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SERIES H: AUDIOVISUAL AND MULTIMEDIA SYSTEMS

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**Operator requirements for full-service VDSL in  
ITU-T Recommendations H.610 and H.611**

ITU-T H-series Recommendations – Supplement 3

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AUDIOVISUAL AND MULTIMEDIA SYSTEMS

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*For further details, please refer to the list of ITU-T Recommendations.*

## **Supplement 3 to ITU-T H-series Recommendations**

### **Operator requirements for full-service VDSL in ITU-T Recommendations H.610 and H.611**

#### **Summary**

This Supplement is based on the Full-Service VDSL Focus Group Technical Specification (FGTS) – Part 1 "FS-VDSL Operators Requirements" and complements the specifications found in ITU-T Recs H.610 and H.611.

#### **Source**

Supplement 3 to ITU-T H-series Recommendations was agreed by ITU-T Study Group 16 (2001-2004) on 30 May 2003.

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## Supplement 3 to ITU-T H-series Recommendations

### Operator requirements for full-service VDSL in ITU-T Recommendations H.610 and H.611

#### 1 Scope

ITU-T Recs H.610 and H.611 define the architecture and operations, administration monitoring and provisioning (OAMP) requirements for the delivery of video, data and voice services across a VDSL access network to an in-home environment, known as a Full-Service VDSL (FS-VDSL) network.

This Supplement provides the operator requirements for services and infrastructure deployment upon which these Recommendations were based. The intent was to maximize commonality of the operators' requirements to help vendors to implement common products, which can then be offered in all international markets thereby achieving economies of scale.

The Recommendations aim to enable the provisioning of a bundle of triple-play services in a reliable way, with minimal user intervention, respecting the key requirements of security and conditional access to the content and at a cost compatible with mass market deployment. Only the elements that need to be specified to achieve an interoperable low-cost platform are included in these specifications. It is intended that each service provider can define and evolve a distinct portfolio of competitive services using the 'bricks' defined in the Recommendations with downloadable software configuration.

VDSL is referenced throughout the Supplement as the physical layer technology; however, the architectural specifications contained herein could be equally applicable to CPE and Access Networks employing other broadband physical layer technologies.

#### 2 References

The following references are provided for information. At the time of publication, the editions indicated were valid. All references are subject to revision; users of this Supplement are therefore encouraged to investigate the most recent edition of the references listed below.

- [1] Committee T1, T1.424-Trial Use, *Interface Between Networks and Customer Installations – Very-high Speed Digital Subscriber Lines (VDSL) Metallic Interface (Trial-use Standard): March 2002 – Part 1 – Functional Requirements and Common Specification.*
- [2] Committee T1, T1.424-Trial Use, *Interface Between Networks and Customer Installations – Very-high Speed Digital Subscriber Lines (VDSL) Metallic Interface (Trial-use standard): March 2002 – Part 2 – Technical Specification for Single-Carrier Modulation (SCM) Transceivers.*
- [3] Committee T1, T1.424-Trial Use, *Interface Between Networks and Customer Installations – Very-high Speed Digital Subscriber Lines (VDSL) Metallic Interface (Trial-use standard): March 2002 – Part 3 – Technical Specification for Multi-Carrier (MCM) Transceivers.*
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- [6] ITU-T Recommendation H.610 (2003), *Full-Service VDSL – System architecture and customer premises equipment*.
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- [8] ITU-T Recommendation H.611 (2003), *Full-Service VDSL: Operations, Administration Maintenance & Provision aspects*.
- [9] ETS 300 019-1-3, *Equipment Engineering (EE); Environmental conditions and environmental test for telecommunications equipment; Part 1-3: Classification of environmental conditions – Stationary use at weatherprotected locations*.
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- [17] EURESCOM Project P917 BOBAN (08, Jan. 01), *Broadband cabinet survey, specification and demonstration*.
- [18] CISPR 22 (2003), *Information technology equipment – Radio disturbance characteristics – Limits and methods of measurement*.
- [19] CISPR 24 (1997), *Information technology equipment – Immunity characteristics – Limits and methods of measurement*.
- [20] Telcordia Technologies GR-1089-CORE (2002), *Electromagnetic Compatibility and Electrical Safety – Generic Criteria for Network Telecommunications Equipment*.
- [21] Telcordia Technologies GR-487 (2000), *Generic Requirements for Electronic Equipment Cabinets*.
- [22] ETSI EN 302 099, *Environmental Engineering (EE); Powering of equipment in access network*.
- [23] ITU-T Recommendation G.993.1 (2001), *Very high speed digital subscriber line foundation*.

### 3 Definitions

This Supplement defines the following term:

**3.1 optical network unit (ONU):** Normally the ONU would designate only the optical termination. However in this Supplement the term "ONU" is used as an overall concept that includes the switching matrix, VDSL line terminations, powering circuitry, and it may also include POTS/ISDN splitters, environmental sensors, back-up batteries and wire cross-connection jumpers.

### 4 Abbreviations

This Supplement uses the following abbreviations:

|       |  |
|-------|--|
| AAL   | ATM Adaptation Layer                       |
| ADSL  | Asymmetrical Digital Subscriber Line       |
| ANSI  | American National Standard Institute       |
| ASP   | Application Service Provider               |
| ATM   | Asynchronous Transfer Mode                 |
| BER   | Bit Error Ratio                            |
| BLES  | Broadband Loop Emulated Service            |
| BRAS  | Broadband Remote Access Server             |
| CAM   | Conditional Access Module                  |
| CBR   | Constant Bit Rate                          |
| CCS7  | Common Channel Signalling No. 7            |
| CCTV  | Closed Circuit Television                  |
| CLASS | Customer Local Area Signalling Services    |
| CLEC  | Competitor Local Exchange Carrier          |
| CO    | Central Office                             |
| CPCM  | Copy Management and Copy Protection        |
| CPE   | Customer Premises Equipment                |
| CSA   | Carrier Serving Area                       |
| DAVIC | Digital Audio Visual Council               |
| DBA   | Dynamic Bandwidth Assignment               |
| DBS   | Direct Broadcast Satellite                 |
| DBTV  | Digital Broadcast Television               |
| DHCP  | Dynamic Host Configuration Protocol        |
| DLC   | Digital Loop Carrier                       |
| DLEC  | Distribution Local Exchange Carrier        |
| DRM   | Digital Rights Management                  |
| DSA   | Distribution Serving Area                  |
| DSL   | Digital Subscriber Line                    |
| DSLAM | Digital Subscriber Line Access Multiplexer |

|         |   |
|---------|---|
| ECM     | Entitlement Control Message                       |
| EMC     | Electromagnetic Compatibility                     |
| EMS     | Element Management System                         |
| EPG     | Electronic Programme Guide                        |
| ETSI    | European Telecommunications Standards Institute   |
| FPD     | Functional Processing and Decoding block          |
| FSAN    | Full-Service Access Network                       |
| FS-VDSL | Full-Service VDSL                                 |
| FTTB    | Fibre To The Building                             |
| FTTCab  | Fibre To The Cabinet                              |
| FTTCurb | Fibre To The Curb                                 |
| FTTEx   | Fibre To The Exchange                             |
| FTTH    | Fibre To The Home                                 |
| GbE     | Gigabit Ethernet                                  |
| HDTV    | High-Definition TV                                |
| HTML    | Hypertext Markup Language                         |
| IAD     | Integrated Access Device                          |
| IEEE    | Institute of Electrical and Electronics Engineers |
| IGMP    | Internet Group Management Protocol                |
| ILEC    | Incumbent Local Exchange Carrier                  |
| ILMI    | Integrated Local Management Interface             |
| IM      | Instant Messaging                                 |
| IoTV    | Internet on TV                                    |
| IP      | Internet Protocol                                 |
| IPSec   | Internet Protocol Security                        |
| ISDN    | Integrated Services Digital Network               |
| ISP     | Internet Service Provider                         |
| LAN     | Local Area Network                                |
| MGCP    | Media Gateway Control Protocol                    |
| MIB     | Management Information Base                       |
| MPEG    | Moving Picture Experts Group                      |
| MTBF    | Mean Time Between Failures                        |
| MTTR    | Mean Time To Repair                               |
| NAT     | Network Address Translation                       |
| NTSC    | National Television Systems Committee             |
| OAM     | Operation, Administration and Maintenance         |
| ODN     | Optical Distribution Network                      |

|       |   |
|-------|---|
| OLT   | Optical Line Termination                                      |
| ONU   | Optical Network Unit  |
| OPI   | Optical Plant Interface                                       |
| OTU-C | Optical Termination Unit – Central Office                     |
| OTU-R | Optical Termination Unit – Remote                             |
| PAL   | Phase Alternation Line  |
| PBX   | Private Branch Exchange                                       |
| PKI   | Public Key Infrastructure                                     |
| PON   | Passive Optical Network                                       |
| POTS  | Plain Old Telephone Service                                   |
| PPP   | Point-to-Point Protocol                                       |
| PPPoA | PPP over ATM  |
| PPPoE | PPP over Ethernet   |
| PPV   | Pay Per View  |
| PS    | POTS or ISDN Splitter   |
| PVR   | Personal Video Recorder                                       |
| QoS   | Quality of Service  |
| RFT-C | Remote Feeding Telecommunication circuit – Current limited    |
| RFT-V | Remote Feeding Telecommunication circuit – Voltage limited    |
| ROW   | Right Of Way  |
| SDH   | Synchronous Digital Hierarchy                                 |
| SECAM | Séquence Couleur Avec Mémoire (Sequential colour with memory) |
| SME   | Small-Medium Enterprise                                       |
| SNMP  | Simple Network Management Protocol                            |
| SNR   | Signal-to-Noise Ratio   |
| SOHO  | Small Office – Home Office                                    |
| SONET | Synchronous Optical Network                                   |
| STB   | Set-Top Box   |
| TDM   | Time Division Multiplexing                                    |
| VBI   | Vertical Blanking Interval                                    |
| VBR   | Variable Bit Rate   |
| VC    | Virtual Connection  |
| VDSL  | Very high-speed Digital Subscriber Line                       |
| VLAN  | Virtual Local Area Network                                    |
| VoATM | Voice over ATM  |
| VoD   | Video on Demand   |
| VoDSL | Voice over DSL  |

|       |  |
|-------|--|
| VoIP  | Voice over IP                            |
| VP    | Virtual Path                             |
| VPI   | Virtual Path Identifier                  |
| VPN   | Virtual Private Network                  |
| VTP   | VDSL Termination Processing              |
| VTP/D | VTP and/or VTPD                          |
| VTPD  | VDSL Termination Processing and Decoding |
| VTU-C | VDSL Termination Unit – Central Office   |
| VTU-R | VDSL Terminal Unit – Remote              |
| WDM   | Wavelength Division Multiplexing         |

## 5 Architecture and services

### 5.1 Introduction

This Supplement is focused on broadband access networks that use VDSL technology to reach the customers. This transmission technology can carry bandwidth-demanding services to both residential and business customers, exploiting the high-value existing telephone copper distribution network infrastructure.

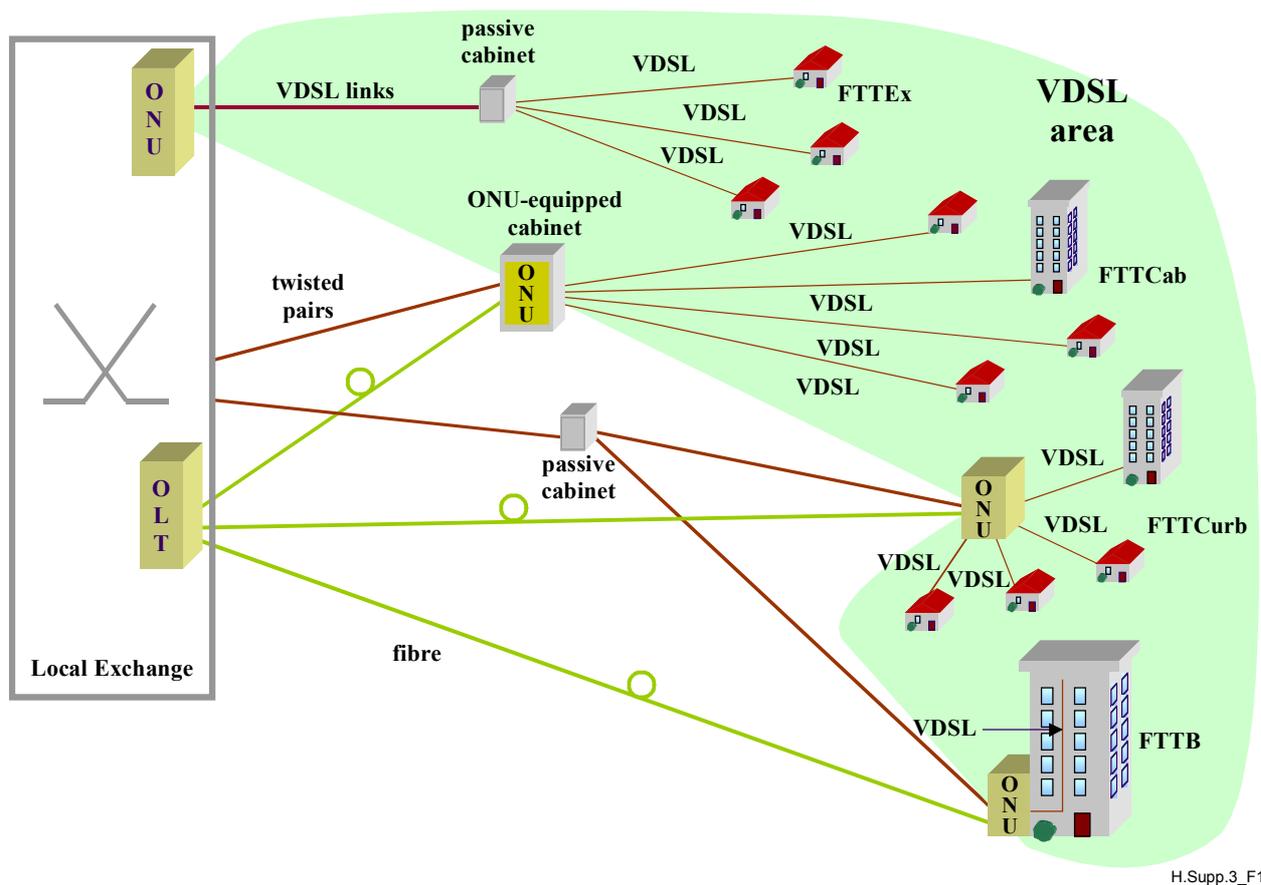
VDSL stands for Very high-speed Digital Subscribers Line. Like ADSL, VDSL capabilities are dependent on the distance between the end-customer and the operator equipment and the condition of the existing copper plant supporting the services. In all cases, as with ADSL, the idea is to use the telephone copper pairs to transport high bandwidth services to the customers.

In its design, VDSL is able to support various bit rates, in asymmetrical and symmetrical mode, depending upon loop conditions.

ITU-T Recs H.610 and H.611 are based on operator interest in both of the frequency plans defined in ITU-T Rec. G.993.1 Annex A (formerly known as plan 998) and Annex B (formerly known as plan 997) and the bit rates reported in Table 1.

**Table 1 – Bit rates of interest for the Operators**

|               | <b>Asymmetric profiles</b>                                     | <b>Symmetric profiles</b>                   |
|---------------|--|---|
| North America | 22 Mbit/s /3 Mbit/s<br>15 Mbit/s /1 Mbit/s                     | 13 Mbit/s<br>6 Mbit/s                       |
| Europe        | ETSI A4 (23 Mbit/s /4 Mbit/s)<br>ETSI A3 (14 Mbit/s /3 Mbit/s) | ETSI S3 (14 Mbit/s)<br>ETSI S1 (6.4 Mbit/s) |



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**Figure 1 – Architecture of the VDSL access system in the operator network**

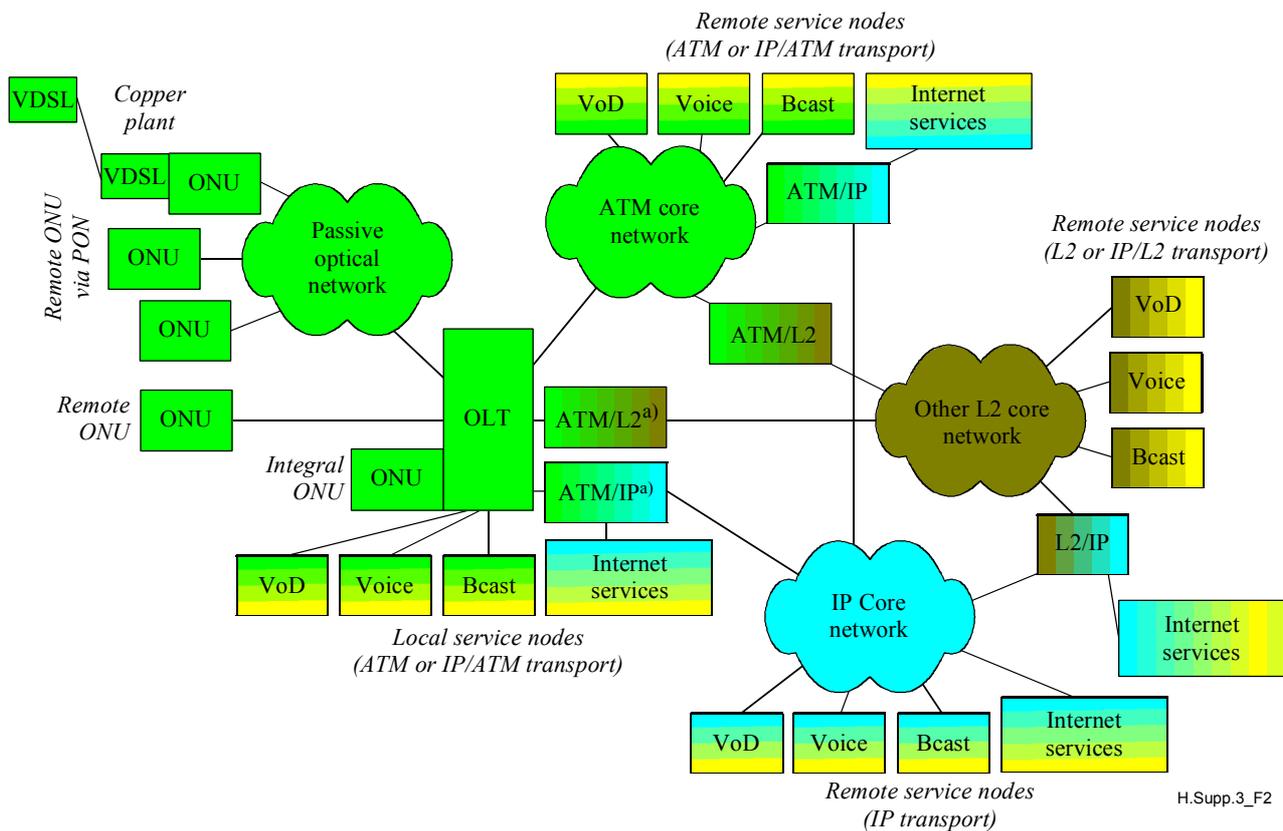
Both asymmetrical and symmetrical services are expected to be deployed in each market served. Asymmetrical services are typically focused on the residential market, whereas symmetrical services are typically targeted at the SME/SOHO markets.

In asymmetrical mode, the available bandwidth allows for the delivery of voice services, high-speed Internet, interactive applications and various video centric services to the end users, all this simultaneously on the same copper pair. This mode is well suited for the residential market.

The symmetrical mode, on the other hand, is well suited for the business market where flow of information is more than likely to be bidirectional for data and file transfers and web access.

## 5.2 The Full-Service VDSL platform architecture

Figure 2 gives a pictorial representation of the Full-Service VDSL network configuration. As shown, the various services (Internet, POTS/ISDN and video) are aggregated at the Optical Line Termination (OLT), which then distributes the content via a fibre link to the Optical Network Units (ONU) connected to it.



<sup>a)</sup> A local ATM/IP and/or ATM/L2 service node may be implemented in the same equipment as the OLT (the ATM interface becomes internal to the equipment).

**Figure 2 – FS-VDSL platform architecture**

It should be pointed out that the same manufacturer typically provides the OLT/ONU combination, because the OLT/ONU design often includes transport of proprietary information on the fibre link in addition to the standard service content. Proprietary information can be for maintenance purposes or for more effectively managing the flow of information between the two entities. In reality, the OLT/ONU combination should be viewed logically as a single entity. The fibre link between both is simply an extension between both backplanes.

In order to keep the data rate manageable across the platform for delivery of high bandwidth broadcast services, multicasting should be applied at the appropriate points.

### 5.3 Services description

The large 2-way bandwidth available with VDSL enables services requiring large bandwidth, e.g., video, to be offered to customers. Several services, available on copper pairs to different home appliances simultaneously, are reported in the following clauses.

Based on the number of simultaneous TV channels to be offered, the system should be capable of dynamically allocating bandwidth to either TV- or PC-based services. This is referred to as Dynamic Bandwidth Allocation (DBA).

#### 5.3.1 TV-based service descriptions

This clause discusses the services that could be deployed as part of the TV-based services offering. The list is not all-inclusive, however it represents the majority of the features currently provided or planned on competitive networks. Table 2 lists the typical bandwidth associated with some TV-based services offerings.

In order not to unduly increase the complexity and the cost of the FS-VDSL platform, some technical constraints have been taken into account in the implementation of the services offering.

**Table 2 – TV-based services**

| <b>TV-based services</b>   | <b>Typical bandwidth (downstream)</b> | <b>Note</b> |
|--|---------------------------------------|-------------|
| Broadcast TV – e.g., MPEG2   | 1 to 6 Mbit/s                         | 1, 3        |
| High-definition TV – HDTV  | 6 to 19 Mbit/s                        |             |
| Pay Per View and NVoD – e.g., MPEG2  | 1 to 6 Mbit/s                         | 1           |
| VoD – e.g., MPEG2  | 1 to 6 Mbit/s                         | 1           |
| Navigator and EPG (can be locally launched and updated in non real time)   | Less than 0.5 Mbit/s                  |             |
| Picture in Picture – two MPEG2 channels  | Up to 12 Mbit/s                       | 1, 2        |
| Picture in Browser – one MPEG2   | Up to 9 Mbit/s                        | 1, 2        |
| Personal Video Recorder PVR – replay MPEG2 file off hard disk  | 1 to 6 Mbit/s local                   | 1           |
| iTV – TV telephony features  | Less than 64 kbit/s                   |             |
| – TV browser (same as Internet access rates)   | Up to 3 Mbit/s                        |             |
| – TV e-mail (same as Internet access rates)  | Up to 3 Mbit/s                        |             |
| – TV Instant Messaging (same as Internet access rates)   | Up to 3 Mbit/s                        |             |
| – TV Chat (same as Internet access rates)  | Up to 3 Mbit/s                        |             |
| – TV on-screen notification  | Less than 64 kbit/s                   |             |
| – TV interactive games (same as Internet access rates)   | Up to 3 Mbit/s                        |             |
| – TV Audio Juke Box  | Less than 128 kbit/s                  |             |
| Video conferencing   | Up to 2 Mbit/s                        |             |
| NOTE 1 – Expect that video compression techniques will advance to enable lower bandwidth for both standard definition digital video encoding (1 to 3 Mbit/s), and HDTV (6 to 19 Mbit/s).                         |                                       |             |
| NOTE 2 – More efficient solutions could be available.  |                                       |             |
| NOTE 3 – Satellite transmissions are using higher bit rates (up to 15 Mbit/s peak), but VDSL has physical limited bandwidth, so video transrating could be required in order to allow the provision of services. |                                       |             |

### 5.3.1.1 Broadcast TV

Broadcast TV is a traditional digital television service comprising a single video stream as well as one or more stereo audio streams (multiple languages). The industry standards for encoding should be followed (e.g., MPEG). The signals are transported over the VDSL platform and decoded at the VTPD or at the set-top box(es). The TV signal is decoded back to its original state being analogue form, e.g., NTSC/PAL/SECAM with Dolby AC3 or Musicam audio. These requirements may apply for all Video/Audio content delivery services as described in this clause.

Certain content and features must also be "passed through" such as VBI data (for close caption text, etc.) and Macrovision copy protection for analogue channels. These requirements may also apply for all Video/Audio content delivery services as described in this clause.

The broadcast signals typically comprise Local (e.g., local city, community or closed circuit), national (e.g., Fox, Speedvision) and international TV channels (e.g., BBC, CNN).

Due to local and regulatory restrictions the system must be able to control the "black-out" of certain programs (usually sporting events). The "black-out" area is typically defined by billing address or geographical location.

The system must also be capable of offering packages of channels based on local interest as well as thematic/genre groups such as News, Sports and Kids channels. Certain channels can also be offered individually such as adult channels.

#### **5.3.1.2 High-Definition TV**

HDTV content is becoming more readily available as mandated by the FCC in the USA. At the moment there is relatively limited content available other than some Network feeds, Sporting events and Movie/PPV content. HDTV requires HD encoders and set-top box decoders. The standards dictate 19.2 Mbit/s encoding for HDTV content; however, as this may not always be practical for carriers using VDSL technology, innovative encoding techniques are encouraged to achieve high quality TV at much lower bit rates.

#### **5.3.1.3 Broadcast audio**

This stereo audio service is delivered similar to Broadcast TV; however, the video signal is typically replaced with artist and song/album text information. DMX is an example of this service. The text information can be encoded in MPEG or delivered by other more cost-effective means to the set-top box (data stream).

#### **5.3.1.4 Pay Per View (PPV)**

This service involves streaming movies or special events (e.g., boxing, and football). These signals are typically MPEG-based digital broadcast channels and hence the customer does not have VoD controls. A request is made to join the session and granted at the scheduled start time. Some providers may allow a cancellation period and a buy window (before and after start).

Near-VoD is also another method of delivering PPV. In this case, a movie is streamed on several channels with start times typically staggered every 15 to 30 minutes. The end user can navigate between these channels to jump ahead or jump back during the movie within a predetermined NVoD viewing window.

PPV should not be limited to a single program or channels. A PPV purchase could also include multiple events (e.g., complete set of Star Wars movies over a weekend) and multiple channels (NCAA playoffs).

In order to prevent unauthorized purchases, the system (EPG) should include a "Purchase PIN" in addition to the "Parental Control PIN".

#### **5.3.1.5 Video on Demand (VoD)**

In a true VoD service, the end user accesses the movie from a library directory. The library may include a search engine that accesses movie descriptions and ratings. Parental and Purchase PINs must be included to avoid unauthorized purchases. As with PPV, the encoding is typically based on MPEG digital video.

VoD controls typically include "VCR type" controls (Pause, Play, Fwd, Rwd) as well as additional "DVD type" controls (skip ahead, back, nX fast forward) and features (additional info, interviews, angles and clips).

Access to the movie is usually controlled by business rules such as predetermined VOD viewing window or number of plays allowed per purchase.

#### **5.3.1.6 On-screen navigator**

With many new services now available on the TV set, an on-screen navigator is usually essential enabling the customer to easily navigate between the various Broadcast/PPV/VOD service segments, the EPG, the interactive TV applications and the system configuration and customization screens, as well as other services which may be delivered to the TV in future.

### **5.3.1.7 Electronic Programme Guide (EPG)**

A large multi-channel environment renders the traditional paper TV guide impractical. A user-friendly EPG enables the customer to quickly scroll through programming, view program descriptions and ratings, search for a title, actor or key word, set reminder (force tune or record), set parental controls and PIN numbers, view purchases, view account and service provider information and alter account subscription. A typical EPG will include at least 7 days of programming information.

The EPG may also provide a PIP (Picture In Picture) video window and audio pass through capability.

### **5.3.1.8 Picture in Picture (PIP)**

The inclusion of a PIP feature as part of the VTPD (multiple decoder STB that includes the VDSL Modem) may be desirable.

The simplest method is to enable two broadcast signals from the set-top box to connect to a customer's PIP dual tuner TV set.

The VDSL VTPD solution however has the added capability of overlaying two of the broadcast streams and decoding to a single output stream. In this case a PIP-capable TV set is not required. The customer could also have the capability to reverse the video feeds, disable/enable PIP feature, change channels in one or both windows, resize the PIP window and move the PIP around the screen. One-touch toggle control would be preferred for ease of use.

Creative methods of displaying the content in the PIP window are encouraged to minimize bandwidth required.

### **5.3.1.9 Picture in Browser**

Similar to PIP, this feature enables the end user to set to TV signal in a window overlaid onto, or designed into, the browser page.

As with PIP, the end user should be able to disable, resize, change the channel and move the window around the screen. One-touch toggle control would be preferred for ease of use.

### **5.3.1.10 Personal Video Recorder (PVR)**

The PVR can be used for many opportunities. This clause will only describe customer-controlled "VCR-like" features.

Typical PVR functionality includes the ability to program the set-top box to record programs from the broadcast TV service. This is similar to a typical home VCR with the following exceptions: the PVR Hard Disk Drive (HDD) is included as an inherent component within the VTPD or set-top box, the customer uses the EPG to select the program to record (either one time or multiple times) and a filing system is included for easy movie management. DRM may need to be considered as content is stored digitally onto the PVR.

Due to the high bandwidth capabilities of the VDSL system, a network-server-based PVR solution may also be a desirable solution.

### **5.3.1.11 Interactive TV**

iTV can include many Internet based convergent applications. These make use of the high-speed data connectivity and always on features of the data service. These may also integrate into services offered by an ISP/ASP on a common customer account.

The Picture in Browser feature could be enabled with these services so that the end user can continue to watch/listen with a smaller program window and toggle to full screen in a one-touch command.

For iTV services, the use of a user-friendly remote control and wireless keyboard is essential.

- **TV telephony features**

Simple display of CLASS services on screen. This could include Caller number ID and Caller name ID, Caller log, web-activated calls. The end user should be able to enable/disable the display.

- **TV web browser**

A TV-based browser must run persistently (always on) when enabled. This will allow the customer to toggle between the TV programming and the web without having to re-launch the browser. The browser and set-top box must include TV-friendly features that make browsing on the TV a value-added service. These may include anti-aliasing colour correction, anti jitter, text resizing, margin wrapping, scroll bars, zoom features and some of the more traditional browser features. The browser should be compatible with many of the Internet plug-ins especially those focused on entertainment and graphics/animation.

- **TV e-mail**

A TV friendly e-mail client would include most of the typical PC features; however, these must be designed with the TV in mind. Compatibility with "attachments" must be considered.

The persistent connection should advise the customer of incoming messages. An end user should also be capable of setting several accounts for the home.

This service may either be server-based (IMAP, POP) or Web-based. The TV e-mail service may be linked to an ISP service hence creating convergence across the PC and TV appliances. The system should be compatible with popular Web-based mail systems.

- **TV instant messaging**

As with e-mail, the Instant Messaging client could be closely linked to an ISP service or can be treated independently. In order to maximize customer value, the IM service should be compatible with current web based IM services.

The persistent connection should advise the end user of incoming messages as well as identify on-line buddy lists.

The ability to run IM with PIP video window may lead to interesting service capabilities bridging discussion with a TV program.

- **TV notification**

The system should take advantage of the always-on high-speed connection and render on-screen notification messages associated with incoming e-mail and instant messages. The end user should have the ability to enable/disable this feature.

- **TV chat**

TV chat is similar to and compatible with existing chat services on the Internet today (chat rooms, news groups, dialog boxes, etc). The content rendering must be suitable for TV viewing.

The ability to run TV chat with PIP video window may lead to interesting service capabilities bridging discussion with a TV program.

- **TV interactive games**

Interactive games could represent single player and multi-player games. These should be server-based and either downloaded or played directly from a network server.

The simplest interactive games solution includes a walled garden selection of pre-loaded games on the set-top box.

The VTP/D and set-top capabilities (CPU, RAM, HDD, Flash, Graphics engine, etc.) will determine how compelling each game will be.

DRM rules will need to be considered.

- **Music juke box**

This service would enable the playback of audio titles selected from a library. The content may be downloaded to a hard disk or played back directly from a network or in-home server. DRM requirements should be considered. Several popular audio codec formats exist such as MPEG2, MP3, Real Networks and WMP.

### 5.3.2 PC-based service descriptions

This clause briefly discusses the services that could be deployed as part of a PC-based services offering. Table 3 lists the typical bandwidth associated with some PC-based services offerings.

**Table 3 – PC-based services**

| PC-based services   | Typical bandwidth (downstream) | Note |
|---|--------------------------------|------|
| High-Speed Internet Access (browsing, IM, chat, FTP, VPN access, etc)                   | Residential: Up to 3 Mbit/s    | 1    |
|   | SME/SOHO: Up to 6 Mbit/s       | 2    |
| Server-based e-mail   | As above                       |      |
| Live TV on PC   | 300 to 750 kbit/s              |      |
| Video on Demand   | 300 to 750 kbit/s              |      |
| Video conferencing  | 300 to 750 kbit/s              |      |
| Interactive games   | 300 to 750 kbit/s              |      |
| NOTE 1 – Typically asymmetrical with lower upstream rates such as 128, 256, 640 kbit/s. |                                |      |
| NOTE 2 – Typically symmetrical service.   |                                |      |

#### 5.3.2.1 High-speed Internet access

This service provides end user with access to the Internet. Several service options based on downstream and upstream bit rates and aggregated monthly bandwidth (e.g., downloaded bytes) may be delivered. This service is typically "always on". End users would access all web-based applications through this service (Webmail, chat, instant messaging, web browsing, FTP, etc). An ISP may also offer value-added services such as firewall, virus detection, parental controls, VPN corporate network access, etc.

#### 5.3.2.2 E-mail access

Traditional IMAP or POP mail service offered by the ISP.

#### 5.3.2.3 Live TV on PC

This service would involve the delivery of live video/audio media though the network. The content is typically encoded using standard web codecs such as Windows Media Player (WMP), Real Network, MPEG variants, AVI, MIDI, etc. The client PC typically uses a software codec to decode the media streams.

#### 5.3.2.4 Video on Demand

This represents a true VoD solution and can entail either real-time streaming or download to HDD. DRM will need to be taken into consideration.

### **5.3.2.5 Video conferencing**

This represents a bidirectional service between two or more end users, exchanging real-time video and audio information.

### **5.3.2.6 Interactive games**

This could include both local and network-based games and could be either single or multiple player games. In most cases, a portion of the game is downloaded to the client PC. DRM will need to be taken into consideration.

### **5.3.2.7 Voice services descriptions**

As with ADSL, it is currently a basic requirement that VDSL systems shall not disturb the lifeline telephony as carried on the copper loop within the current standard spectral frequencies using splitting filters. This includes all existing and planned CLASS features. The lifeline telephony service can be either POTS or ISDN BRA.

Derived voice can be implemented in different ways, e.g., over IP (VoIP) or over ATM (VoATM). It is envisaged that for residential customers up to 4 voice channels will be required, while 30 channels are probably adequate for business customers. Appropriate quality of service is required to meet the needs of customer's e.g., low cost, average quality service for residential customers, high quality, high availability for business customers.

Service features equivalent to existing CLASS features, Centrex, etc. are required to be supported.

## **6 Service offering**

Various combinations of services can be offered to customers. They are discussed within this clause. It should be noted that in all cases the POTS/ISDN service is also present on the copper loop infrastructure: existing standard POTS/ISDN frequencies and service features (example: CLASS, indicators, ring tones, dial-up modems, etc.) are assumed to be unaffected by the VDSL spectrum and services.

The communication services that can be offered are the ones described in 5.3, and can be classified as voice services, data services or video/media services. These services can be bundled in various combinations to suit the needs of the end customers.

This clause assumes that the services can be offered either individually or aggregated in bundled offers. It should be noted that it is expected that FS-VDSL systems will support the different service types over multiple networked appliances in the customer environment.

The following subclauses show examples of possible service scenarios and their implementations.

### **6.1 PC/Internet only service**

This segment represents the traditional ISP/ASP services. The service management facility will be responsible for the setting of bit rates in both upstream and downstream directions individually. This offering would consist of a VDSL connection providing a PC Internet access service alone for customers who are not interested in TV/entertainment segment of services, or SOHO and SME locations.

Bit rates could range from hundreds of kbit/s up to tens of Mbit/s depending on the specific service (e.g., Home working, point-to-point leased lines, etc.).

A number of PC and IP appliances may be simultaneously "on line".

PPPoE, PPPoA, Firewall and VPN software are assumed to be loaded within the IP appliance, PC or Internet Gateway products and not necessarily included within the VTP/D products.

## **6.2 Broadcast content and EPG**

An FS-VDSL system must enable the end user to access the main video services traditionally offered by a cable or DBS service provider in combination with additional services feasible with such a system.

There shall be the possibility to control the number of channels being delivered simultaneously, i.e., One-stream service, Two-stream service, etc. This offering would provide digital broadcast channels comprising digital video and audio programming. An electronic program guide (EPG) is essential to navigate and control activities. This guide should enable the end user to view future program listings (typically including titles, actors, producers, start-end-duration times, and program ratings). The EPG should also enable the user to operate search, reminder and record functions. The EPG is assigned to either a stream or a TV set location; hence, a separately controllable EPG is required for each TV stream in the customers' home

Parental control should also be supported.

These services are typically similar to those provided by the cable or DBS companies and hence, in certain countries, may require regulatory approval. The business model may consist of various channel packaging options ranging from large thematic groups (Locals, News, Sports, etc.) to individual channels (speciality programming, etc.).

On-screen display of Telephony CLASS information should be considered as part of this first basic service bundle. This is provisioned as a chargeable feature so it must be controllable by the system.

Note that text overlays may be required for the audio services showing for example artist and song information.

Basic VBI information and application must be supported within the broadcast service offering for closed captioning, teletext interactivity triggers, etc.

Note that iTV systems that embed information in the VBI, may need to be transported and be compatible with the VDSL systems. These may include Wink, ATVEF and HMP.

The addition of a Pay Per View service may be essential to compete with the Cable/DBS industry. PPV is a stream that is purchased by the consumer via the EPG system. The EPG listings must hence include a complete listing and purchase PIN code system.

The PPV purchase may be limited to a single event (i.e., a movie), multiple events on one or more channels and may also extend for a predetermined period of time (i.e., World Cup).

## **6.3 Broadcast plus Video on Demand**

It should be noted that VoD refers to the unicast provision of various content, (e.g., video, music, games) following a user request.

VDSL is capable of supporting network-based Video on Demand service along with the broadcast TV services. Although technologically the TV channel and the VoD channels are different, mainly one being broadcast (or multicast) while the other is on demand (or unicast) and fully controllable by the end user (stop, pause, play, ffwd, rwd). It is expected that the VoD channel will require similar bandwidth (video streams) to a typical broadcast TV channel, and as such, can share the same bandwidth on the VDSL line. For example a customer on a 3-TV stream system can simultaneously watch 1 VoD program and 2 broadcast channels, or 2 VoD programs and 1 broadcast channel, etc.

The purchased events must be authorized prior to viewing and tracked both on the EPG and back to the billing system.

## 6.4 Broadcast plus Internet on TV services

Ideally the IoTV service will be available on multiple sessions/appliances. For example a single-stream service could access one session... a three-stream service could access three IoTV sessions i.e., three impressions of the browser running independently. In order to create an effective service and customer experience, the IoTV applications must be capable of running persistently in the VTPD or set-top boxes. This will enable toggling for TV to IoTV (without relaunching the browser) as well as allow for addition value-added features such as e-mail, chat, IM and notification while watching a TV program.

## 6.5 Combined TV/Entertainment and PC/Internet

This offering is a combination of the above-mentioned services.

## 6.6 PC/Internet and derived voice services

This offering is a combination of the above-mentioned data services combined with derived voice services. For the consumer market a full service offering consisting of video, data and voice services is conceivable.

## 7 Digital content protection

As mentioned in the previous clauses, the VDSL system is designed to support the delivery of valuable content across the network. The service may include broadcast TV and other on-demand services such as Video On Demand, Pay Per View, etc. All content will be transported digitally. This clause identifies the security requirements for the types of service proposed in ITU-T Recs H.610 and H.611.

### 7.1 Purpose

This is to ensure that the FS-VDSL Recommendations will meet the content owners' expectations, regulatory rules covering commercial availability, as well as budgetary constraints. Security, in the form of digital content protection, is basically an economic exercise. It is a balancing act striking for equilibrium amongst the value of the content, the cost of providing the level of security desired, and the effort required for breaking the protection in order to gain access to the content without paying for it.

### 7.2 Goals

The general goals of the FS-VDSL digital content protection requirements and any implementation thereafter should address the following objectives:

- **Content protection** – Content must be protected to ensure integrity as well as not be accessed illegally either for simple viewing or more severely, for illegal copying and distribution.
- **Subscriber management** – To ensure that only legitimate users may access the content, FS-VDSL security must be capable of supporting processes such as user identification, authentication and authorization.
- **Secure network communications** – Transmission must be safe from eavesdropping, unauthorized modification, insertion, deletion, or replays.
- **Reasonable cost** – The cost and complexity to implement the security must be reasonable.
- **Network element interoperability** – Network elements, including CPEs, from multiple vendors must inter-operate and support the security requirements.

- **System renewability** – Any security implementation must support system renewability of security methods and algorithms when required.
- **Associative business rule capability** – The ultimate goal would be to associate the business rules and use policy with the content.

### 7.3 Security threats

The following summarizes the possible security threats that are relevant to the FS-VDSL system architecture and video services:

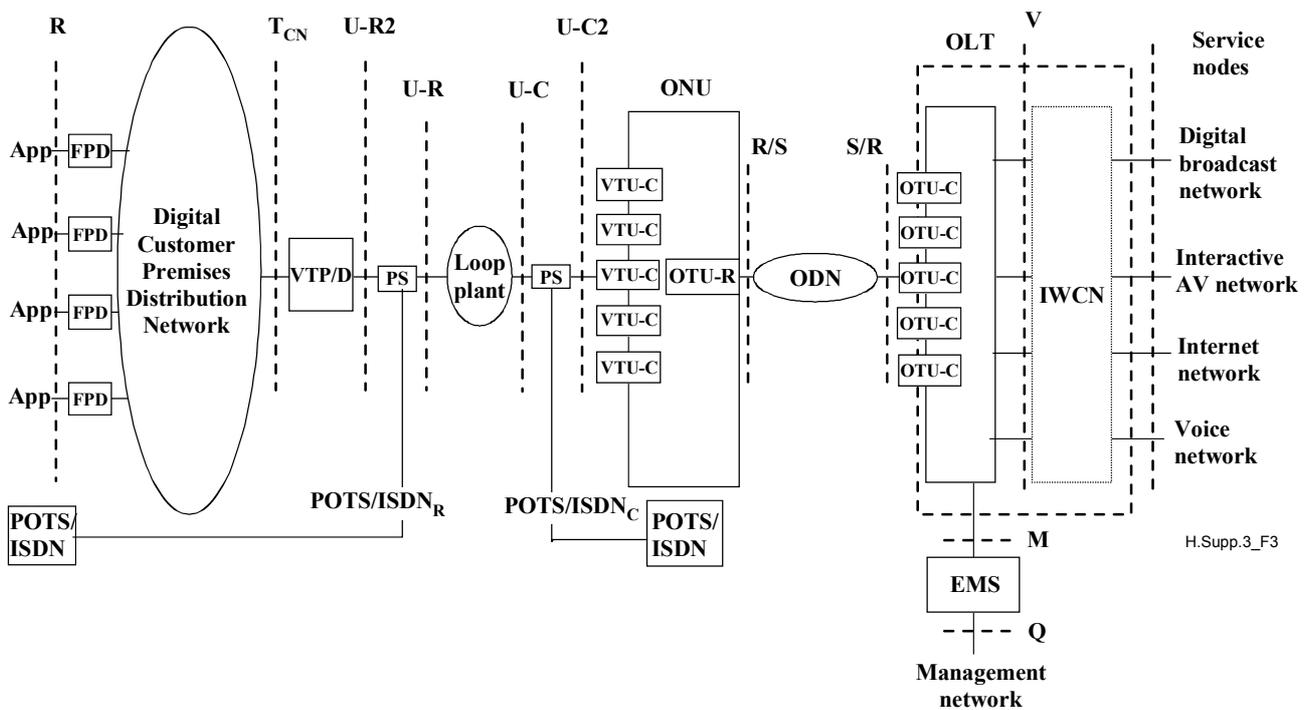
- **Network element clones** – One or more network elements may be masqueraded in order to redirect the content to illegal or fraudulent recipients. This is highly unlikely but nonetheless it is possible. Network elements must therefore support remote surveillance and be monitored continuously via certain control paths to ensure that the entire network is secured and intact. In addition, network elements should always be located in a physically secured environment.
- **Protocol attacks** – A weakness in the proposed FS-VDSL access protocol, if any, may be manipulated to allow illegal access to the content. This may include replay, eavesdrop, and man-in-the-middle attacks.
- **CPE clones** – CPE may be masqueraded as another CPE by duplicating its permanent identity and keys.
- **CPE attacks** – The CPE identity or the secret cryptographic keys may be obtained by either breaking the physical security of the CPE or by employing cryptanalysis. Further, the CPE data path, memory and/or storage may be broken into, digital content redirected and usage information removed.
- **CPE output copying** – Digital content may be copied illegally if output of "clear" digital content is allowed.
- **Repudiation** – A customer may repudiate a particular service (e.g., PPV-based VoD service) and deny responsibility for paying for it. As mentioned earlier, content protection being a balancing act, this type of fraudulent claim is usually not worth the effort to prevent. Most service providers rely on the service agreement contract the users signed when they subscribed to the service, and frequent billings to avoid the users from running up a substantial amount of outstanding charges.

### 7.4 FS-VDSL security model

The goal of the FS-VDSL security model is to protect digital video content from illegal use. Other services such Internet access, voice over IP (or packet) and the traditional POTS services are considered to be outside of the scope of the current clause.

#### 7.4.1 FS-VDSL system architecture re-visit

Figure 3 depicts the FS-VDSL system architecture. For details, refer to ITU-T Rec. H.610.



**Figure 3 – Schematic diagram depicting the FS-VDSL reference model**

#### 7.4.2 The security model

Based on the proposed VDSL access architecture model as depicted, the security model can be described to have the following functional components relevant to the targeted video services:

- 1) Digital Broadcast Network;
- 2) Interactive AV Network;
- 3) OLT;
- 4) ODN;
- 5) ONU;
- 6) VDSL Loop Plant;
- 7) VTP/D;
- 8) Digital Customer Premises Distribution Network;
- 9) FPD.

The Digital Broadcast Network and the Interactive AV Network are outside the scope of the FS-VDSL Recommendations. The other functional components and their respective security threats may be grouped together into security blocks as follows:

- **Network elements** – This includes the OLT, ODN and ONU. The possible threats are mainly Network Element Cloning and Network Level Protocol Attacks. OLT and ONU are vendor-specific network devices. Even though they are expected to be interoperable, the cost of cloning such devices and the effort required to insert them into the dedicated ODN network without alarming the system operation will be extremely high. Physically, the locations of the OLT and ONU are secured, and logically, ATM as transport protocol is extremely difficult and costly to break into. Still, it is important that the OLT and ONU provide continuous remote monitoring, surveillance and mechanised management capability to prevent such an attack taking place.

- **Access loop** – This includes the VDSL loop plant. The possible threat is network-level protocol attack. Since ATM is the transport protocol, the same argument will hold that it will be expensive to attack the content by tapping into the ATM virtual circuits. Nonetheless the threat of such attack is real. Since there is no possible way to physically shield the copper pair from tapping, this kind of attack can be less obvious and may not even cause any alarm to the system operation. There are two reasons why this kind of attack has not been widely tried. Firstly, the cost of a protocol analyser for tapping into the ATM VCs can be expensive. It can be as high as tens of thousands of dollars. Secondly, the content is not worth nearly as much. Obviously then, when operators start to transport valuable content such as first-run movies over VDSL, other means of protection such as encryption of the content may be required.
- **CPE** – This includes the VTP/D, Digital Customer Premises Distribution Network and FPD. Based on the proposed CPE architecture and the two recommended video delivery mechanisms (i.e., MPEG/ATM and MPEG/IP/ATM), the CPE security block may be further subdivided into the following two models:
  - **Centralized model** – For the centralized model, the VTPD functions as an end point of the ATM virtual circuits as well as the end point of the digital content delivery. The content is then decoded immediately. The output of the VTPD is in analogue TV (such as PAL, NTSC, etc.) or other analogue video formats. No content in digital format will be forwarded from the VTPD, over the Customer Premises Distribution Network, to FPD or any other devices. In the centralized model, the possible security threats are the CPE cloning, CPE attacks and CPE output copying. These threats can be counteracted by the requirements listed in the "CPE protection" section.
  - **Decentralized model** – For the decentralized model, the VTP, functioning as an ATM VC end point, terminates the ATM transport. The VTP, however, then forwards the content in its original digital format, over the Ethernet (with IP as the transport) continuously to other devices over the Customer Premises Distribution Network within the household. Security threats in the decentralized model are the network-level protocol attacks, CPE cloning, CPE attacks and CPE output copying. Since the content is transported in its original digital format over the Customer Premises Distribution Network, over IP and Ethernet, protocol attack can be achieved much more easily and IP protocol analysers are much less expensive than ATM protocol analysers. In fact, a personal computer with the proper software can function as an IP protocol analyser. For the decentralized model, content protection by means of encryption has become a definite requirement.

## 7.5 Security mechanisms

### 7.5.1 CPE protection

The following protection mechanism enables CPE (such as VTP/D and FPD) to properly protect the content and meet the necessary security requirements:

- Each CPE must have its own unique identity.
- For CPE that requires supporting and deciphering encrypted content, the CPE must have its own decryption key that is somehow wrapped with its own unique identity.
- The design and manufacture of the CPE must be tamper proof.
- CPE's own unique identification, any non-public keys, cryptographic algorithms or other secrets/confidential information can never be revealed.
- Change of the embedded unique identification cannot be attempted.
- The design of the CPE shall not allow switches, buttons, jumpers or traces to be cut or altered.

- The design of the CPE control functions and service menus shall not allow the content protection technologies to be defeated.
- The design of the CPE shall not allow the protected content to be exposed to unauthorized copying.
- The design of the CPE shall not allow the core security functions to be circumvented or defeated by using general tools such as screwdrivers, jumpers, clips and soldering irons or specialized electronic or software tools such as EEPROM readers and writers, debuggers or de-compilers.
- The design of the CPE shall render the CPE useless if an attempt to remove or replace the hardware components that implement security functions is detected.
- The design and manufacture of the CPE shall support the following content and key management functions:
  - Protected content shall not be present on any user accessible buses in unprotected analogue or in unencrypted, compressed digital form.
  - Keys used to support content encryption and/or decryption shall not be present on any user-accessible buses in unencrypted form.
- Keys, key generation and cryptographic functions shall be embedded in silicon circuitry or firmware that cannot be easily read.
- Software implementations of security functions shall be designed to perform self-checking of the integrity of its component parts and be designed to result in a failure of the security function to provide authorized authentication and/or decryption in the event of unauthorized modification.
- Failure of a security function shall cause the CPE to stop receiving and playing back the protected content.
- The resource of the CPE shall be sufficient to support content decryption and rules processing.
- The design and manufacture of the CPE shall support system enhancements through renewability for any changes of underlying security algorithms and/or processes, or future compatibility with other security recommendations and works in progress.
- The design and manufacture of the CPE must have an embedded system logging function and be able to support any client/server based audit trail application.
- The design and manufacture of the CPE must support remote diagnostics.

### **7.5.2 Access control**

A second method of digital content protection is provided by "access control". Different from the "content encryption" methods, Access control transports the content in the clear and uses "subscriber management" capability, either in the network or in the CPE, to ensure that only legitimate users may access the content. Access control, however, does not prevent a malicious user from stealing the content via a legitimate user account. This is especially true and tempting in the case of "decentralized CPE" deployment scenario. Access control must therefore be used only in the "centralized CPE" deployment, and even that, it must be coupled with "CPE protection" to provide a reasonable level of security.

### **7.5.3 Content encryption**

The third method of digital content protection is by encryption. Encryption techniques can be roughly segregated into two classes: symmetric and asymmetric encryptions. Symmetric encryption is efficient in terms of system resource demand and file size compactness, whereas asymmetric encryption is effective in terms of strong security and key uniqueness. For video encryption, which

means huge file sizes and high bandwidth processing, security industry in general employs both techniques, i.e., symmetric encryption for the content itself and asymmetric encryption for the key managements.

The following summarizes the implementation requirements for content encryption recommended for FS-VDSL systems:

- Uses industry accepted algorithms and key lengths to encrypt the content data payload. The encryption algorithm and technique deployed must be video format-agnostic and be able to support both non-real-time video such as VOD service, and real-time events such as live sports with "on-the-fly" encryption of live video streams.
- Best to encrypt the content at source of origination (e.g., encoding house, post production facility, studio) prior to distribution whenever possible.
- Content to remain encrypted in storage on network, distribution to consumer end users and in storage at consumer premises.
- Content decryption keys should be wrapped, delivered and stored separately from content.
- The encryption implementation, for mainly the key and not necessarily the content, must be flexible to allow easy and seamless integration with 3rd party e-commerce and subscriber management systems.
- Best to make use of network-based subscriber management system as well as unique CPE identification.
- The encryption system deployed should be interoperable with other industry security architectures such as 5C, CPCM, etc.

#### **7.5.3.1 Conditional access**

The term "conditional access" can be traced back to the analogue TV broadcast era. Analogue-based conditional access is still being used by most cable systems for protecting their premium channels. Basically, it tries to confuse the receiver by removing synchronization information or manipulate the gain control. For FS-VDSL systems "conditional access" means the use of cryptography for controlling the access to the digital content.

The basic principle of cryptographic conditional access is as follows: The content is encrypted at the video head-end site by a symmetric encryption technique known to both the encryption and decryption devices. The encryption key plus certain other encryption-related information together is called ECM (Entitlement Control Message). When the encrypted packet arrives at the receiver (i.e., the VTP/D or FPD), it is first sent through the CAM (Conditional Access Module) for decryption. CAM can be built directly into the receiver or in a secure device like a smart card. The implementation of CAM must be governed by the CPE protection guidelines. Symmetric encryption is not a strong encryption if key length is short (e.g., 64 bits), therefore the key needs to be changed over time. Key change frequency is implementation-specific but usually it should be proportional to how secure the encryption is. The general principle is to change the key before the content can be attacked by brute force cryptanalysis.

The symmetric keys are wrapped by an asymmetric encryption technique (e.g., PKI) in order to provide user authentication and non-repudiation capability. The actual implementation of the key and subscriber management systems is implementation-specific, and is outside the scope of this Supplement. Most service providers prefer conditional access, as they inherently become the gatekeepers of the key management, hence owning the business relationship with the end users.

Technically speaking, encryption-based conditional access and Digital Rights Management (DRM, to be discussed in the following clause) are similar. The differences between them are summarized as follows:

- Firstly, it is the system flow within the receiving device. Conditional access functions like a secure conduit (similar to the concept of IPSec) and content is in the clear before entering and after departing from the conduit, whereas in the Digital Rights Management system, content stays encrypted all the time and is decrypted only when displayed. Because of this fundamental difference, Conditional access is not recommended when copying of content from one device to another at the consumer location is allowed (e.g., super-distribution of content).
- Secondly, it is the core network security. Conditional access provides the secure delivery but it does not protect the distribution of the content before it enters the conditional access system. In order to ensure core network security, operators may need to extend the head end of the conditional access to the content source, resulting in unnecessary and complicated OAM&P issues.
- Thirdly, it is the digital content cache in the network. Conditional access is not designed to support network caching and has no concept of allowing content to stay encrypted within the pipe. As such, digital cache must be handled as if it is a content source, resulting in unnecessary and cumbersome encryption process, and complicated user management issues.
- Fourthly, it is the key management. Conditional access is meant for secure delivery of the content across a network. Digital rights management, on the other hand, is meant for securing the content and not necessary the delivery of it.

### **7.5.3.2 Digital Rights Management**

Digital Rights Management (DRM) is an emerging technology that allows digital content to be published on an unsecured network, and content owners (or their representatives) to maintain the copyright. Most DRM implementations are application-level cryptographic solutions. As such, the intent of the FS-VDSL Recommendations is not to specify what DRM implementation should be. Rather, this Supplement details the essential requirements to ensure that the VDSL system will support whatever the DRM implementation will be.

The following summarizes a set of guidelines on how to support DRM systems:

- CPE protection as specified in 7.5.1 must be fully enforced.
- CPE identification must be made available for and retrieved easily by DRM applications.
- CPE is capable of supporting and seamlessly integrating with any 3rd DRM solutions.
- CPE is capable of supporting the coexistence of more than one DRM applications, although these DRM applications may not need to be instantiated and run concurrently.
- CPE vendors may choose to support DRM at firmware or hardware level. However, this should not jeopardize the support of other DRM applications to run at application level.
- CPE, as specified in the CPE protection clause, must provide a secured storage for keys.
- CPE system log files must be easily retrievable.
- The solution should cover the encryption and content distribution directly from the owner sites, user and key management system, e-commerce for royalty and fee payments, and most importantly, the CPE management.
- The system should separate the rights information from the encryption and delivery of content.

- The system should store the rights information on the network and be able to deliver the rights information for decryption of the content on demand. However, for broadcast TV support, on-demand delivery of rights information may not be fast enough for channel zapping.
- The DRM solution should be format-agnostic.

## 8 Requirements for deployment

This clause deals with the deployment of active equipment in the outside plant. In the case of an FS-VDSL network, this active equipment is represented by the ONU as shown in Figure 8.

The following clauses provide data on some present access copper plants and some required features for an Optical Network Unit designed to operate in these access networks. This information was compiled by the operators involved in the preparation of the FS-VDSL Recommendations, and is intended to help equipment vendors in designing the most suitable solutions.

### 8.1 Access network for VDSL deployment

The VDSL technology allows the reuse of existing copper networks to carry broadband services to residential customers and SME. Since VDSL performance suffers degradation due to crosstalk and cable attenuation, a careful analysis of existing access networks is required to understand the level of VDSL penetration while minimizing investments in new infrastructures (for example, large investments in laying fibre in early stages of deployment). Given this intention, some information about network characteristics has been gathered. The network survey has focused on areas where it is thought that VDSL will be deployed initially.

#### 8.1.1 Today's copper networks

Two general models of typical access networks are represented in Figures 4 and 5: the former applies mainly in Europe, while the latter is more suitable for North America.

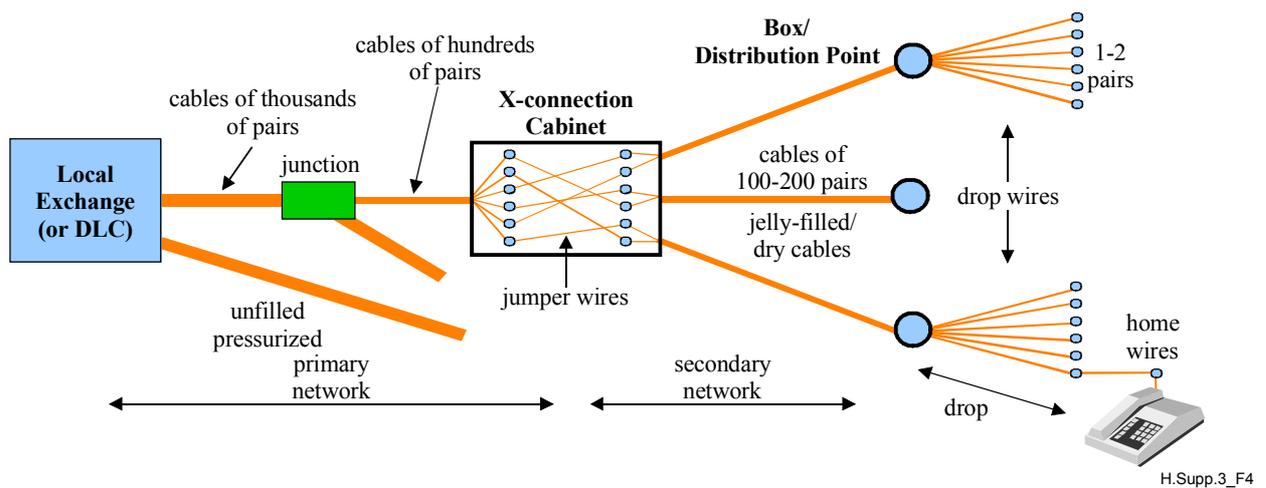
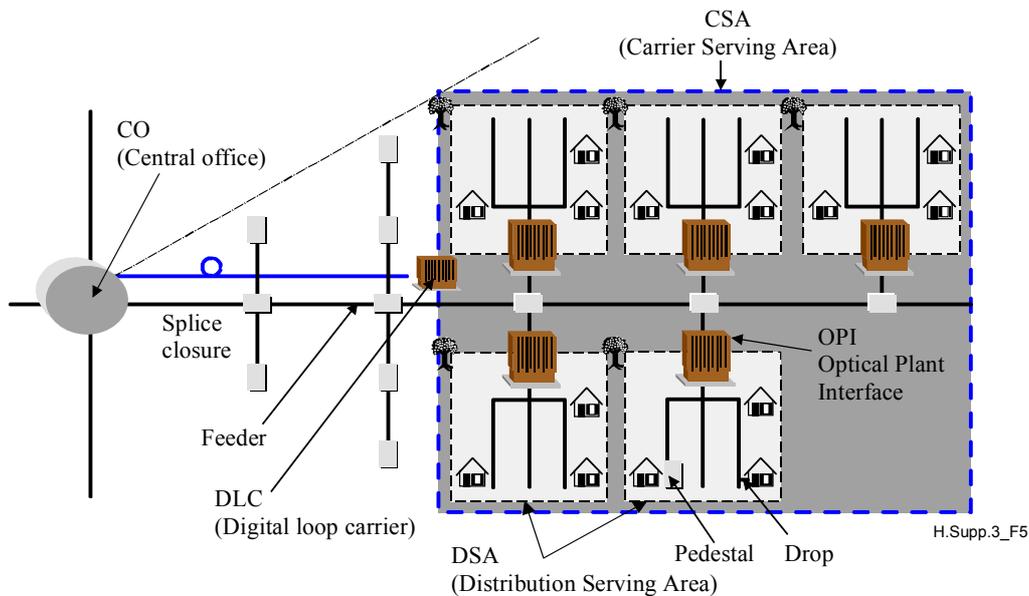


Figure 4 – General model of an access network (Europe)



**Figure 5 – General model of an access network (North America)**

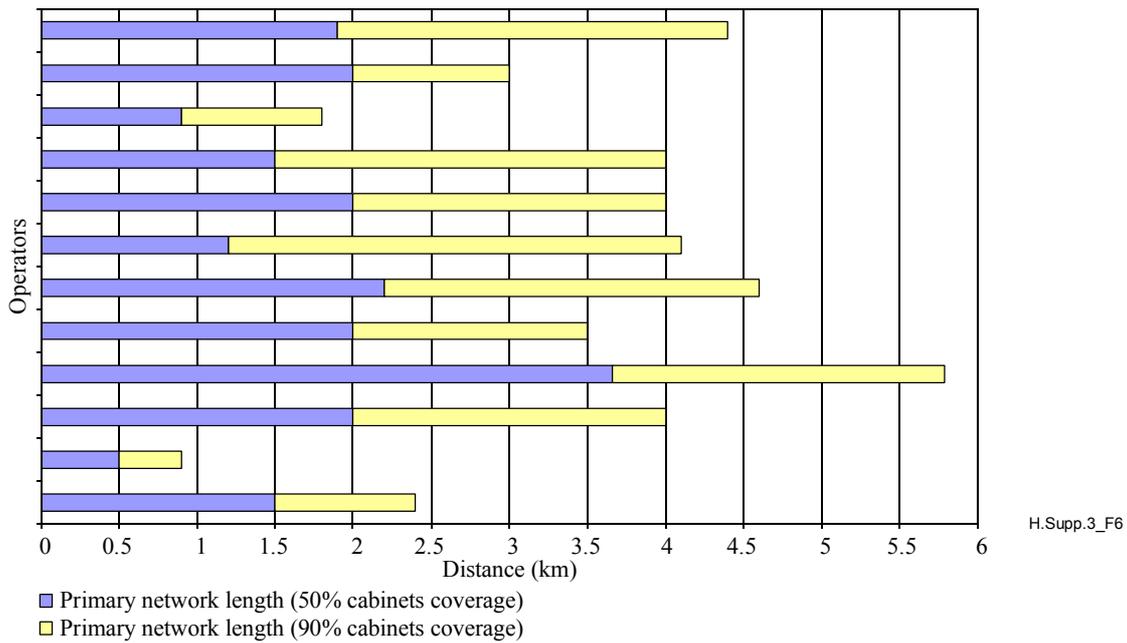
Hereafter some definitions of various entities of the access network are reported:

- **Cabinet/Optical Plant Interface (OPI)** – The cabinet/OPI is a major passive flexibility point where it is possible to access the twisted pairs cables for a significant number of customers. Typically the cabinet is within 100 to 1500 metres of the customer building. The cabinet location is an interesting point to collocate the ONU because of the large number of potential homes served.
- **Terminal box** – The terminal box represent the nearest telco-owned flexibility point to the customer. Typically the box would either be within the building or in the external plant and it is also known as the distribution point or pedestal. The box and the cabinet/OPI form part of the network operator-owned infrastructure and are subject to regulatory constraints. Sometimes in-building infrastructures are owned and managed by the building owner and not subject to regulatory constraints. Some operators are considering installing the ONU within an enhanced enclosure, maybe located in a controlled environment, able to feed a certain number of boxes or cabinets.
- **DLC** – The Digital Loop Carrier (DLC) is an active device usually located at the entrance of the Carrier Serving Area (CSA) to provide POTS services to the community. DLCs were deployed by operators to serve customers too far from the Central Office (CO) and are fed by fibre or DS-1 lines from the CO. DLCs can also serve the data function provided by the ONU, if so equipped.
- **CSA** – Carrier Serving Areas (CSAs) are geographical areas that delimit the ability by an operator to provide POTS service to a community. CSA definition has evolved with time to include the ability to provide DSL service. CSAs typically vary from within 1 km long (in dense areas) to 3 km (in suburban areas) in the residential segment to offer maximum service flexibility and provide data services without special loop engineering. The DLC is usually located at the entrance of a CSA.

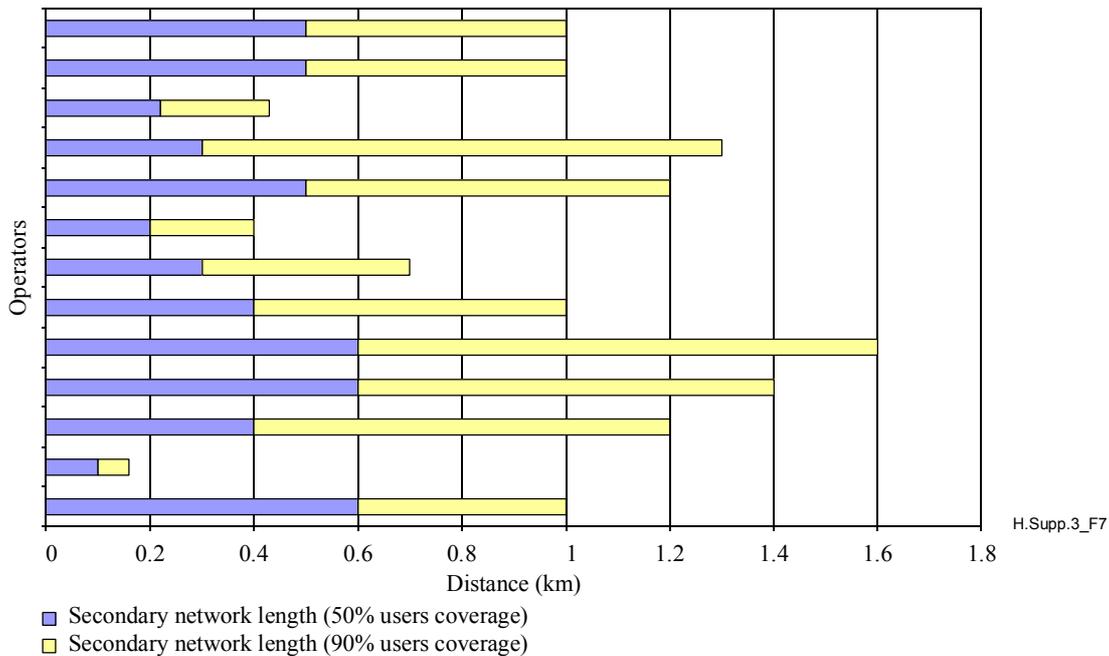
- **DSA** – The Distribution Serving Area (DSA) represents a geographical area where the last outside plant point of physical interconnection between the CO and the residential customers is located. At the entrance of the DSA, there is the OPI that can provide interconnection service to between 300 and 700 residential customers and is the interface point between the feeder and distribution facilities.

Obviously the deployment strategy of each FS-VDSL operators will be affected by the characteristics of the operator's access network. Some interesting figures provided by operators about their access network coverage are reported in Figures 6 and 7. The values are referred to the zones where VDSL will be deployed in first stages, not to all the access network coverage.

In Figure 6 the primary network length refers to the section between the CO/DLC and the cabinet/OPI (primary network/CSA); in Figure 7 the secondary network length refers to the section between the cabinet/OPI and the box (secondary network/DSA).



**Figure 6 – Example Primary/CSA network coverage for some operators**



**Figure 7 – Example Secondary/DSA network coverage for some operators**

Another interesting figure is the average number of households that can be served from a terminal box, a cabinet/OPI or a DLC, as reported in Table 4.

**Table 4 – Average number of household served at various points of the access network**

|                     | Operators |      |     |     |     |     |     |      |      |      |         |     |     |
|---------------------|-----------|------|-----|-----|-----|-----|-----|------|------|------|---------|-----|-----|
| <b>OPI/Cabinet</b>  | 250       | 600  | 250 | 500 | 250 | 200 | 350 | 200  | 500  | 400  | 200-400 | 350 | 110 |
| <b>Terminal box</b> | 20        | 25   | 20  | 8   | 4   | 12  | 7   | 1    | 8    | 4    | N/A     | 10  | 7   |
| <b>DLC</b>          | N/A       | 1890 | 250 | N/A | N/A | 200 | N/A | 1000 | 2000 | 2000 | 600-900 | 450 | N/A |

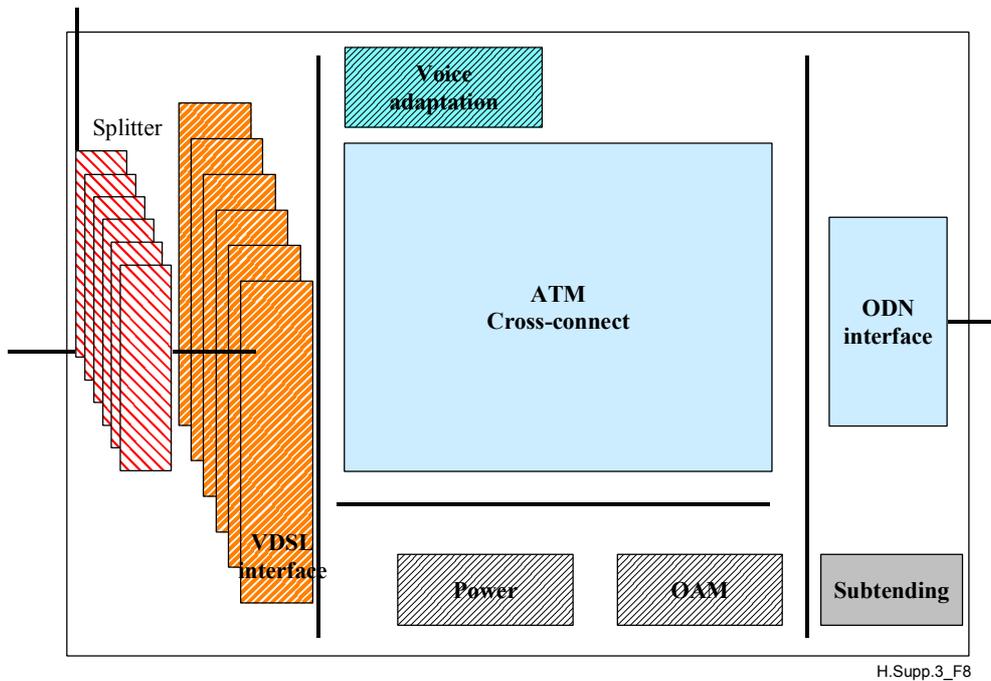
## 8.2 ONU deployment issues

Although the individual needs of operators vary widely because of their different regulatory, business and structural environment, the structure of access networks is similar and it is possible to define a common platform specification based on requirements from the operators involved in the preparation of the FS-VDSL Recommendations.

The Optical Network Unit is the most important network element for the deployment of VDSL in the access network and some information on the desired features of a FS-VDSL ONU have been gathered. These requirements are intended to represent some guidelines to assist vendors in designing the most suitable solutions for the operators, in order to obtain volume cost reductions. Complete detailed specifications for the ONU are not provided, but some highly desirable characteristics from the operators' point of view are outlined.

### 8.2.1 ONU general scheme

The ONU serves as an ATM cross-connect between the VDSL lines and the Optical Distribution Network. A general diagram of ONU functional blocks is represented in Figure 8. In addition to the blocks which perform the functions described above, there are other blocks necessary to power the equipment, manage the alarms, interface the fibres and the copper pairs and so on.



**Figure 8 – ONU functional blocks**

### 8.2.2 Powering

The issue of powering an ONU is strictly related to its size and varies widely between a small ONU serving tens of customers at the building and a large cabinet ONU intended for hundreds of customers. The power consumption is determined in the first place by the number of VDSL ports. The power drained by an ONU is expected to be no more than 1 watt per VDSL port on average, including all of its functional blocks, such as the optical section, fans, the alarm equipment, etc. Innovation to reduce ONU power consumption is strongly encouraged.

Several schemes have been considered for ONU powering. An ONU with 100 ports and more is expected to be locally powered and its back-up power (where implemented) is planned using batteries.

The majority of the operators consider battery autonomy from 2 to 8 hours at 25° C adequate. Since very low temperatures can significantly decrease this value, it is important to keep batteries at a suitable temperature. Also the lifetime of batteries is affected by the temperature variation and a minimum useful lifetime of 10 years in standard conditions (+25° C) is recommended.

It is also strongly recommended to use batteries requiring no maintenance and having low gas emission (and ensure that ONU enclosure is capable of dissipating gas emissions).

An optional scheme using remote powering is also highly desirable, particularly for FTTCab architecture, i.e., for outdoor-located ONU, where it could be more difficult to access the main electricity network and manage batteries. For remote power feeding two options are envisaged:

- a) Using dedicated power feed: Since usually there will be a need to lay a fibre to the street cabinet, it might be possible to lay a power cable with the fiber. With this approach it is expected to deliver about 200 watts up to 3 km.
- b) Using regular telco pairs: According to the limitations imposed by RFT-C and RFT-V circuit (ITU-T Rec. K.50). This solution seems to be suitable for small ONU, requiring few dedicated wire pairs for power feeding.

This approach is attractive because no batteries are required at the ONU, so that it is possible to rely on centralized feeding and backup capabilities, reducing significantly the size of the ONU and the operational costs (no battery management).

Other powering schemes have been discussed, such as solar panels and reverse powering from the user side, but they are not currently considered viable for power feeding the ONU.

### 8.2.3 Dimensions

The number of VDSL users that an ONU must be able to support is typically very different in a FTTCab or in an FTTB architecture. The target number of lines that an ONU should be able to serve at the Cabinet or at the Box in operators' opinion is reported in Table 5.

**Table 5 – Number of VDSL lines served by an ONU**

|               | Operators |       |         |        |                      |    |       |         |         |       |
|---------------|-----------|-------|---------|--------|----------------------|----|-------|---------|---------|-------|
| <b>FTTCab</b> | 800       | 60-90 | 200-300 | 80-140 | 48-64<br>4-8<br>8-16 | 40 | 48-96 | 100-200 | 128-160 | 12-48 |
| <b>FTTB</b>   | 50        | 4-30  | 20-40   | 20-40  | 8-16                 | 20 | 24-96 | 100+    | 128-160 | 4-12  |

Typically the ONU could serve the same number of users served today by a passive cabinet/OPI or terminal box; however, some operators are planning to have centralized ONUs serving a larger number of users, being connected to more than one cabinet or box. This could typically affect the configuration of wiring blocks.

The physical size of the ONU is related to factors such as the achievable number of VDSL ports, the total power consumption, and the heat dissipation and temperature issues. Also, accessibility to internal equipment for installation and maintenance is a consideration. Reducing the size of the ONU (compatibly with required functionalities) must be a driving point in designing the equipment since operators, especially in FTTCab scenario, could have difficulties in finding space and obtaining Right of Way/easements from local authorities or private land owners. Underground deployment is also considered an interesting way to solve this problem.

### 8.2.4 Enclosure protection rating

The enclosure of the ONU must comply with a level of protection IP 55 or IP 65, as described in EN 60529 (degrees of protection provided by enclosures (IP code)) or Bell Core GR-487 (Core) for North America

During transportation, the equipment shall withstand, without degradation, exposure to the environmental conditions described in ETS 300 019-1-2, Class 2.3: Public transportation.

### 8.2.5 Expandability

It is required for an ONU to have a certain degree of modularity regarding the number of VDSL lines that it can support. It must be possible to reach the maximum number of lines by adding VDSL modules when necessary. In this way operators can save extra costs, buying only the number of modules that they really need and having the possibility of expansion by the simple addition of new cards. A challenge in this scenario is to ensure the physical integrity of the ONU and avoiding exposing the electronics to the environment.

The suitable number of VDSL ports per module has been estimated to be 8-12 for a small ONU and 16-32 (if a high-density integration will be feasible) for a large ONU. These values allow a certain level of integration without giving up flexibility.

An ONU may include a subtending block to connect additional secondary ONUs to the OLT through the primary ONU ODN interface. This feature, considered optional, would allow a further degree of flexibility and expansion capacity.

### 8.2.6 Environment

An ONU is required to operate in the following environmental conditions:

- Class 3.2 of ETS 300 019-1-3 for stationary use at partly temperature-controlled locations is suitable for ONUs intended for FTTE<sub>x</sub> and FTTB (inside the building) deployment.
- Class 4.1 of ETS 300 019-1-4 for stationary use at non-weather protected location is required for ONUs intended for FTTC<sub>ab</sub> (outside environment) deployment.

In some countries Class 4.1E (non-weather protected locations – extended) of ETS 300 019-1-4 could be requested for ONUs designed for FTTC<sub>ab</sub> (outside environment) deployment.

The temperature and humidity ranges of the three classes are reported in the Table 6.

**Table 6 – Parameters for different environmental classes**

| Class                  | Unit | 3.2 | 4.1 | 4.1E |
|------------------------|------|-----|-----|------|
| Low air temperature    | °C   | –5  | –33 | –45  |
| High air temperature   | °C   | 45  | 40  | 45   |
| Low relative humidity  | %    | 5   | 15  | 8    |
| High relative humidity | %    | 95  | 100 | 100  |

Passive cooling (with non-forced heat transfer from inside the ONU to the outside) is the preferred solution, because it has lower costs, minimum maintenance and mitigates noise issues.

For underground deployment particular care must be paid to waterproof enclosures and cooling issues. To avoid gas emission from batteries, remote feeding schemes seem more appropriate.

### 8.2.7 EMC and protections

The ONU must be compliant with the following specifications about EMC and protections:

- ITU-T Rec. K.34 for electromagnetic environmental conditions;
- ITU-T Rec. K.43 for immunity requirements;
- CISPR 22 for emission;
- CISPR 24 for immunity;
- ETSI 300 386-2 for operation in environment "other than telecommunication centre";
- ITU-T Rec. K.45 for resistibility;
- GR-1089-CORE for EMC and electrical safety for telecommunications equipment;
- ITU-T Rec. K.35 for bonding configurations and earthing;
- ETSI EN 302 099 "Powering of Equipment in access network";
- ITU-T Rec. K.46 for lightning.

Some Operators may have to submit to more severe national requirements.

### 8.2.8 Availability

Operators require an availability of the access network of 99.99%. This corresponds to a maximum downtime of 53 min/yr for the access network section (this figure comprises the ONU/OLT, ODN, and copper pairs).

This 53 min/yr should be allocated to the active equipment and the network according to Table 7.

**Table 7 – Downtime per access network element**

| Access Network Element | Max. Downtime/yr/channel |
|------------------------|--------------------------|
| OLT                    | 10 min                   |
| Network (cables, etc.) | 17 min                   |
| ONU                    | 26 min                   |

It is assumed that the failed hardware is a field replaceable module. To calculate the Mean Time Between Failures (MTBF) of the active equipment it's necessary to define the Mean Time to Repair (MTTR) for each kind of device. The MTTR is assumed to be:

- 2 hours for the OLT;
- 6 hours for equipment outside the central office building (ONU).

The requirements on Mean Time Between Failure (MTBF), calculated according to the following formula:

$$MTBF = \frac{MTTR}{Downtime / yr}$$

are the following:

- OLT MTBF = 12.0 years;
- ONU MTBF = 13.8 years.

Each ONU and OLT manufacturer should, when requested, be able to supply design documentation showing component MTBF calculations and describing how component MTBF and component redundancy are used to meet operators' availability objectives.

### **8.2.9 Summary table**

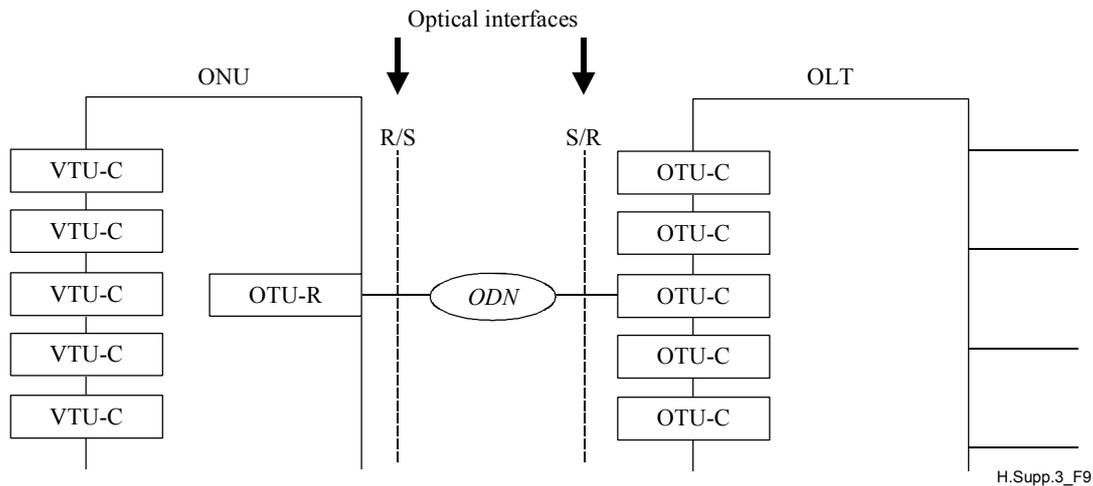
According to the considerations discussed in the preceding clauses, specifications for three different types of ONU are reported in Table 8 as an example and summary of the requirements of the operators involved in the preparation of the FS-VDSL Recommendations.

**Table 8 – Characteristics of three types of ONU**

|                                    | Large-sized ONU  | Medium-sized ONU                    | Small-sized ONU  |
|------------------------------------|--|-------------------------------------|--|
| <b>Number of lines served</b>      | 300  | 100                                 | 24   |
| <b>Local powering arrangements</b> | 230 V 50 Hz AC (Europe)<br>110 V 60 Hz AC (North America)  |                                     |  |
| <b>Remote powering</b>             | No   | Optional with dedicated power cable | Optional with telco pairs (RFT-C/RFT-V) or dedicated power cable |
| <b>Battery autonomy</b>            | Optional 2-8 hrs   |                                     |  |
| <b>Add-on cards modularity</b>     | 16-32  | 16-32                               | 8-12   |
| <b>Subtending module</b>           | Optional   |                                     |  |
| <b>Environmental conditions</b>    | ETS 300 019-4 Class 4.1 (Class 4.1E could be required) for FTTCab<br>ETS 300 019-3 Class 3.2 for FTTB  |                                     |  |
| <b>Cooling</b>                     | Active   | Active/passive                      | Passive  |
| <b>Heating</b>                     | Optional (see environmental conditions)  |                                     |  |
| <b>Availability (MTBF)</b>         | 13.8 years   |                                     |  |
| <b>Dual homing</b>                 | Optional   | Optional                            | No   |
| <b>Alarms</b>                      | Required (see OAM specification)   |                                     |  |
| <b>Metallic test access</b>        | Optional (see OAM specification)   |                                     |  |
| <b>EMC and protections</b>         | ITU-T Rec. K.34<br>ITU-T Rec. K.43<br>CISPR 22<br>CISPR 24<br>ETSI 300 386-2<br>ITU-T Rec. K.45<br>GR-1089-CORE<br>ITU-T Rec. K.35<br>ETSI EN 302 099<br>ITU-T Rec. K.46 |                                     |  |
| <b>Optical interface</b>           | See clause 9   |                                     |  |

## 9 Optical Distribution Network requirements

This clause discusses the segment of access network between R/S and S/R reference points of the FS-VDSL architecture. These are the interfaces between the OLT and the ONU, as described in Figure 9.



**Figure 9 – Optical interfaces between ONU and OLT**

The intent of this clause is not to specify the architecture of the optical part of the access network, but to provide specific requirements for the optical interfaces between the ONU and OLT.

Use of standardized interfaces (STM-1/4, OC-3/12, G.983, 1 Gbit/s interfaces) is preferred as it takes advantage of standards (with complete technical description), which are familiar to operators for addressing known deployment, implementation and measurement issues.

Since interoperability is not strictly required between the ONU and OLT from different manufacturers, use of proprietary interfaces may represent an opportunity for innovation to lower costs. It is also important to understand how these proprietary interfaces could evolve towards standardized ones.

In the case of proprietary optical interfaces, between R/S and S/R reference points of the FS-VDSL architecture, the operators have considered it necessary to outline a minimum set of requirements at the Physical Medium Level which proprietary interfaces must satisfy.

These requirements are given below:

- network architecture (point to point or point to multipoint);
- fibre type;
- bit rates for downstream/upstream directions;
- bidirectional transmission (1 fibre WDM or 2 fibres);
- operating wavelength;
- minimum optical attenuation range between S/R and R/S reference points;
- supported split ratio (point to multipoint);
- optical connectors.

No requirements are specified for the following:

- maintenance wavelength;
- launched power at the S/R and R/S points;
- sensitivity at the S/R and R/S points;
- equipment reflectance at the S/R and R/S points.

The operators involved in the preparation of the FS-VDSL Recommendations have expressed their preferences on the above requirements for proprietary optical interfaces. The results of this survey are given in Table 9. This table reports the view of the majority.

Regarding the proprietary interfaces, it should be noticed that, at the physical layer, the operators' preferences align very closely with existing standards (e.g., ITU-T Rec. G.983) with the need to consider evolutions towards 1 Gbit/s interfaces and beyond.

**Table 9 – Operator survey regarding optical interfaces**

| <b>Requirement</b>                                   | <b>Value</b>   | <b>Operators' answer</b> |
|--|--|--------------------------|
| Architecture   | P2P  | Y                        |
|  | P2MP   | Y                        |
| Fibre type   | G.652  | Y                        |
| Bit rate downstream                                  | 622.08 Mbit/s  | Y and higher rates       |
| Bit rate upstream                                    | 155.52 Mbit/s  | Y and higher rates       |
| Bidirectional transmission mode                      | 1 fibre WDM  | Y                        |
|  | 2 fibres   | Y                        |
| Optical wavelength                                   | 2 fibres<br>Up: 1.26-1.36 $\mu\text{m}$<br>Down: 1.48-1.58 $\mu\text{m}$ | Y                        |
|  | 2 fibres<br>1.26-1.36 $\mu\text{m}$                                      | Y                        |
| Minimum attenuation range between S/R and R/S points | 10 dB for P2P  | Y                        |
|  | 25 dB for P2MP   | Y                        |
| P2MP supported split ratio                           | 32   | Y and possibly others    |
| Optical connectors                                   | Standardized connectors  | Y                        |





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