

Redes Ópticas Metro-Acesso

=Parte 1=

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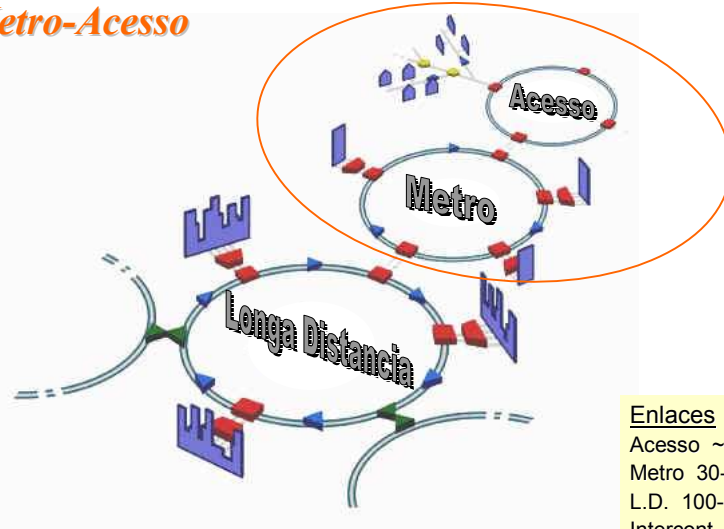


Sumário

- **Redes Ópticas de Acesso**
 - Redes Metropolitanas (distribuição/acesso)
 - Redes Locais
 - ❑ Redes FTTX
 - ❑ Redes HFC (híbridas)
- **Redes WDM**
 - Redes de Alta Agregação e Alta Capacidade
 - ❑ Metropolitanas (tronco)
 - ❑ Longa Distancia (tronco)



Natureza & Extensão Metro-Acesso



Enlaces
Acesso ~20 km
Metro 30-50 km
L.D. 100-500 km
Intercont. >1000,k



Capacidade & Alcance

2019

Redes Óticas (resumo)	Distancia/Alcance (enlaces)	Capacidade (enlaces)
Metro-Acesso (distribuição)	= até 20-30 km (típico)	= 1 a 10Gb/s (cada λ) WDM ~ 10-20 (fixo)
Metro-Tronco (backbone)	= 40-60 km	40-100 Gb/s (cada λ) WDM \approx 20 (reconfiguravel)
Longa Distancia (interurbano) (nacional e intl.)	100-500 km > 1000 km	100-200 Gb/s (cada λ) WDM >24 (reconfiguravel)



Redes Ópticas de Acesso

- ❖ Conceitos Básicos; Definições
- ❖ Arquiteturas e Padronização;
 - Gpon-Epon; Brasil e mundo;
- ❖ Protocolos de Acesso Óptico
- ❖ WDM no acesso;
- ❖ Redes HFC;
 - Produtos e Experimentos.



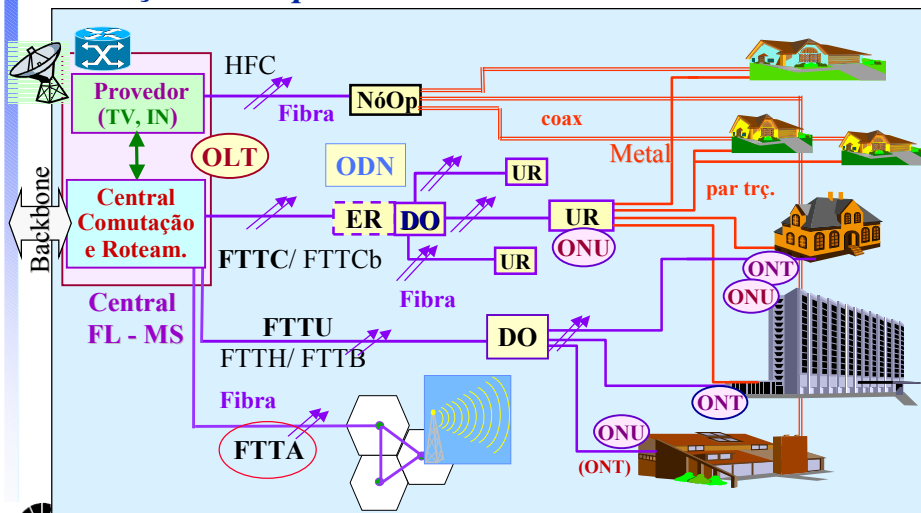
Rede Óptica de Acesso (alta capacidade):

- O que é uma Rede de Acesso? (qual o tamanho ?)
 - ☉ É essencialmente a Rede Local, que com advento de fibras e *wireless* se estende na região Metropolitana (Metro-Acesso);
 - ☉ mas pode se estender até *bem longe* (áreas rurais; pequenas cidades, mega-cidades;;); distancias até 20km é um bom número...
 - Definição :
 - ☺ É a rede que interconecta os Usuários finais (entre si e à Central de Serviços (comutada ou roteada)]; (pequenos e medios)
 - ☺ Redes corporativas e grandes usuarios não!
 - ☺ divide-se em *sub-redes*;
 - Rede Ótica Primária (transporte multiplexado)
 - Rede Secundária (acesso individual; ou quase...);
 - Rede Passiva (PON) ;
 - *rede secundaria pode ser cabeada ou wireless!*
- ...(cont.) >>>>



Redes Ópticas de Acesso

Evolução de Arquiteturas

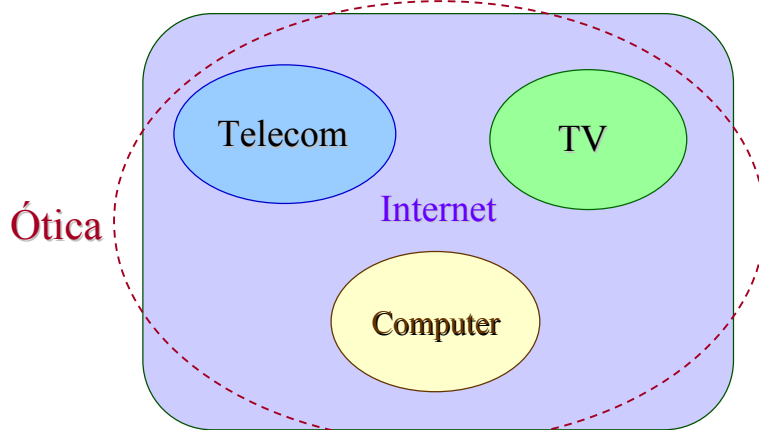


=> todas as siglas serão vistas adiante >>>



Mundo Digital Integrado - Redes Ópticas de Acesso

Panorama Tecnológico Atual --



=> .afinal "tudo" pela Ótica (muito Internet) !! (Internet não é Web!)

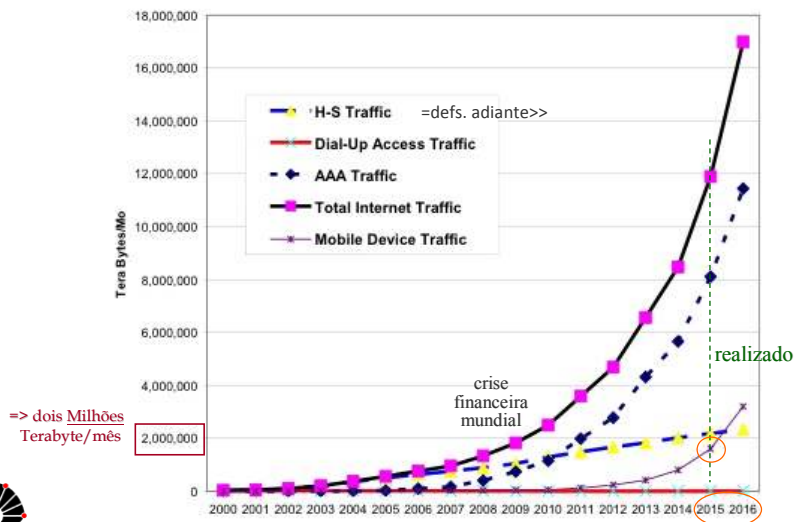


Redes de Acesso

Evolução de Tráfego Total

Internet Traffic and Component Comparison
in TeraBytes/mo.

Fonte: IGI - Intl. Gatekp
2011-12



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Redes de Acesso

Evolução de Tráfego Total

AAA traffic = All Metro-Access networks require secure and efficient provision of **Authentication Authorization and Accounting (AAA)** services, which forms the **backbone of service administration** including the mechanism to decide what services a user can access, at what Quality of Service (QoS) and how much to bill them.

Dial-up = acesso discado;

HS traffic = high speed. (banda-larga)



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Redes de Acesso

Evolução de *Tráfego Total*

Lightwave Staff (Dec. 2017)

- Verizon Communications Inc. (NYSE, NASDAQ: VZ) has a purchase agreement with Corning Inc. (NYSE: GLW) for the supply of **fiber-optic cable** and **associated hardware** to support its **wireless broadband networks**.
- Verizon will be installing up to **20 million km** of **fiber** each year through 2020. They will use the fiber as part of its efforts to create an **optical infrastructure** to improve 4G LTE coverage, accelerate 5G deployments, and support **high-speed broadband to residential and business customers**.

EXFO -- FTTA = fiber to the antenna (*video*) [Set.2015] >> >>

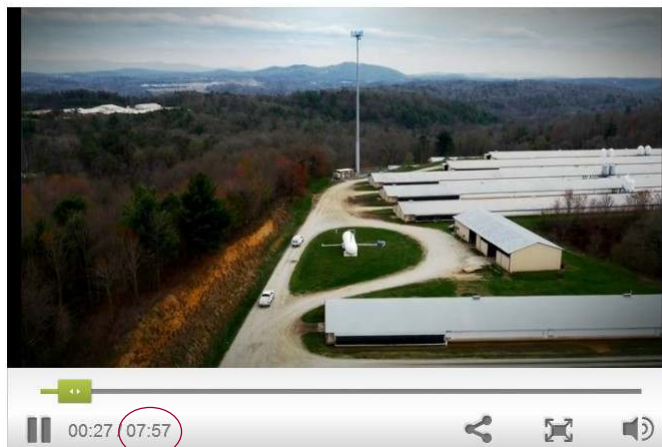
- <http://www.exfo.com/ftta-to-z>
- Fiber-to-the-antenna (FTTA) is being deployed every day, everywhere. But take a glimpse into the day-to-day of today's telecom daredevils: the **tower climbers** who are taking fiber to the top!!
- *This video shows Real world environment and how delicate fiber installation is. It also mentions all relevant parameters we'll be discussing... (at GPON specs)*



Taking Fiber to the Top

September 23, 2015

<https://www.youtube.com/watch?v=pBr5osVZ9Q4>



Contribuição Alan Teixeira , set.2021.



Redes Ópticas de Acesso (Telecom & Dados)

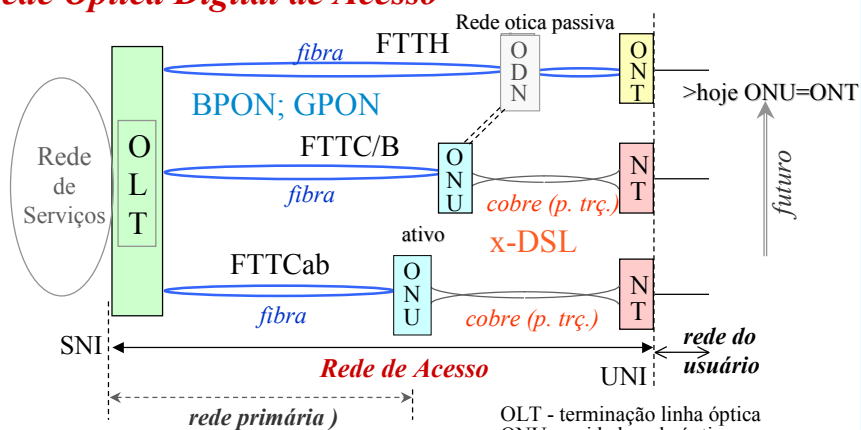
• Padrões ITU-T

- ❑ Soluções incluindo PDH, SDH, telefonia, e serviços banda-larga (IP) ;
- ❑ Convergência fibra-wireless não faz parte,... embora hoje seja o principal "driver" de tráfego no acesso.

<https://www.itu.int/en/ITU-T/publications/Pages/default.aspx>



Arquitetura e Evolução Rede Óptica Digital de Acesso



Ref.: ITU-T, G.984 (G-PON, 2008).
ITU-T G.983 (B-PON, Jan.2005) ;
iniciada como FSN-GX (Ago.96) ,

OLT - terminação linha óptica
ONU - unidade rede óptica
ODN - rede distribuição óptica
ONT - terminação rede óptica
NT - terminação rede (metal, p.trç.)
SNI - interface nó serviços
UNI - interface nó usuário



Arquitetura e Evolução

Rede Óptica Digital de Acesso

Definições

- ❑ **FTTH/U** - fiber to the home/user: (1:10) é hoje a solução integrada de fibra ao assinante, residencial ou peqs.empresas. (A idéia original de meados-anos 90, FTTH - fibra na "residência" não foi viável tecnô-econômica/te durante mais de uma década; hoje disponível em todo mundo).
- ❑ **FTTB** - fiber to the building: (1:50) esta ainda é a mais usada solução para assinantes de médio-grande porte (empresas) e em condomínios comerciais e residenciais de alta renda.
- ❑ **FTTC** - fiber to the curb: (1:100) fibra até a calçada, significando que a fibra vai até um nó da rede, pequeno, localizado em armário óptico (sem comutação). Condomínios de média-alta renda, comerciais ou residenciais. Comunidades rurais (remotas).



Arquitetura e Evolução

Rede Óptica Digital de Acesso

Definições (cont.)

- ❑ **FTTEx/Cab** - fiber to the exchange/cabinet: (1:1000) fibra até central remota/distribuída (armário ótico de distribuição com comutação*); difere FTTC pela abrangência, e pode incluir comutação e roteamento.
- ❑ **FTTA** - fiber to the antenna: (*new!*) fibra até ERB; conexão fibra ótica/celular móvel (*wireless*). Esta pode ser considerada a solução realmente do futuro (começando agora), em banda larga, usuários 4G (e 5G...):
 - ☑ 10 Mb/s estacionário; ~2-5 Mb/s movim. lenta; <2 Mb/s rápida;
 - ☑ **triple-play**: voz, dados&imagem; **video-real**;
 - ☑ um aspecto crucial das *redes wireless* é a estatística de trafego vs. capacidade instalada e disponível -- é frequente a instabilidade e saturação da rede.





Redes Ópticas de Acesso – BPON - GPON - EPON



Famílias BPON-GPON começaram final década de 1990; e não param mais...

- (pré-historia: há uma “optical local network” - PDH, 1994 -- ainda *in force!*)
- BPON - *broadband passive optical network* (ini, 1998) ; [atualiz. - *in force*]
 - G.983.1 (geral, 2005); 983.2 (gerencia 2002-2005); 983.3 (wavelength, 2001); g.983.4 (DBA, 2001) ; g.983.5 (sobrevivencia serviços, 2002) ;
- GPON - *Gigabit-capable PON* (ini., 2003)
 - G.984.1 (geral, 2003-2008); g.984.2 (physical layer, 2003); g.984.3 (transm. layer, 2004); g.984.4 (gerencia, 2004) ; g.984.5 (enhancement band, 2007) ; g.984.6 (extensao alcance, 2008) ; g.984.7 (longo alcance, 2010)
- EPON - *Ethernet-based optical access* (ini., IEEE, 2003)
 - G.985 (100Mb/s, anno); g.986 (1Gb/s, anno); g.987 (10Gb/s, 2010-2012)
- XG-PON - *10-gigabit PON* (g.987, 2010-2012)
 - *Atention:* notar que g.987 é a mesma(!) EPON-10G e XG-PON]



Redes Ópticas de Acesso – BPON -- GPON

- ❑ ITU-T Recomm. G.983.1 -- Broadband optical access systems based on Passive Optical Networks (B-PON) [Jan.2005] (revista)
 - This Recommendation is to describe flexible access networks using optical fibre technology. The focus is on a network to support services with a bandwidth requirement to include video and distributive services.
 - This Recommendation concentrates on issues relating to ATM over a passive optical network, other solutions are not precluded;
 - This Recommendation is part of the G.983.x series.
The other components of this series:
 - G.983.2 (2002), ONT management and control interface for B-PON;
 - G.983.3 (2001), Broadband optical access system with increased service capability by wavelength allocation;
 - G.983.4 (2001), Broadband optical access system with increased service capability using dynamic bandwidth assignment (DBA);
 - G.983.5 (2002), Broadband optical access system with enhanced survivability;
 - This Recommendation proposes the general characteristics for BPON based on operators' service requirements;



Requisitos da Rede PON (camada dependente do meio)

G.983.1
(2005)

- **8.2.1 Digital signal nominal bit rate**
- The transmission line rate should be a multiple of 8 kHz. BPON systems will have nominal line rates (downstream/upstream) of:
 - -- 155.52 Mbit/s/155.52 Mbit/s;
 - -- 622.08 Mbit/s/155.52 Mbit/s;
 - -- 622.08 Mbit/s/622.08 Mbit/s;
 - -- 1244.16 Mbit/s/155.52 Mbit/s;
 - -- 1244.16 Mbit/s/622.08 Mbit/s.



Requisitos da Rede PON (camada dependente do meio)

G.984.1
(2008)

Table I.2 – Examples of UNI and services

UNI (Note 1)	Physical interface (Note 2)	Service (Note 3)
10BASE-T ([b-IEEE 802.3])	–	Ethernet
100BASE-TX ([b-IEEE 802.3])	–	Ethernet
1000BASE-T ([b-IEEE 802.3])	–	Ethernet
[b-ITU-T I.430]	–	ISDN (BRI)
[b-ITU-T G.703]	PDH	DS3, (ATM, E1, E3)
[b-ANSI T1.102], [b-ANSI T1.107]	PDH	T1, DS3

NOTE 1 – There are many other services accommodated in GPON, but those services do not have specified UNIs.

NOTE 2 – Each item in the "physical interface" column is illustrated by the corresponding entry in the "UNI" column.

NOTE 3 – The column labelled "service" shows which services can be supported

PDH	Taxa	Canais de Voz (*)
Sigla	(Mb/s)	
E-0	0,064	1
E-1	2,048	30
E-2	8,448	120
E-3	34,368	480
E-4	139,264	1920

(*) equivalencia exata.

Ref.: ITU-T, G.984.1_GPON, Mar.2008)



Requisitos da Rede PON (camada dependente do meio)

Downstream

Esta tabela tem e mantém
parametros relevantes

ITU-T
G.983.1 (1998)

Revisão 2005
quase igual!

Nova
ITU-T G.983.1
Jan. 2005 (p.15-19)

Para uso profissional
recomenda-se verificar os
originais g.983.x e g.984.x



Table 4-Down-622, Optical interface parameters of 622Mbit/s downstream direction

Items	Unit	Single Fibre		Dual Fibre	
OLT Transmitter					
Nominal bit rate	Mbit/s	622.08		622.08	
Operating wavelength	nm	1480 - 1580		1260 - 1360	
Line code	-	Scrambled NRZ		Scrambled NRZ	
Mask of the transmitter eye diagram	-	Figure 6		Figure 6	
Transmitter reflectance	dB	N.A.		N.A.	
minimum ORL of ODN at point S	dB	more than 32		more than 32	
Mean launched power MIN Class B/C	dBm	-2/-2		-2/-2	
Mean launched power MAX Class B/C	dBm	+4/+4		+3/+3	
Launched optical power without input to the transmitter	dBm	N.A.		N.A.	
Extinction ratio	dB	more than 10		more than 10	
Tolerance to the transmitter incident light power	dB	more than -15		more than -15	
Nominal source type	-	MLM	SLM	MLM	SLM
Maximum RMS width	nm	-	-	1.4	-
Maximum -20dB width	nm	-	1	-	1
Minimum side mode suppression ratio	dB	-	30	-	30
ONU Receiver					
Receiver reflectance	dB	less than -20		less than -20	
Bit error ratio	-	less than 10 ⁻¹⁰		less than 10 ⁻¹⁰	
Minimum sensitivity Class B/C	dBm	-28/-33		-28/-33	
Minimum overload Class B/C	dBm	-6/-11		-7/-12	
Consecutive identical digit immunity	bit	more than 72		more than 72	
Jitter transfer	-	Figure 8		Figure 8	
Jitter tolerance	-	Figure 9		Figure 9	
Jitter generation in 1.3MHz bandwidth	UI RMS	0.02		0.02	
Tolerance to the reflected optical power	dB	less than 10		less than 10	

Direitos reservados Blue Sky Consulting

Requisitos da Rede PON (camada dependente do meio)

Upstream

Esta tabela tem e mantém
parametros relevantes

ITU-T
G.983.1 (1998)

Revisão 2005
quase igual!

Nova
ITU-T G.983.1
Jan. 2005 (p.15-19)

Para uso profissional
recomenda-se verificar os
originais g.983.x e g.984.x



Table 4-Up-155, Optical interface parameters of 155Mbit/s upstream direction

Items	Unit	Single Fibre		Dual Fibre	
ONU Transmitter					
Nominal bit rate	Mbit/s	155.52		155.52	
Operating wavelength	nm	1260 - 1360		1260 - 1360	
Line code	-	Scrambled NRZ		Scrambled NRZ	
Mask of the transmitter eye diagram	-	Figure 7		Figure 7	
Transmitter reflectance	dB	less than -6		less than -6	
minimum ORL of ODN at point S	dB	more than 32		more than 32	
Mean launched power MIN Class B/C	dBm	-4/-2		-4/-2	
Mean launched power MAX Class B/C	dBm	+2/+4		+1/+3	
Launched optical power without input to the transmitter	dBm	less than Min sensitivity -10		less than Min sensitivity -10	
Extinction ratio	dB	more than 10		more than 10	
Tolerance to the transmitter incident light power	dB	more than -15		more than -15	
Nominal source type	-	MLM	SLM	MLM	SLM
Maximum RMS width	nm	5.8	-	5.8	-
Maximum -20dB width	nm	-	1	-	1
Minimum side mode suppression ratio	dB	-	30	-	30
OLT Receiver					
Receiver reflectance	dB	less than -20		less than -20	
Bit error ratio	-	less than 10 ⁻¹⁰		less than 10 ⁻¹⁰	
Minimum sensitivity Class B/C	dBm	-30/-33		-30/-33	
Minimum overload Class B/C	dBm	-8/-11		-9/-12	
Consecutive identical digit immunity	bit	more than 72		more than 72	
Tolerance to the reflected optical power	dB	less than 10		less than 10	

Direitos reservados Blue Sky Consulting

Arquitetura da Rede de Acesso – OLT – Head-end

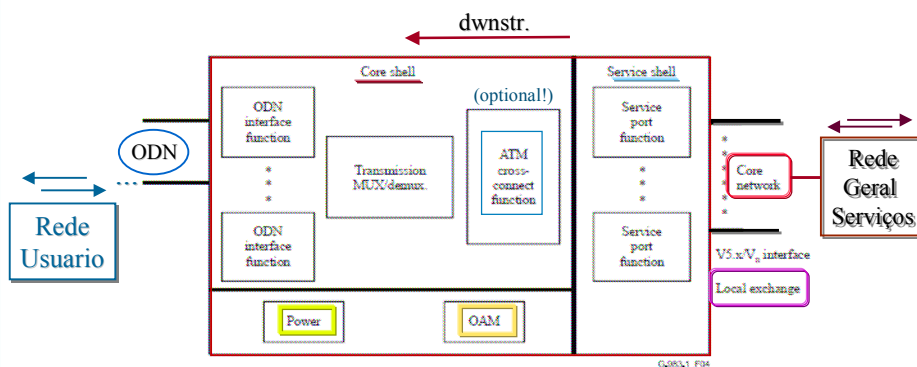


Figure 4/G.983.1 – Example of OLT functional blocks



Arquitetura da Rede de Acesso – ODN – rede passiva de distribuição

5.6 Optical Distribution Network functional block

- In general, the Optical Distribution Network (ODN) provides the optical transmission medium for the physical connection of the ONUs to the OLTs.
- Individual ODNs may be combined and extended through the use of optical amplifiers (see ITU-T Rec. G.982).

5.6.1 Passive optical elements

- The ODN consists of passive optical elements:
 - – single-mode optical fibres and cables;
 - – optical fibre ribbons and ribbon cables;
 - – optical connectors;
 - – passive branching components;
 - – passive optical attenuators;
 - – splices.



- ❑ Specific information required to describe passive optical components is described in = ITU-T Rec. G.671.
- ❑ Specific information required to describe optical fibres and cable is described in = ITU-T Rec. G.652.



Arquitetura da Rede de Acesso –

ONU/ONT -- Armário Ótico ou Caixa (*depende da rede*)

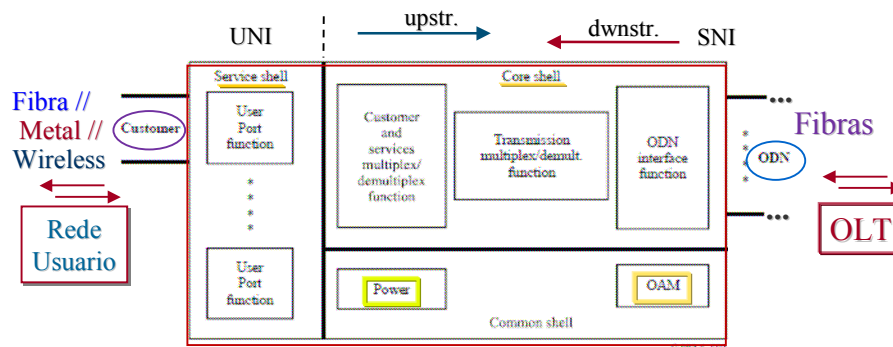


Figure 3/G.983.1 – Example of ONT functional blocks



Requisitos da Rede PON (*camada dependente do meio*)

☞ from GPON g.984.1 (Mar.2008):

8 Logical reach

Logical reach is the maximum distance between ONU/ONT and OLT except for the limitation of the physical layer. In GPON, the maximum logical reach is defined as 60 km.

9 Physical reach

Physical reach is the maximum physical distance between the ONU/ONT and the OLT. In GPON, two options are defined for the physical reach: 10 km and 20 km.

It is assumed that 10 km is the maximum distance for FP-LD to be used in the ONU for high bit rates such as 1.25 Gbit/s or above.

10 Differential fibre distance

In GPON, the maximum differential fibre distance is 20 km. This affects the size of the ranging window and provides compliance with [ITU-T G.983.1].

12 Split ratio

The larger the split ratio is for GPON, the more attractive it is for operators.

However, a larger split ratio implies greater optical splitting, which creates the need for an increased power budget to support the physical reach.

Split ratios of up to 1:64 are realistic for the physical layer, given current technology.

Anticipating the continued evolution of optical modules, the TC layer must consider split ratios up to 1:128.



Redes Ópticas de Acesso – BPON => GPON

- ITU-T Recomm. **G.984.1** - Gigabit-capable Passive Optical Networks (G-PON): General characteristics – [Mar.2008] (*in force!*)
 - This Recommendation describes a **flexible optical fibre access network** capable of supporting the **bandwidth requirements of business and residential** services;
 - **downstream** direction : systems with line rates 1.2 Gb/s and 2.4 Gb/s;
 - **upstream** direction :: 1.2 Gb/s and 2.4 Gb/s ;

=> Symmetrical and Asymmetrical (upstream/downstream) Gigabit-capable Passive Optical Network (GPON) systems are described.

 - **As much as possible**, this Recommendation maintains characteristics from ITU-T G.983.x- series. This is to promote backward-compatibility with existing optical distribution networks (ODNs) that complies with those Recommendations (**with revisions in force**);
 - This Recommendation proposes the general characteristics for **GPON** based on **operators' service requirements**;



Redes Ópticas de Acesso – GPON => XGPON

g.987 - XG-PON - 10Gb/s capable GPON (*Jan.2010*)

Scope

- This Recommendation addresses the general requirements of **10-Gigabit-capable** passive optical networks (XG-PON) systems, in order to guide and motivate the physical layer and the transmission convergence layer specifications.
- The **general requirements** include **examples of services, user network interfaces (UNIs) and service node interfaces (SNIs)**, as well as the principal **deployment configurations** that are requested by network operators. This Recommendation includes the system and operational requirements to meet the needs of supporting various business and residential applications.
- **As much as possible**, this Recommendation maintains characteristics from [ITU-T G.982], and the [ITU-T G.983.x], and [ITU-T G.984.x] series of Recommendations. This is to promote **backward compatibility with existing optical distribution networks (ODN)** that comply with those Recommendations.
- Furthermore, this Recommendation provides a mechanism that enables seamless subscriber migration from Gigabit PON (Generic term to represent both G-PON and GE-PON) to XG-PON using the wavelength division multiplexing (WDM) defined in [ITU-T G.984.x].
- There are **two flavours of XG-PONs** based on the upstream line rate: **XG-PON1, featuring a 2.5 Gbit/s upstream path, and XG-PON2, featuring a 10 Gbit/s one**. The initial phase of this Recommendation **only addresses XG-PON1**. XG-PON2 will be addressed at a later phase, when the technology becomes more mature. (*it is now!*)



Redes Ópticas de Acesso – NG-PON2 XG-PON <=> NG-EPON (10G & 40G)

Mar.2013

NG-PON2 systems requirements include :

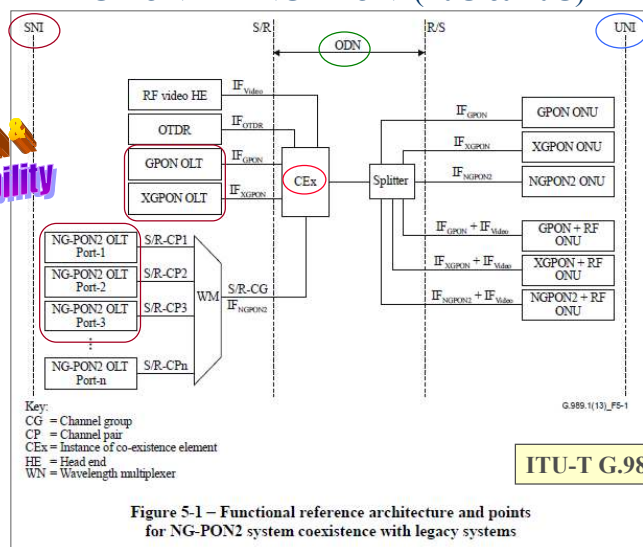
ITU-T G.989.1 (03/2013)

- ❑ Multiple wavelength channel TWDM architecture
- ❑ 4-8 TWDM channel pairs (each channel pair comprising one downstream and one upstream wavelength channel),
 - ⇒ configurable for incremental growth starting from one deployed channel pair (i.e., not all channel pairs need to be active); for example, "pay as you grow" capability of TWDM channels populating in the OLT.
- ❑ Downstream and upstream nominal line rates per channel:
 - ⇒ 10 Gbit/s downstream and 10 Gbit/s upstream
 - ⇒ 10 Gbit/s downstream and 2.5 Gbit/s upstream
 - ⇒ 2.5 Gbit/s downstream and 2.5 Gbit/s upstream
- ❑ Passive fibre reach of at least 40 km and maximum differential fibre distance of up to 40 km; with configurable maximum differential fibre distance as 20 km and optional 40 km;
- ❑ ↑ Capability to reach 60 km, preferably with passive outside plant
- ❑ 40 Gbit/s downstream capacity and 20 km reach with at least 1:64 split
- ❑ 10 Gbit/s upstream capacity and 20 km reach with at least 1:64 split



Redes Ópticas de Acesso – NG-PON2 XG-PON <=> NG-EPON (10G & 40G)

evolution & compatibility



ITU-T G.989.1 (03/2013)

Figure 5-1 – Functional reference architecture and points for NG-PON2 system coexistence with legacy systems



Redes Ópticas de Acesso – NG-PON2 XG-PON <=> NG-EPON (10G & 40G)

Table 7-1 – Examples of UNI and services

UNI (Note 1)	Physical interface (Note 2)	Service (Note 3)
VDSL2 [b-ITU-T G.993.2], ADSL2plus [b-ITU-T G.992.5]	xDSL	xDSL
[b-ITU-T G.703]	PDH	DS3, E1, E3
[b-ATIS 0900102] and [b-ATIS 0600107]	PDH	T1, DS0, DS1, DS3
SDH/SONET		OC3-OC192, STM1-STM64
OTN [b-ITU-T G.872], [b-ITU-T G.709]		OTU1, OTU2
CPRI/OBSAI (Open Base Station Architecture Initiative)		

NOTE 1 – There are many other services accommodated in XG-PON, but those services do not have specified UNIs.
NOTE 2 – Each item in the "Physical interface" column is illustrated by the corresponding entry in the "UNI" column.
NOTE 3 – The column labelled "Service" shows which services can be supported by the physical interface.

ITU-T G.989.1 (03/2013)



Redes Ópticas de Acesso – NG-PON2 XG-PON <=> NG-EPON (10G & 40G)

Fev.2016

Evolution of FTTx Systems 34

ITU-T G.989 WDM-PON

NG-PON2

- Multiplexing method is TDM for downstream and TDMA for upstream.
- Loss budget is 29 dB and 31 dB (nominal classes).
- Split ratio is at least 1:64; 1:256 or more in the logical layer.
- Fiber distance is at least 20 km; 60 km or more in the logical layer.
- OLTs using CFP modules are either 4 X 10 Gb/s or 4 X 2.5 Gb/s.
- OLT incorporates an internal optical amplifier.
- ONT's upstream laser also operates as a Raman pump source for downstream channels.
- ONT uses tunable optical receivers and transceivers in a SFP+ module.

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Arquitetura da Rede – GPON-BPON OLT - ODN - ONU/ONT

Resumo::

- Qualquer **Rede PON** pode ser configurada de diferentes maneiras; todas as recomends. **g.983.x** e **g.984.x** são compatíveis entre si; as **g.987 (XG)** e **g.989** são tb. elaboradas mantendo essa compatibilidade;
- O conceito de função de adaptação (AF) e de ONU/ONT evolutivas, permitem diferentes configurações serem implementadas em diferentes sub-redes, inclusive com diferentes taxas de transmissão (*line-rate*);
- Existe tb. a possibilidade de *overlay* usando **WDM** e/ou multiplas **fibras e cabos**, numa instalação existente ou numa expansão;
- Enfim, o conceito PON mais importante é que fora da **OLT** e das **ONU/ONT** -- quer dizer, na rede externa **ODN** -- *não há nenhum equipamento ativo*.



Redes Ópticas de Acesso => fim da 1a. Parte



Próximos passos ::

- Produtos FTTH/U -- *fiber to the user*
- Tecnologias -- *Padronização*
- Soluções & Implementações
- **Rede HFC**

