation.)

See Appendix VIII of [ITU-T G.9701].

Appendix IX

Examples of the cDTA procedure

(This appendix does not form an integral part of this Recommendation.)

See Appendix IX of [ITU-T G.9701].

Appendix X

Configuration parameters describing preferred net data rate

(This appendix does not form an integral part of this Recommendation.)

See Appendix X of [ITU-T G.9701].

Appendix XI

Fastback use case descriptions

(This appendix does not form an integral part of this Recommendation.)

Introduction

The use of bonded copper backhaul for DP deployment of G.fast could extend the coverage of cabinet deployment by a significant factor. Given a simplistic square law relation between reachable customers and maximum distance from the cabinet, a factor two increase in the number of homes passed should be a conservative estimate of the possible benefit of the technology. While the DPU complexity is higher, the backhaul should be easy to integrate with a cabinet G.fast installation also directly serving residential customers close to the cabinet.

Figure XI.1 shows a high level overview of the FASTBACK architecture. Nearby ADSL2(plus)/VDSL2 and G.fast users may be served from the DPU while more distant ADSL2(plus)/VDSL2 and G.fast users are served from the DPU-FB. Two use cases are described below. For use case 1, dedicated wire-pairs in the cable binder between the DPU and DPU-FB are used for FASTBACK. For use case 2, wire-pairs in the cable binder between the DPU and DPU-FB share FASTBACK and ADSL2(plus)/VDL2 services using frequency division.

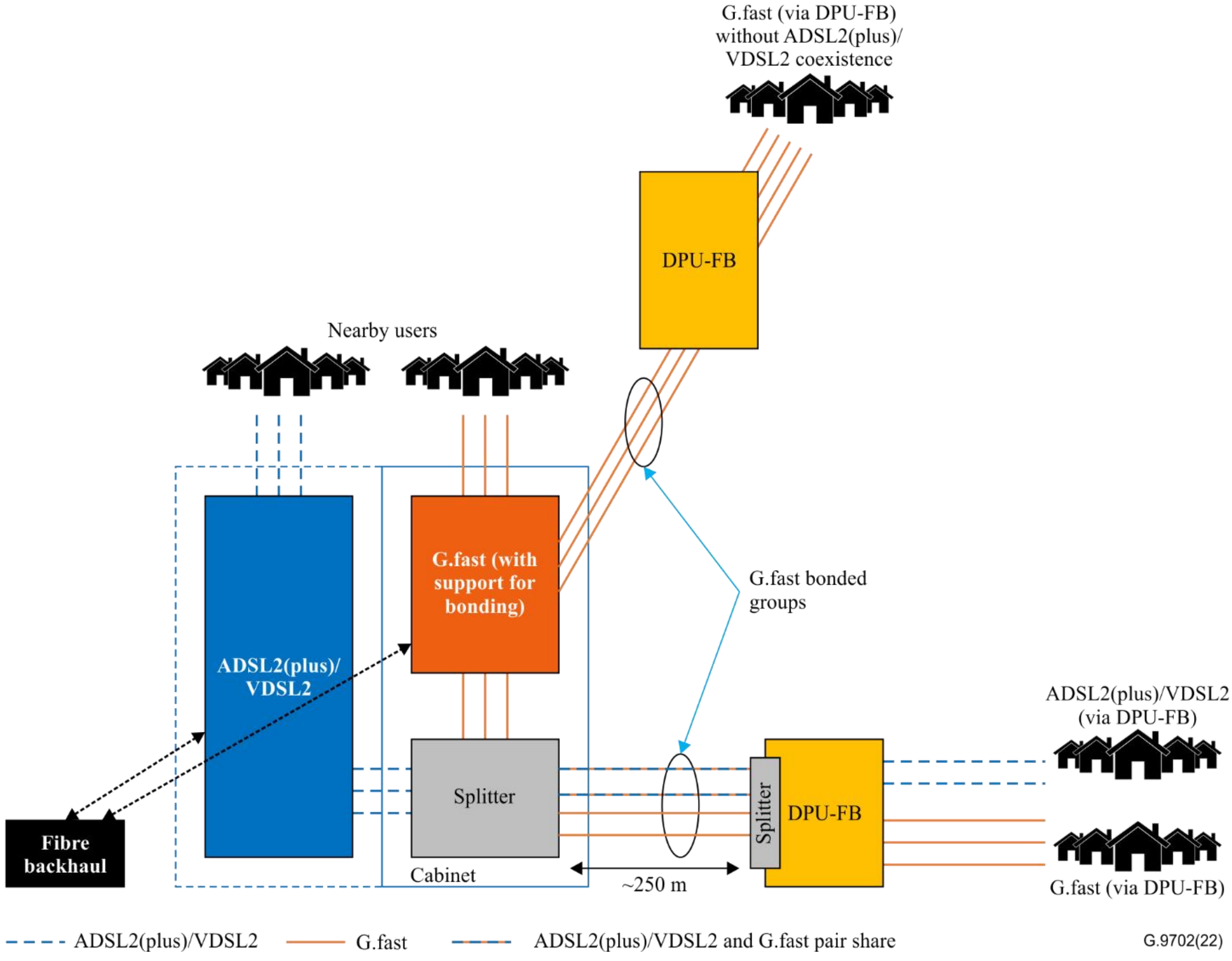

Figure XI.1 – High level FASTBACK architecture

Use case 1 – Dedicated back line wire-pairs

Figure XI.2 illustrates the dedicated back line wire-pairs use case.

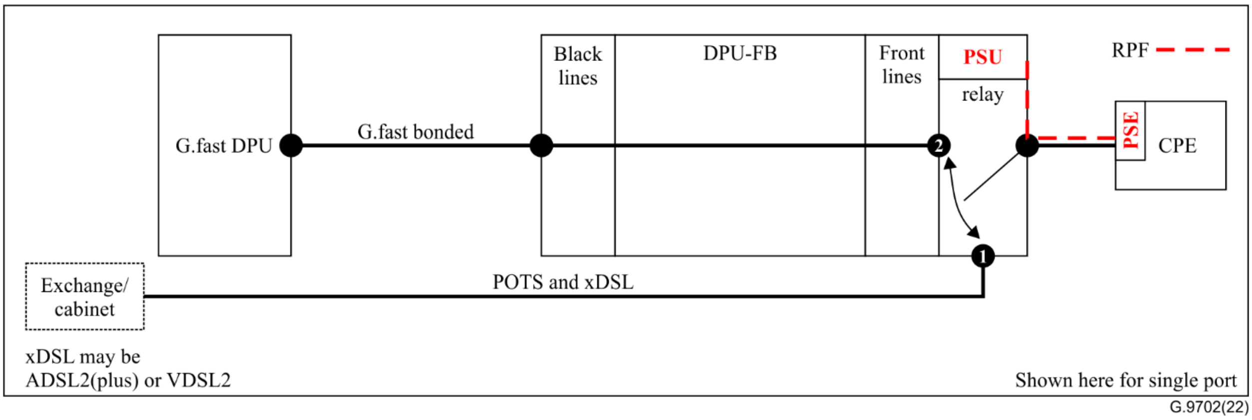

Figure XI.2 – Use case 1 dedicated back line wire-pairs

Back lines connect directly into a DPU-FB without splitters and use handshake tones typical of those used by ADSL2(plus)/VDSL2 operating on separate wire-pairs to the G.fast bonded lines. A relay may be utilized at the front line side to switch between the old and new services. The relay provides zero touch provisioning on detection of RPF. Customers switch from POTS and ADSL2(plus)/VDSL2 on (1) to G.fast on (2). Alternatively, if a cross connect point is available, customers may be manually jumpered between services avoiding the need for a relay but requiring an engineer appointment.

When using a relay, POTS and DC power need to be inactive on the line in order for the CPE PSE to power the DPU-FB and use the G.fast service. Once the relay detects RPF signals from the CPE PSE, the relay switches from position 1 to 2. The CPE may now train with the front line G.fast transceiver.

Use case 2 – Shared back line wire-pairs

Figure XI.3 illustrates the shared back line wire-pairs use case.

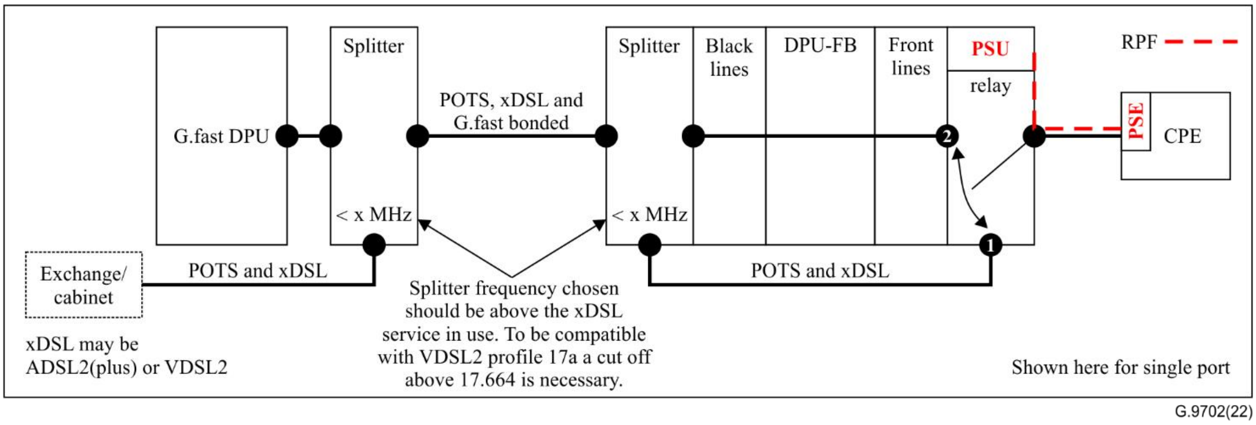

Figure XI.3 – Use case 2 shared back line wire-pairs

Back lines connect into DPU-FB through splitters and use specific handshake tones different from those of ADSL2(plus)/VDSL2 services that share the same twisted pair. The ADSL2(plus)/VDSL2 services use frequencies below a cut-off and the G.fast bonded backhaul use the higher spectrum without interference.

The back line handshake tones (defined in Table 1 of [ITU-T G.994.1]) are intended to be above the frequencies used by ADSL2(plus)/VDSL2 and above the splitter cut-off frequency. ADSL2(plus)/VDSL2 uses a frequency spectrum up to 17.664 MHz. The handshake tones use frequencies above 17.664 MHz to avoid out of band noise from the downstream transmitter and in particular NEXT at the cabinet.

This use case supports RPF and allows zero touch migration between access such as VDSL2 to G.fast served from the DPU-FB. The RPF from a single CPE needs to be capable of powering the DPU-FB for operation on the front line and a minimum of 1 back line. The DPU-FB should train the maximum number of back lines available while also considering the power constraint. This may mean using only a subset of available back line circuits when the number of front line services are limited to reduce power consumption.

POTS and DC power need to be inactive on the line in order for the CPE PSE to power the DPU-FB and use the G.fast service. Once the relay detects RPF signals from the CPE PSE, the relay switches from position 1 to 2. The CPE may now train with the front line G.fast transceiver.

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