GPON in FTTx Broadband Deployments

MR-246

October 2010

Agenda

1. Introduction to the Broadband Forum
2. Market Drivers
3. Technology Overview
4. Business issues and standards gaps
5. GPON in the Access Network
6. GPON in the Aggregation Network
7. TR-069 enabled GPON CPE
8. Conformance and interoperability testing
9. Market adoption and next issues

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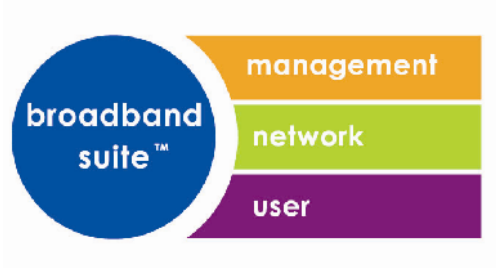
We are the Broadband Forum

http://www.broadband-forum.org

- The Broadband Forum is the central organization driving broadband solutions and empowering converged packet networks worldwide to better meet the needs of vendors, service providers and their customers.

- We develop multi-service broadband packet networking specifications addressing interoperability, architecture and management. Our work enables home, business and converged broadband services, encompassing customer, access and backbone networks.

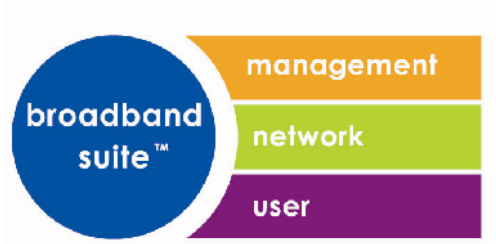
The BroadbandSuite
Goals and Focus

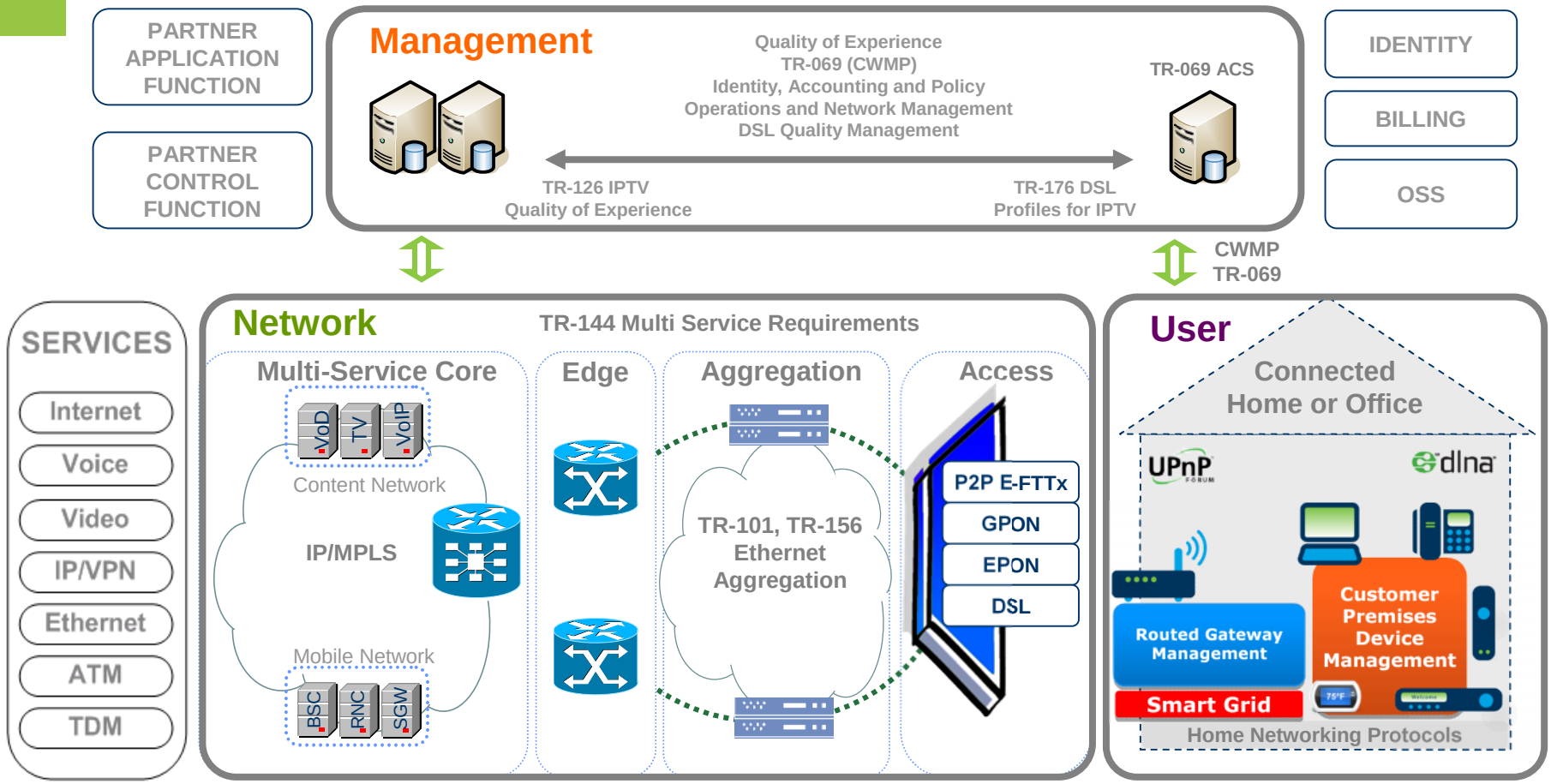


The BroadbandSuite is broken down into three major domains:

- **BroadbandManagement**
  - **Goal –** enhance network management capabilities and enable an intelligent, programmable control layer that unifies diverse networks
  - **Focus** - empower service providers to deliver and efficiently maintain personalized services that enhance the subscriber experience
- **BroadbandNetwork**
  - **Goal** - establish network architecture specifications to support current and emerging services and applications
  - **Focus** - deliver access, aggregation and core specifications that provide inherent interoperability, quality, scalability and resiliency capabilities from end-to-end
- **BroadbandUser**
  - **Goal** - Define unified networking standards by establishing a common set of CPE capabilities within the business, home and mobile environments
  - **Focus** - Simplify the service delivery process by developing common devices' identification, activation, configuration and maintenance specifications

Broadband Forum Scope





Multi Service Architecture & Requirements

Certification, Test and Interoperability

We don’t work alone

Coordinated industry efforts maximize value with minimum overlap

Market Drivers

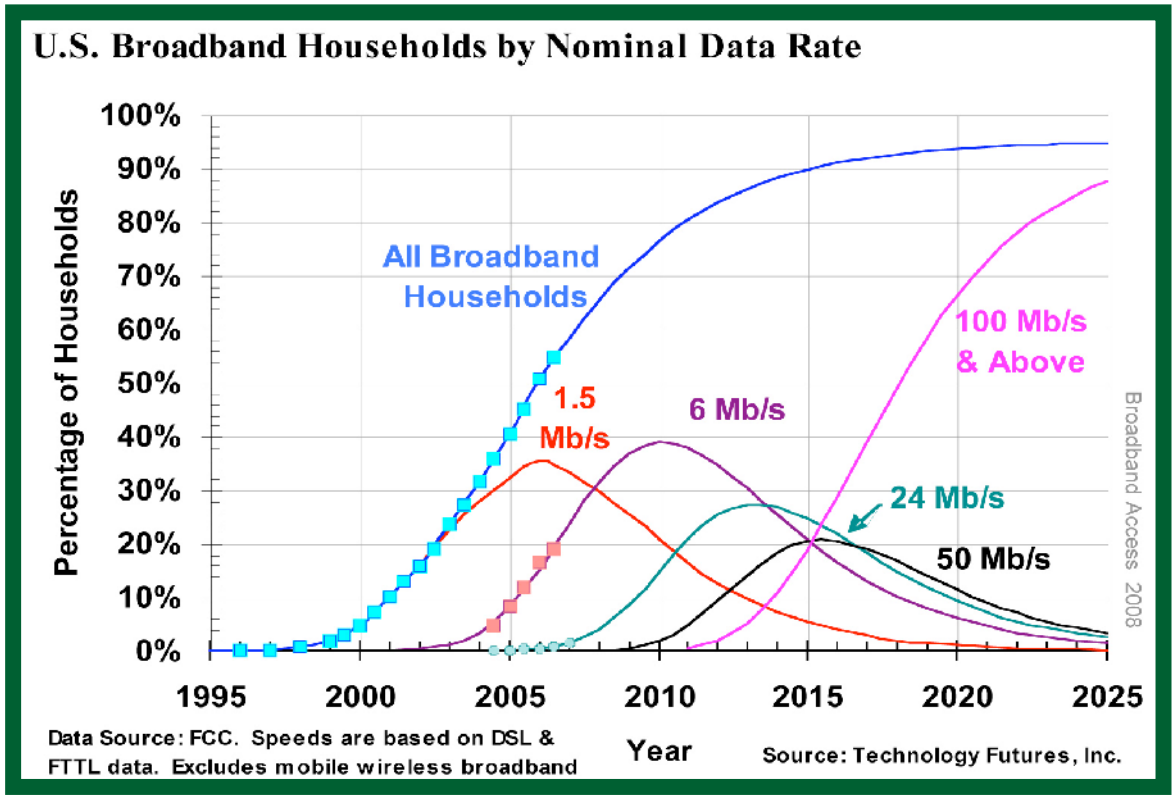
Why Fiber access?

Why PON?

Customer demand for more bandwidth keeps increasing

More applications every day ⇔ More broadband users and more bandwidth per user

IPTV
Libraries
Photos
Videos
Radios
VoIP
Presence
Gaming
Blogging
Messaging
Metering
Health
Cloud
…



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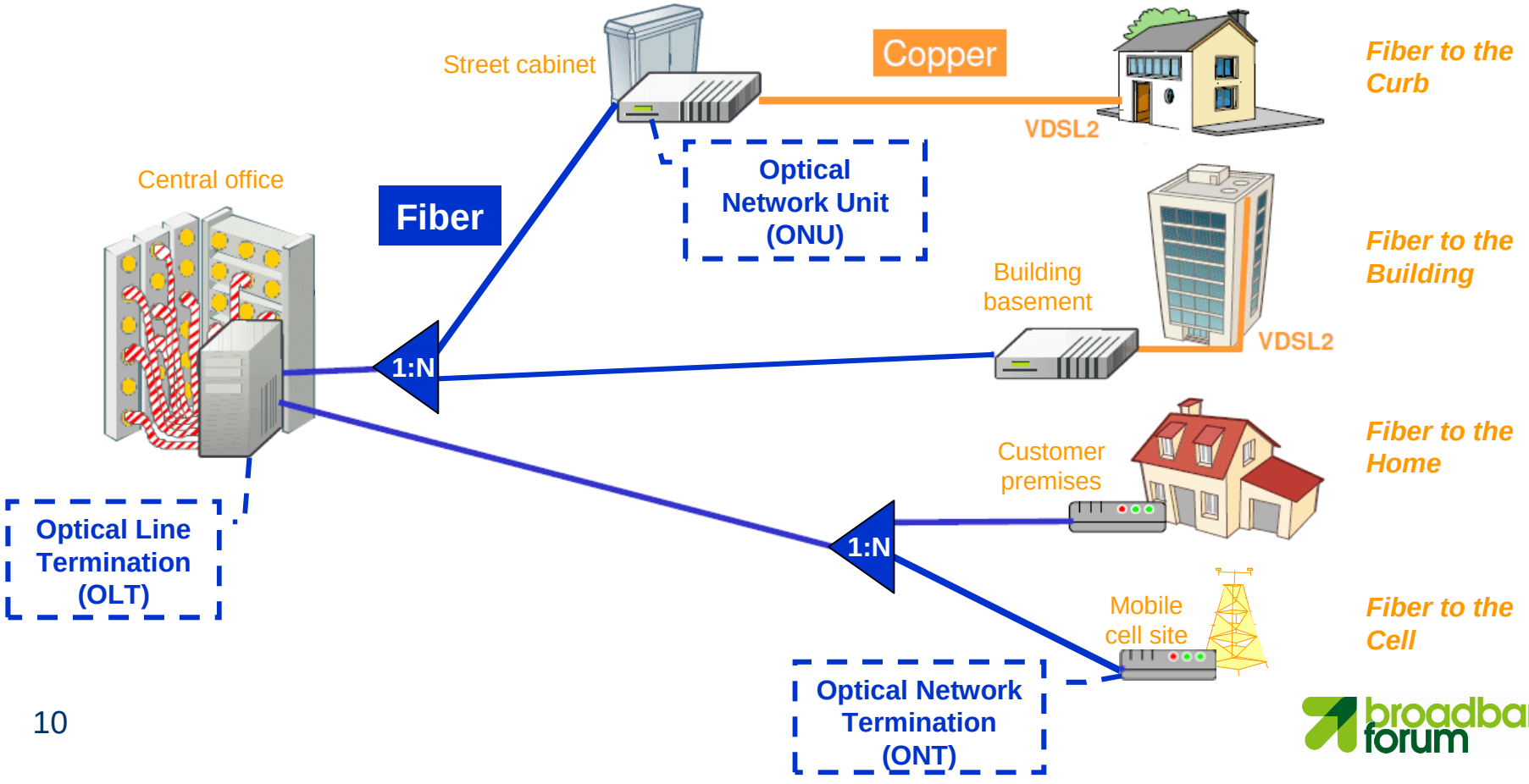
FTTx PON deployment models

- Bandwidth increases as fiber is deployed closer to customers



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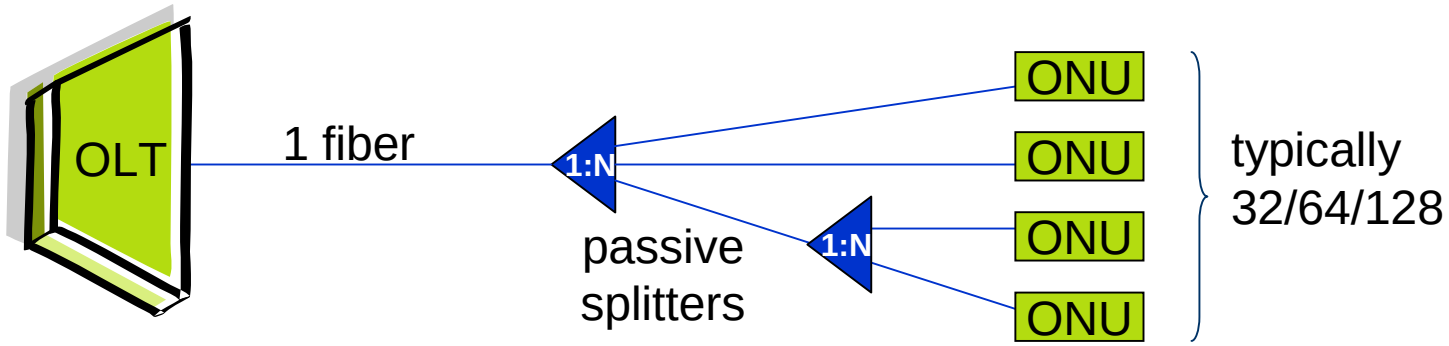
Passive Optical Networks (PON)

- Passive point-to-multipoint infrastructure
  - A single fiber and a single OLT interface to serve multiple ONUs
  - Passive (unpowered) optical splitters
  - PON can operate on any physical topology



☑ Minimal occupancy of ducts and space at Central Office

☑ Less active equipment, optimal availability and energy consumption

DSL and Fiber

- DSL is not going to disappear any time soon
  - The most widely deployed broadband technology
  - Still a lot of innovation ahead
- Fiber has intrinsic assets
  - Greater bandwidth upstream and downstream
  - Longer distances with less active equipment
  - Not sensitive to electromagnetic noise
- Smooth coexistence of xDSL and FTTx in service providers' deployments is a major requirement.

Technology overview

Overview of GPON and XG-PON1 technologies

GPON

- A TDM/TDMA PON that meets full service access requirements
  - Supports multi-services by design
  - Efficient bandwidth utilization
- Support for asymmetric line rate operation: 2.488 Gbit/s downstream and 1.244 Gbit/s upstream
  - Upstream wavelength 1310 nm
  - Downstream wavelength 1490 nm
  - Option for RF Video overlay: wavelength 1550 nm
  - Up to 128 ONUs per fiber tree, but 32 or 64 is more typical.
  - 28dB optical budget to support 20km reach and 1:32 split ratio
  - Optional 32dB optical budget

GPON ITU-T Specifications

- System requirements – G.984.1
- Physical (PMD) layer – G.984.2
- Protocol (TC) layer – G.984.3
- Management (OMCI) layer – G.984.4, superseded by G.988
- Enhanced G-PON spectrum – G.984.5
- Reach extenders for G-PON – G.984.6
- OMCI Implementer's Guide – G.Imp984.4, now included in G.988

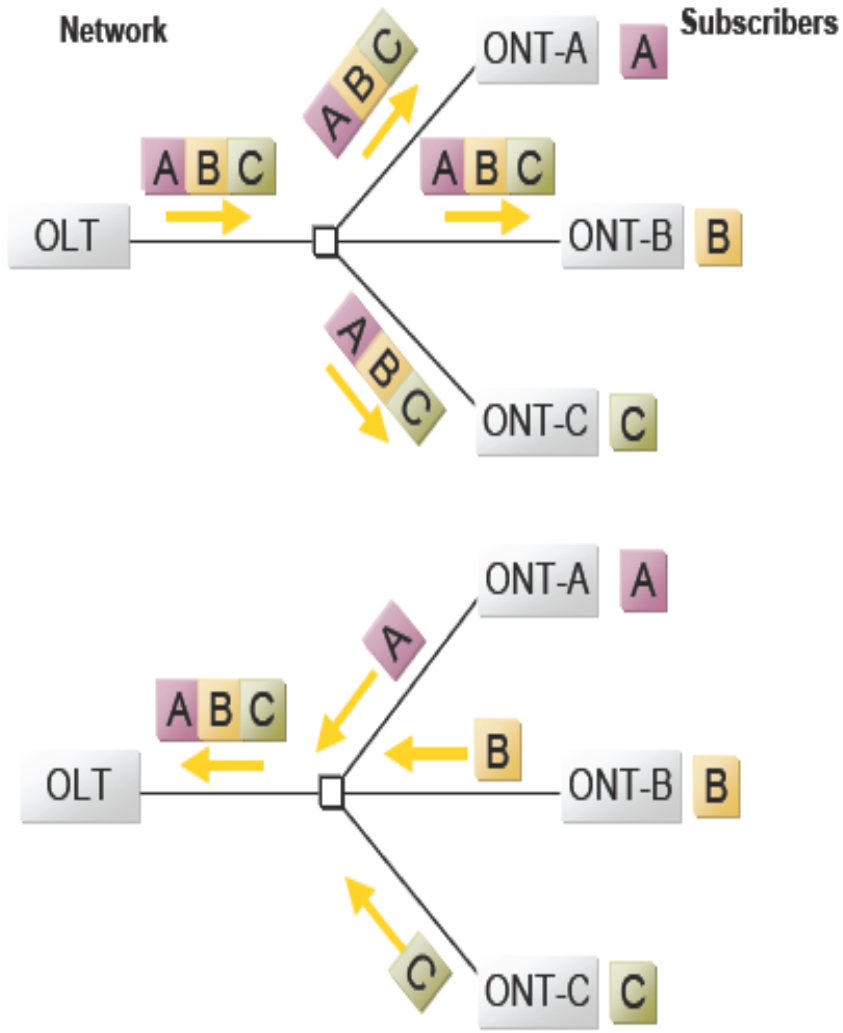
GPON transmission basics

DOWNSTREAM

- Point to Multi-Point, broadcast to all ONUs at the PHY layer
- ONUs only process data addressed to them
- Security addressed by AES (Advanced Encryption Standard, 128-bit key)

UPSTREAM

- Multi-Point to Point
- TDMA (Time Division Multiple Access) mechanism



GPON Encapsulation Method (GEM)

- GEM is a method for encapsulating user frame data for transport over the GPON
- It provides a few simple but essential services
  - Delineates the user data frames inside the GPON partitions
  - Identifies each frame as belonging to a connection / user / ONU
  - Permits fragmentation and reassembly
- A GEM port represents a logical connection associated with a specific traffic flow

Dynamic Bandwidth Allocation (DBA)

- Not all users need all their peak bandwidth all the time
  - Fixed bandwidth allocations are inefficient
- Dynamic bandwidth allocation optimizes usage of the shared medium
  - With DBA, the OLT assesses the bandwidth needs of the ONUs in real time and allocates upstream PON capacity accordingly
- Allows service providers to define flexible service options, oversubscription levels and Service Level Agreements

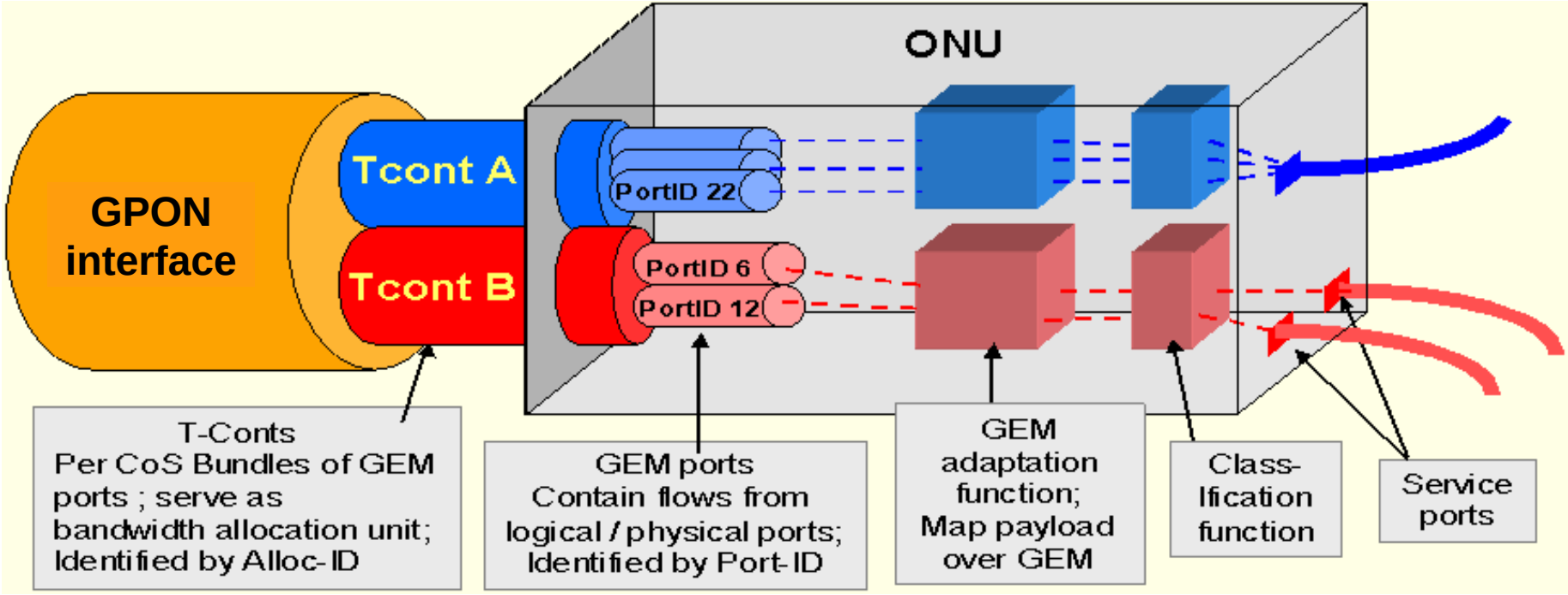
DBA basic and extended models

- DBA basic model supports:
  - Fixed bandwidth (highest priority)
  - Assured bandwidth
  - Non-assured bandwidth
  - Best-effort bandwidth (lowest priority)
- DBA was extended to support multiple Best Effort traffic classes and multiple weights within each traffic class
  - which meets mandatory 4 and optional 6 classes of services for TR-156 and TR-167 traffic management requirements

Traffic containers (T-CONT)

- A grouping of logical connections for the purpose of upstream bandwidth assignment
  - For TR-156 and TR-167, each T-CONT represents a traffic class
  - Each ONU will typically have 4 T-CONTs, supporting 4 traffic classes, plus one T-CONT for OMCI
- OLT schedules upstream traffic across all ONUs according to the priority and weight assigned to each T-CONT, and their buffer occupancy
  - Other bandwidth assignment mechanisms are available, for example fixed bandwidth, assured bandwidth, and non-assured bandwidth.

GEM Multiplexing



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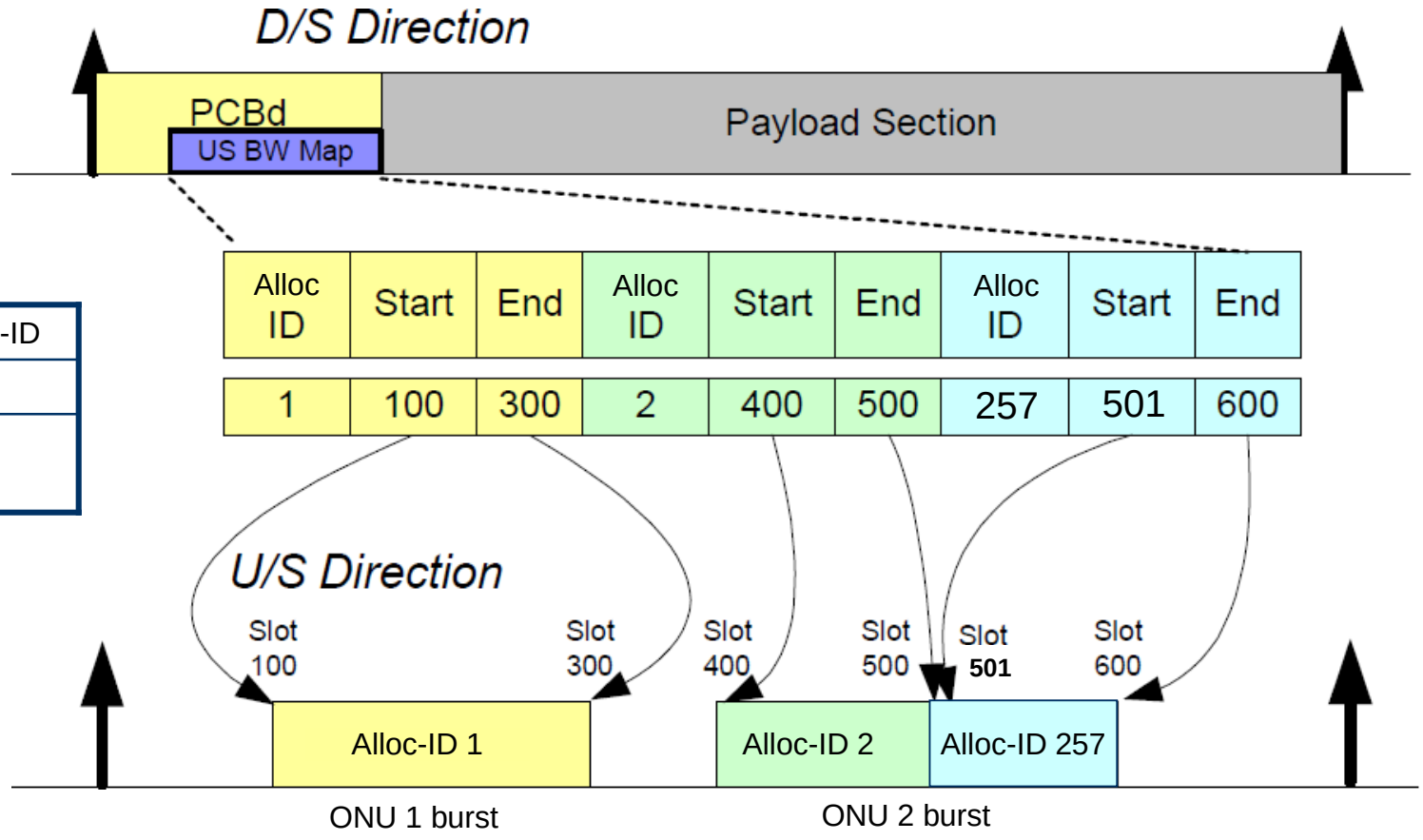
GPON frame and upstream map

ONU-ID	Alloc-ID
1	1
2	2 257



- Time slots for upstream transmission are granted by the OLT, through a bandwidth map available in downstream frames

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OMCI for GPON

- "ONU Management Control Interface"
  - Protocol used by an OLT to control an ONU
  - Provisioning of layer 2 connections for each ONU and user port
  - ONU firmware maintenance, alarms and performance monitoring, QoS management…
- The OMCI Implementer's Guide (G.Imp984.4) defines the subset of OMCI required to support TR-156 and TR-167 architectures

GPON situation today

- Standards are mature
- Many vendors have products
- Many operators have deployments
- Interoperability is a success
  - Full service, multi-vendor, multi-operator
  - Due to the joint effort between the FSAN, the ITU-T and the Broadband Forum

XG-PON1: the next generation

- Downstream 9.95328 Gb/s
- Upstream 2.48832 Gb/s
- Other major enhancements :
  - 29dB optical budget and optionally 31, 33, 35dB
  - Split ratio up to 1:256
  - Extended power saving modes
  - Enhanced security
- GPON and XG-PON1 can run side by side on the same PON, allowing coexistence and seamless migration between technologies.

XG-PON1: ITU-T Specifications

- FSAN and ITU-T (Q2/15) worked together to complete the G.987 series by June 2010
  - G.987: Common definitions and acronyms
  - G.987.1: System requirements
  - G.987.2: Physical media dependent specification
  - G.987.3: Transmission convergence specification
- G.988 ONU management and configuration interface (OMCI) builds on G984.4 to include XG-PON1 as well as GPON
  - OMCI Implementer's guide, TR-142, TR-156 and TR-167 are all directly applicable to XG-PON1!

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Business issues and standards gaps

Introduction to the Broadband Forum areas of work

Integration in triple play deployments

- ☑ Replicate over GPON the multi-services architecture adopted over DSL
- ☑ Leverage platforms and processes used in existing deployments

- Ethernet interfaces (U/V/W) similar to TR-101
  - Only the GPON interface (R/S) is new per TR-156 and TR-167
- TR-069 complements OMCI management for GPON Customer Premises Equipment
  - TR-142 defines the boundary and interface between OMCI and TR-069 management domains

OLT-ONU Interoperability

☑ Allow OLT and ONU to be provided independently
- By different vendors
- By different operators
- By end users themselves (retail model)

- GPON PHY and TC layers standardized by ITU-T
- But an agreed functional cut between GPON OLT and ONU was missing…
  - E.g. is it the OLT or ONU which is required to support adding VLAN tags?
  - BBF TR-156 to resolve this gap

Flexibility to support various business models and device types

- GPON used in access or aggregation networks
- Single Family Units, Single Business Units, Multi Dwelling Units, Multi Tenant Units…
- Ethernet or DSL last drop
- ONU and Routing Gateway as separate devices or integrated into one box

➔ Maximize commonality of architecture to reduce integration costs and guarantee interoperability

Related Broadband Forum documents

- TR-156 : Using GPON Access in the Context of TR-101
- TR-167 : GPON-fed TR-101 Ethernet Access Node
- TR-142 : Framework for TR-069 Enabled PON Devices

Work in progress

- WT-155 : Requirements for GPON RG
- WT-247 : GPON Conformance Test Plan
- WT-255 : GPON Interoperability Test Plan
- PD-205 : GPON Management

Background:

- TR-101: Ethernet based aggregation for DSL access
- TR-069: CPE management protocol

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GPON in the Access Network

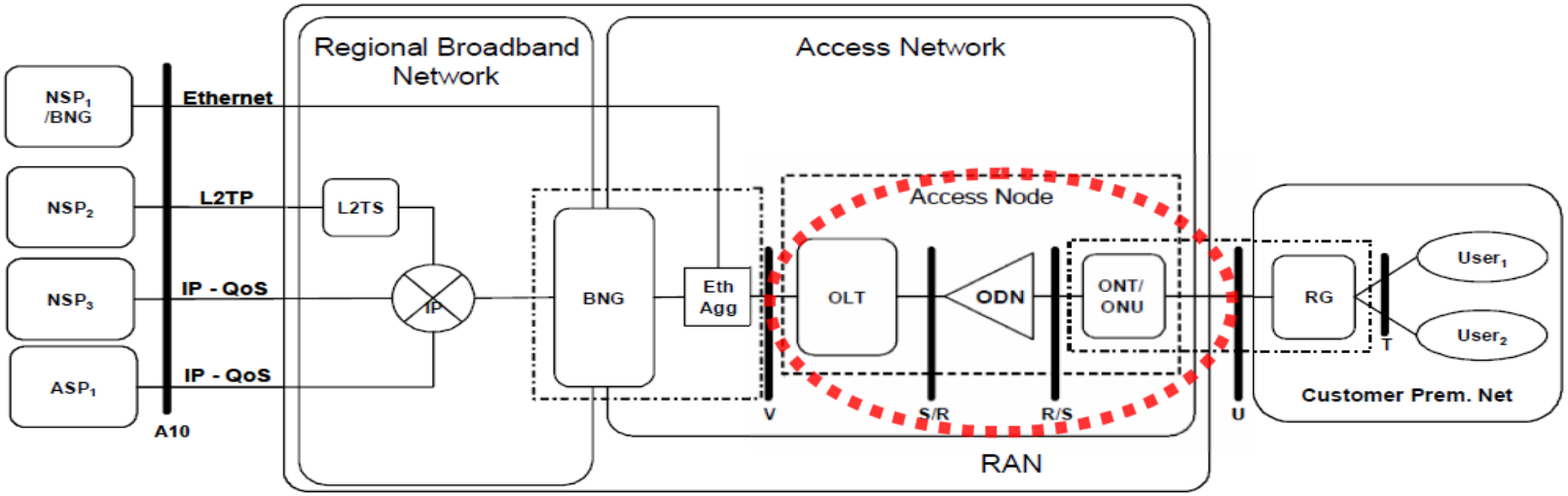
Overview of BBF TR-156
“Using GPON Access in the context of TR-101”

TR-156 Scope

- TR-156 specifies the required capabilities of GPON OLTs, ONUs and ONTs
  - Above the Physical, TC and OMCI layers, which are covered by FSAN/ITU standards
- Supports a variety of deployment scenarios with a converged technical solution
  - FTTH (Fiber To The Home), FITH (Fiber Into The Home), FTTO (Fiber To The Office), MDU (Multi-Dwelling Unit), MTU (Multi-Tenant Unit)
- Aims to ensure interoperability between GPON OLTs and ONUs/ONTs for Ethernet and IP services

TR-156 Network Architecture

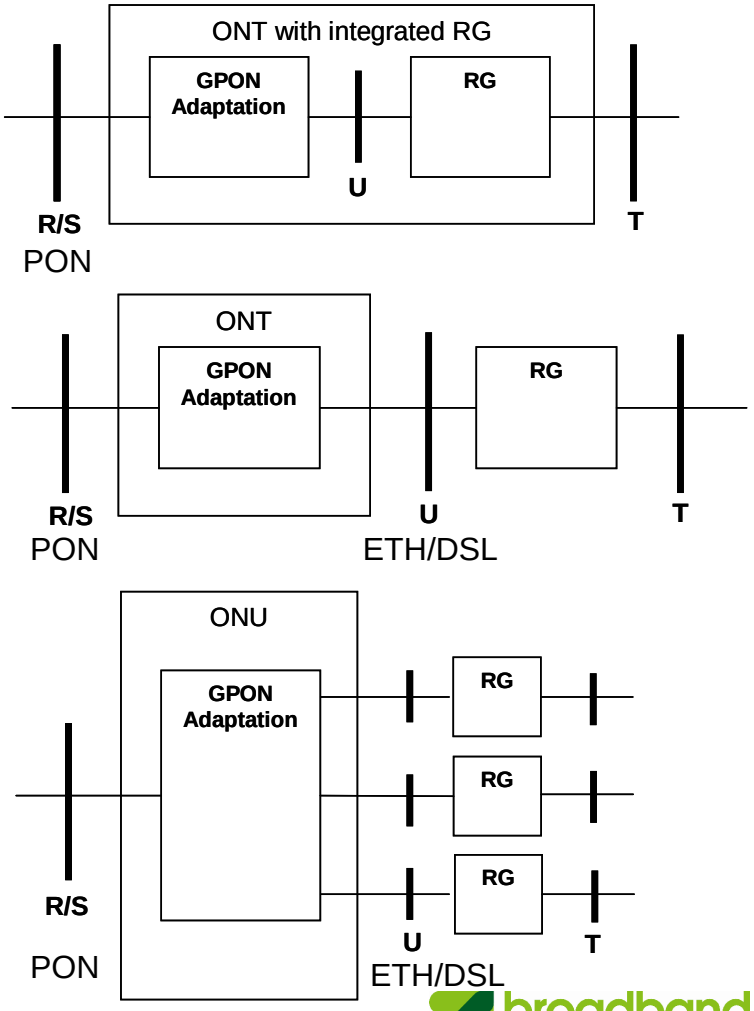
- The entire GPON system performs the role of an Access Node as specified by TR-101
  - U and V reference points remain unchanged
- Aims to integrate seamlessly into broadband service providers' deployments



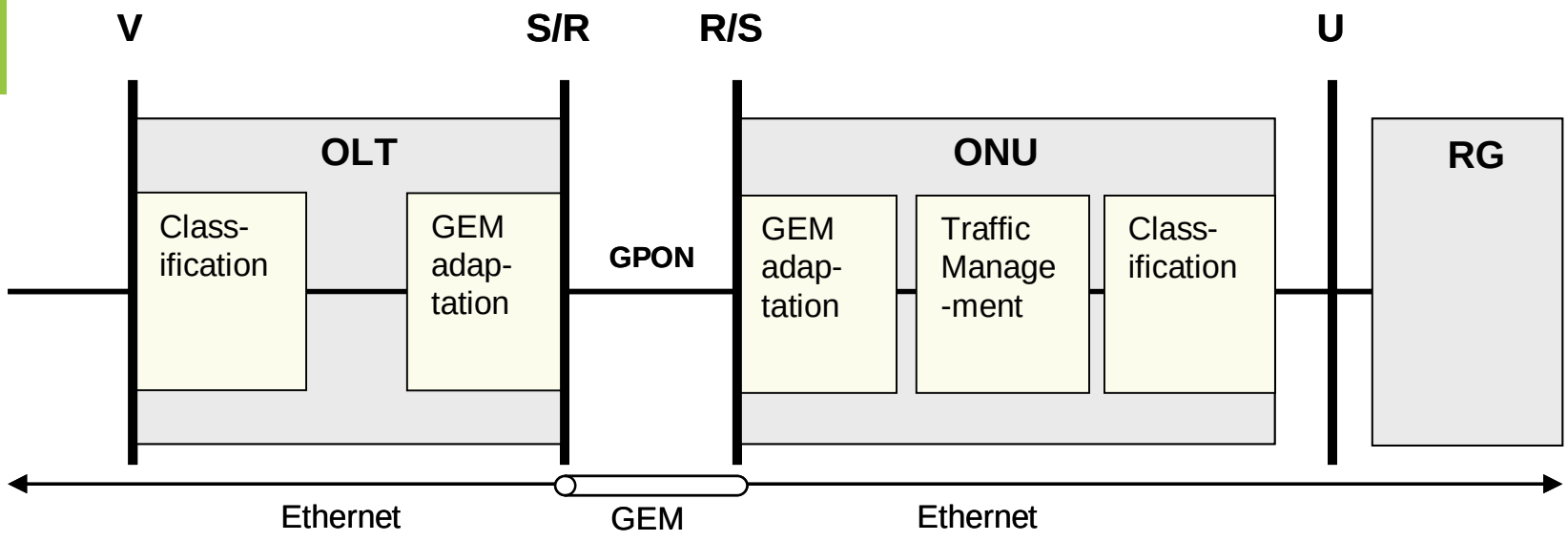
Introduction of GPON access into a TR-101 Network

TR-156 Network Architecture

- ONU and RG functions may reside in the **same** physical device
- ONU and RG may be **separate** physical devices, interconnected via **Ethernet or DSL**
- An ONU may serve one or **several** RGs



TR-156 GPON to Ethernet Adaptation



- OLT and ONU classify Ethernet frames and encapsulate them into GEM frames
- OLT MUST support VLAN tagging & Ethernet switching
- ONU MUST support VLAN tagging - no Ethernet switching required at the ONU

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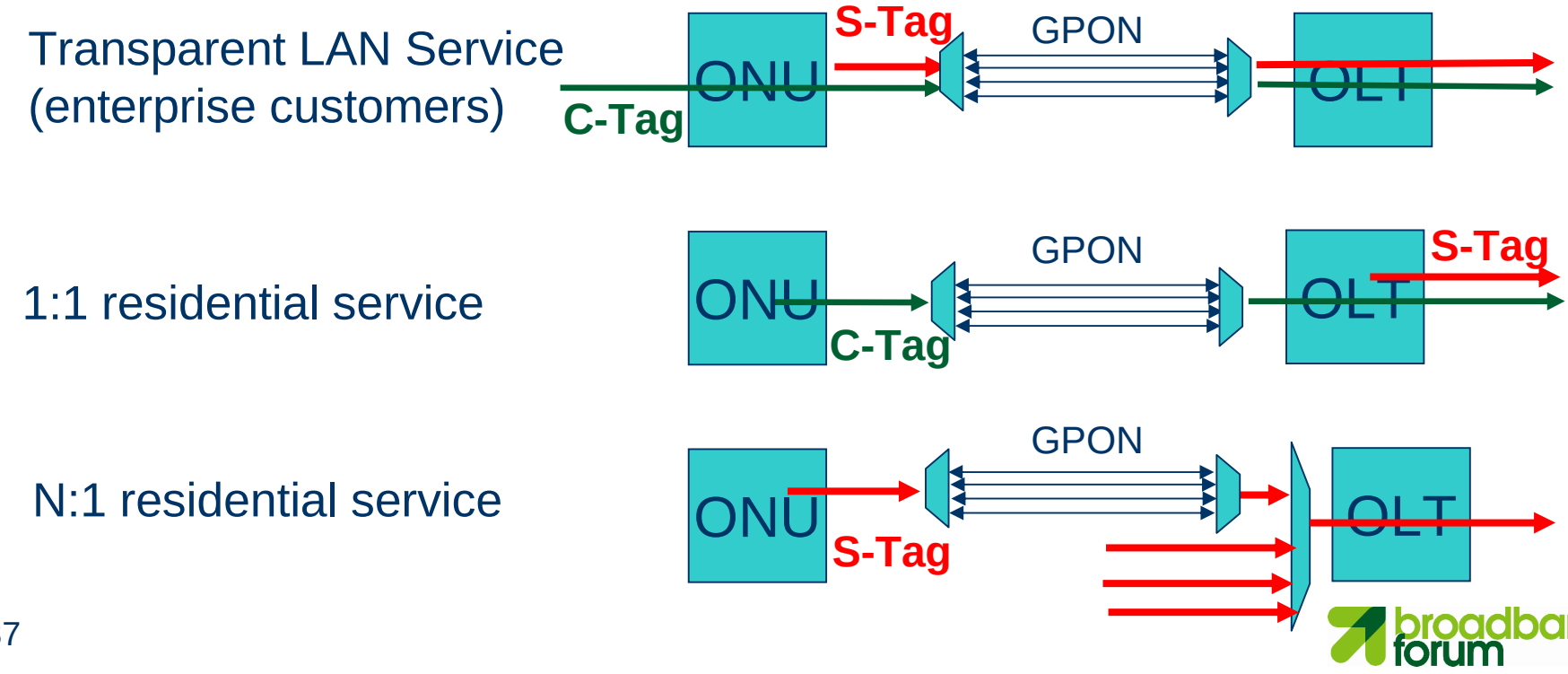
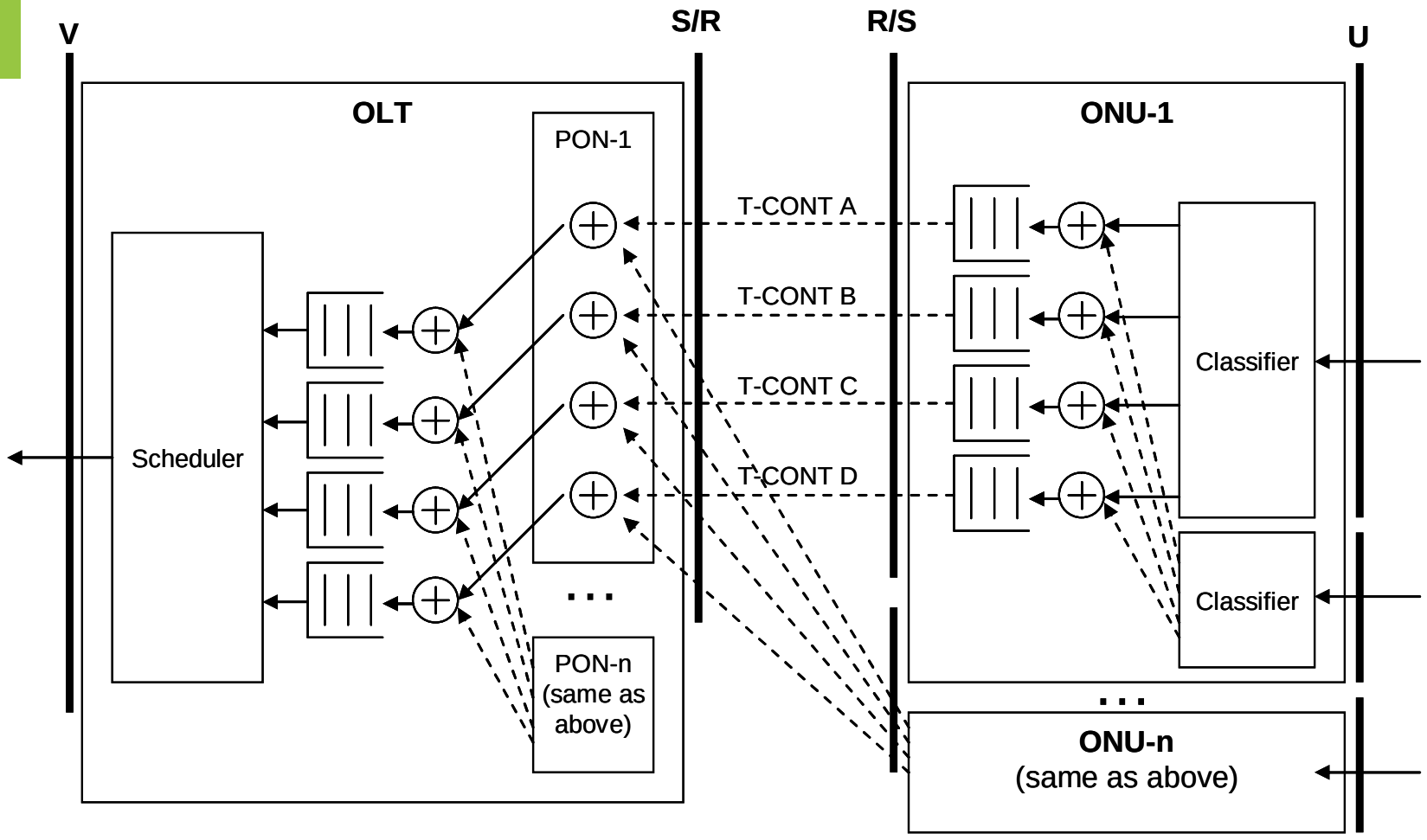
VLAN tagging by OLT and ONU

- TR-156 specifies, for each service, whether it is the OLT or the ONU, which is required to manipulate VLAN C-Tags and S-Tags

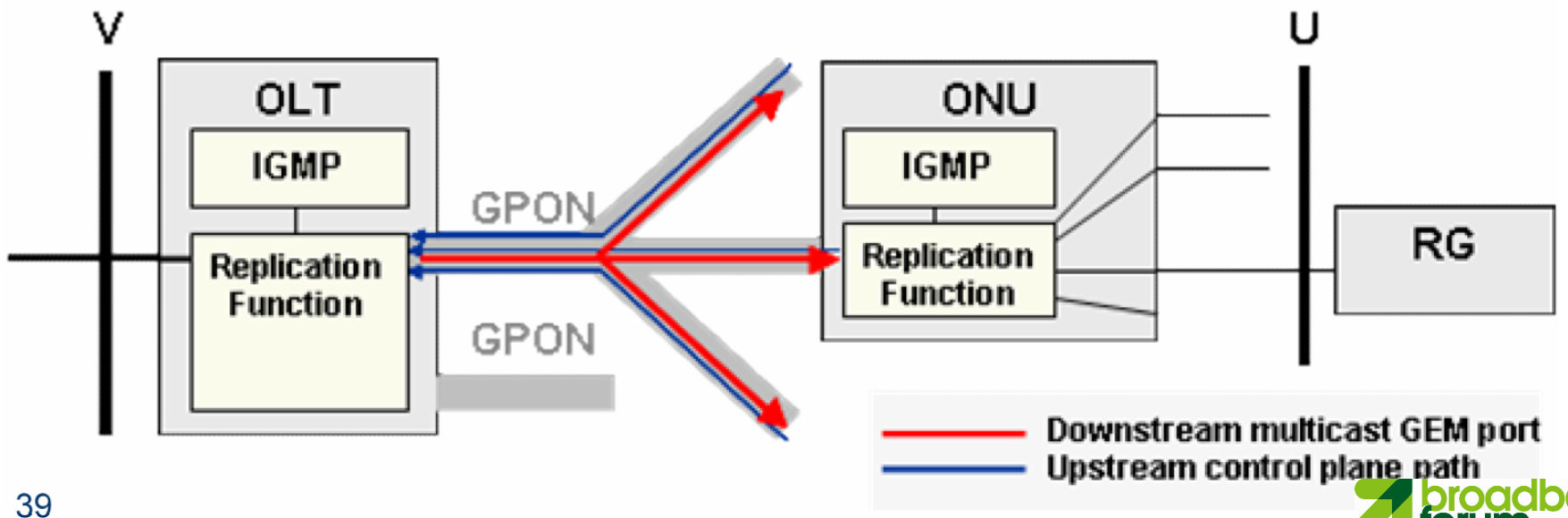


Upstream queuing and scheduling



Multicast support

- GPON is inherently a broadcast transmission system, therefore very suited to transport multicast traffic
- One single unidirectional multicast GEM port is required
- IGMPv3 proxy/snooping at OLT to control replication
- IGMPv3 snooping at ONU/ONT



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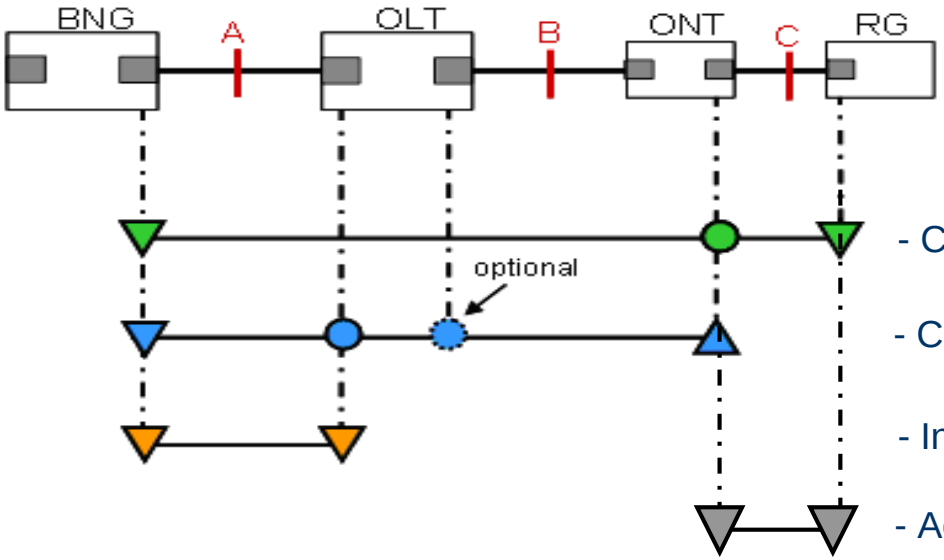
Ethernet OAM

- Connectivity Fault Management per IEEE 802.1ag
- TR-156 specifies OLT and ONU requirements to support Maintenance End Points and Maintenance Intermediate Points for each service



- Customer Maintenance Domain (default level 5)
- Carrier Maintenance Domain (e.g. level 3)
- Intra-Carrier Maintenance Domain (e.g. level 2)
- Access Link Maintenance Domain (default level 1)

MEPs and MIPs in the example of a 1:1 residential service

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Other capabilities required by TR-156

- OLT controls the ONU through OMCI
- Map upstream frames to GEM ports at ONU based on ingress interface and any combination of VID and p-bits
- Map downstream frames to GEM ports at OLT based on any combination of MAC address, S-VID and p-bits
- Support 4 queues at egress of each interface, one per traffic class (6 optional)
- Support of TR-101 security features at OLT
- Support of L2 DHCP Relay and PPPoE IA at OLT
- Support of OLT pre-provisioning with ONUs' serial numbers or registration IDs and their associated ONU-IDs

GPON in the Aggregation Network

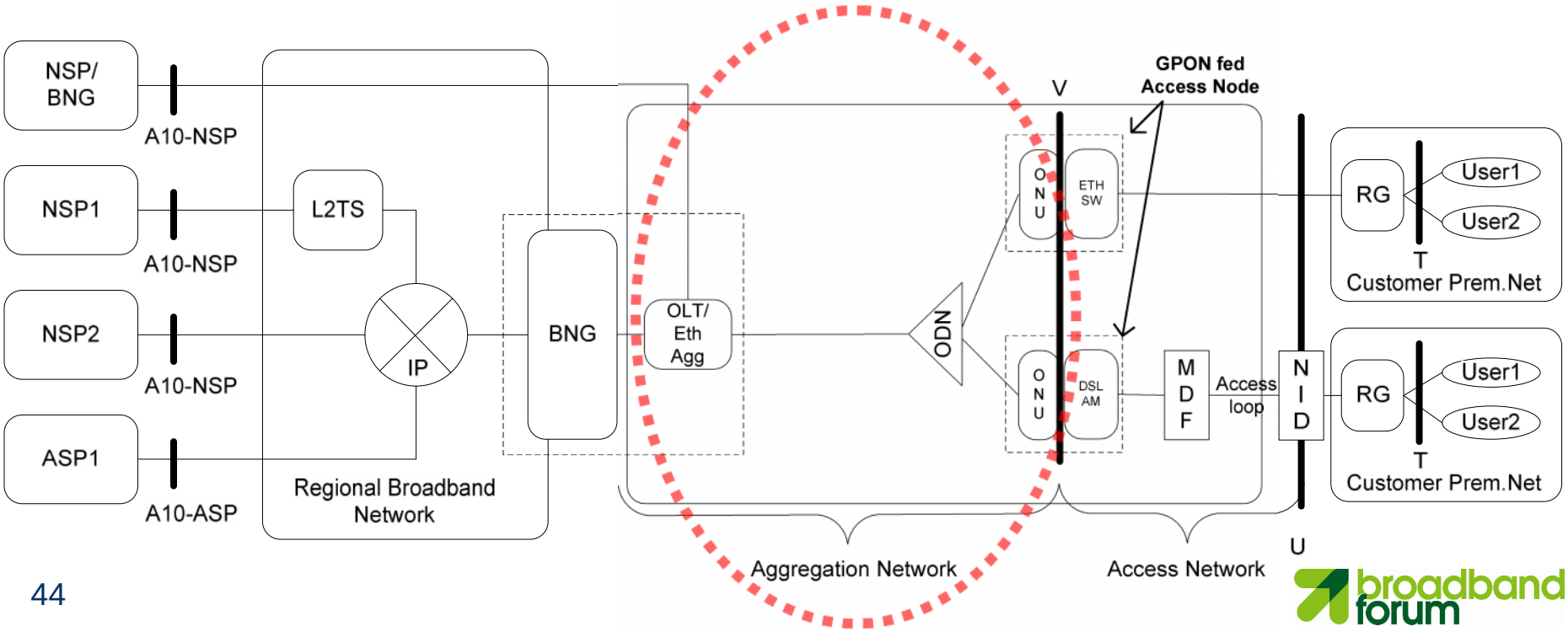
Overview of BBF TR-167
"GPON-fed TR-101
Ethernet Access Node"

TR-167 Scope

- Defines the required capabilities for a GPON system (OLT/ONU) used to feed a TR-101 compliant access node.
  - The GPON system is performing the role of an aggregation node as specified by TR-101 – no effect on the access node.
  - Does not define the physical layer attributes of this system

TR-167 Network Architecture

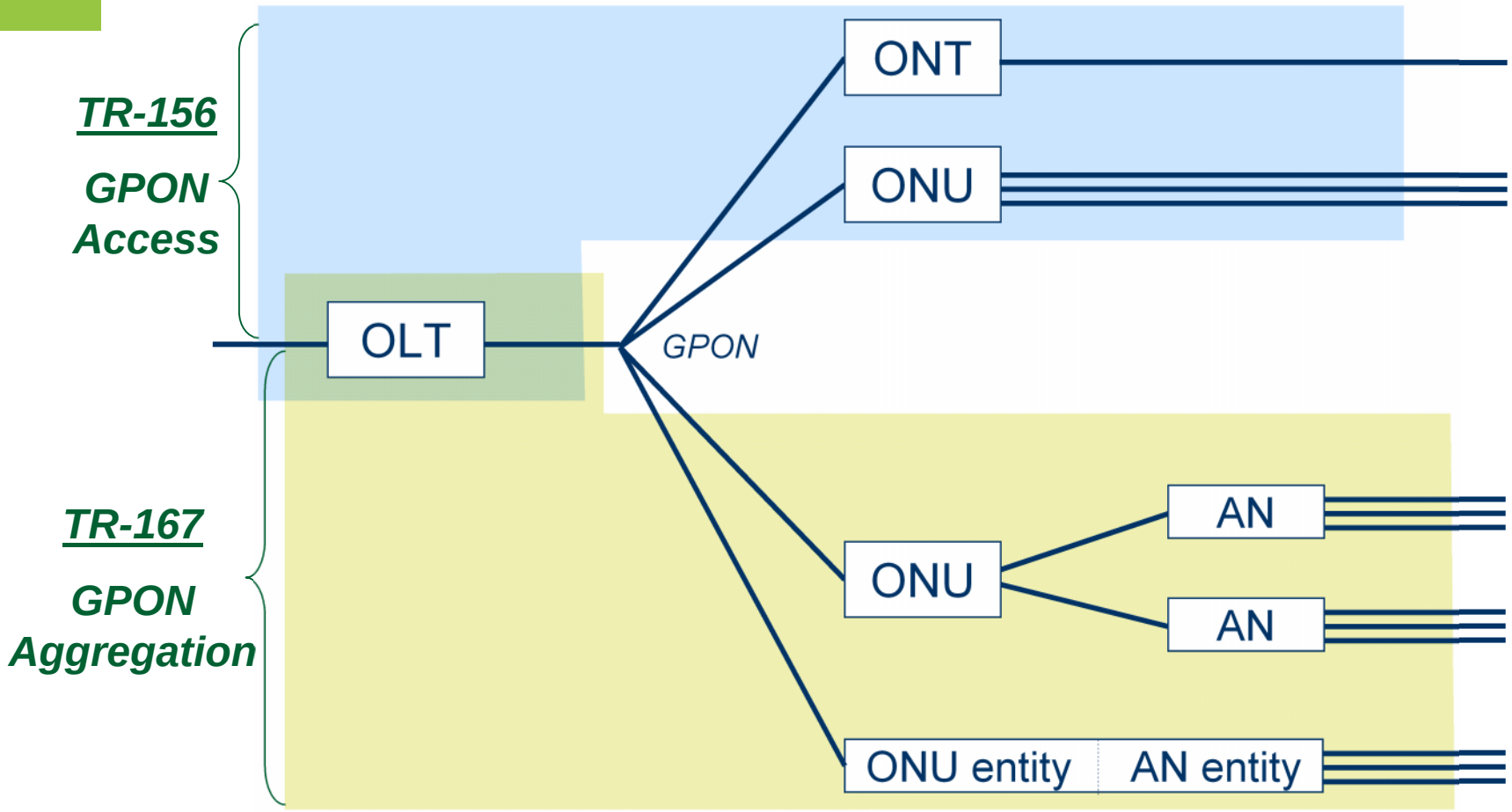
- V Reference point resides downstream of the ONU (between the ONU and the AN)
- The ONU and AN may be in the same physical device



TR-167 Comparison with TR-156

- TR-167 defines aggregation node functionality while TR-156 defines access node functionality.
- In TR-167 the V reference point is downstream of the ONU. In TR-156 the V reference point is upstream of the OLT.
- TR-167 assumes that frames arriving at the ONU Ethernet port are pre-classified and tagged by the access node. In TR-156 the ONU performs classification and tagging of upstream frames.
- TR-167 and TR-156 share a common OMCI MIB for provisioning of the ONU.

TR-167 and TR-156 architectures can be deployed together on the same PON



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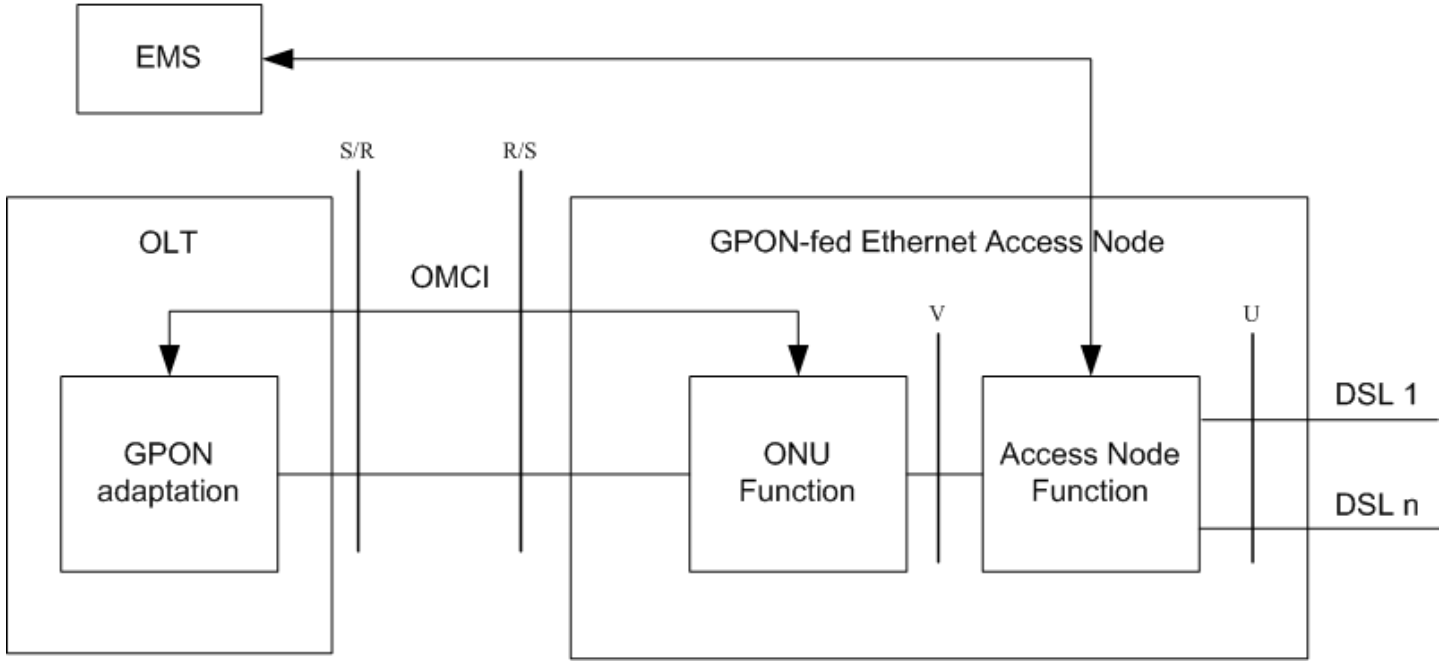
Management of GPON-fed Access Node

- The GPON-fed Access Node is dual-managed:
  - The ONU Function is managed through OMCI, via the OLT
  - The Access Node Function is managed like any TR-101 Access Node (e.g. using SNMP or a command line interface)



Capabilities Required by TR-167

- The ONU maps upstream frames onto GEM ports based on S-VID, p-bits, or a combination of both.
- The OLT maps downstream frames to GEM ports based on any combination of MAC address, S-VID and p-bits.
- The ONU maps downstream frames from GEM ports to V reference point interfaces based on GEM Port.
- Four T-CONTs required; Six T-CONTs optional. One T-CONT is used per traffic class.
- Ethernet interfaces must support 4 queues, one per traffic class. Six queues is optional.
- Support for IGMP v3 snooping and proxy.
- Loop detection and avoidance required on OLT through the use of spanning tree protocols.
- Support of Ethernet OAM

TR-069 enabled GPON Customer Premises Equipment

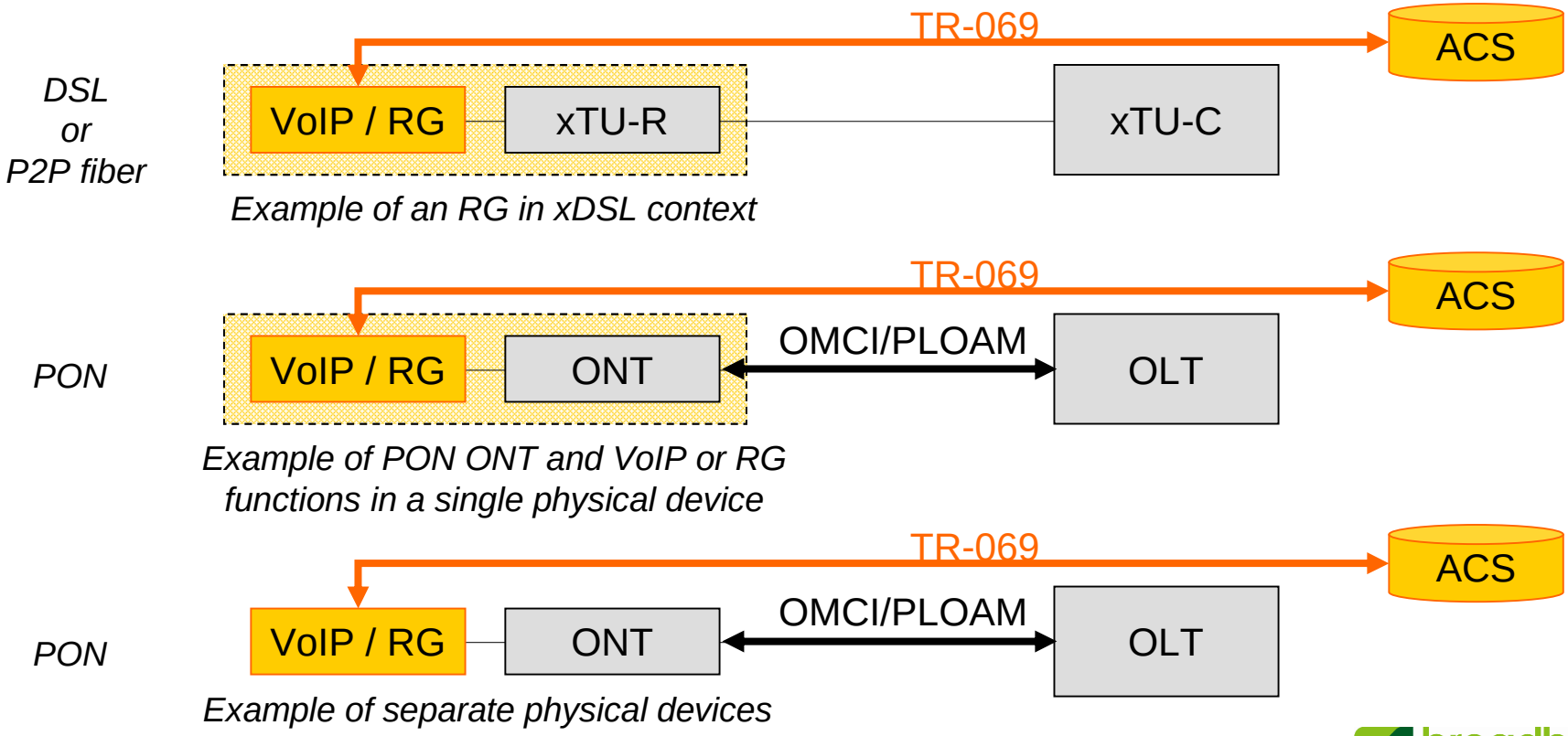
Overview of BBF TR-142 “Framework for TR-069 enabled PON Devices”

GPON CPE remote management

- TR-142 allows PON CPE with L3 capabilities to be remotely configured, troubleshot and managed by an ACS using TR-069, leveraging the same management infrastructure and procedures irrespectively:
  - Whether the PON device is an ONT, a Residential Gateway, or a device connected through a home network
  - Whether the services relying on this device are operated by the access network provider, or independently by another service provider
  - Whatever the access network technology (GPON, EPON, 10GEPON, XG-PON1, xDSL or 3G…)

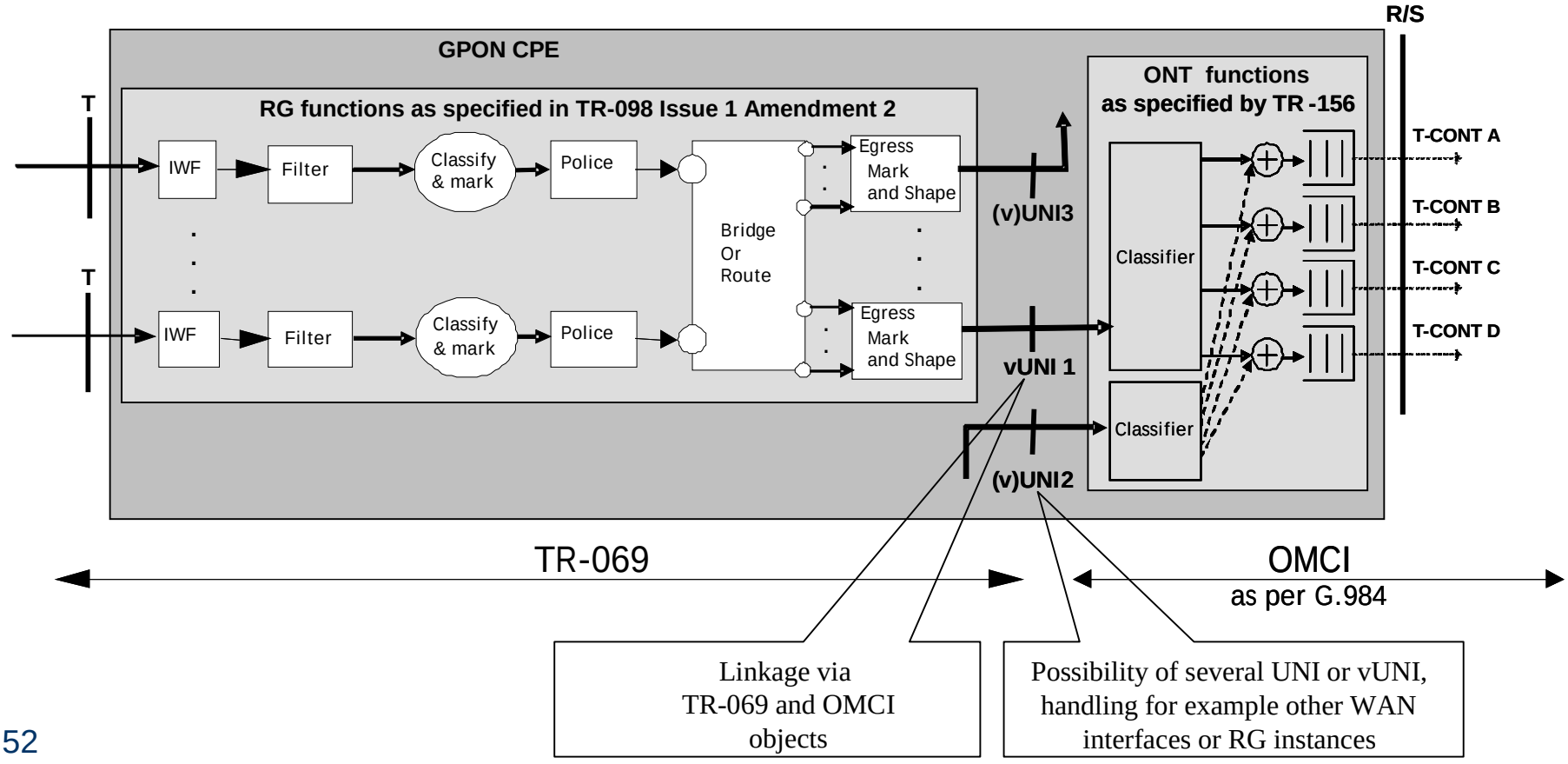
TR-069 and OMCI domains of responsibilities

- TR-142 defines the boundaries and interface between TR-069 and OMCI/PLOAM



The glue between OMCI and TR-069

TR-142 defines a Virtual UNI between the OMCI and TR-069 management domains



GPON CPE: Standards ecosystem

- On Remote management
  - BBF TR-142 for OMCI/TR-069 domain of responsibilities
  - Virtual UNI concept defined in TR-142 and specified in G.984.4 and its successor G.988
  - PON Object models to be specified in TR-098
- On GPON RG requirements
  - Requirements in BBF WT-155
  - Architecture and general requirement inputs from HGI documents

Conformance and interoperability testing

Issues and solutions
Standards interactions

GPON interoperability

- Many strong market drivers:
  - Facilitate competition, promote GPON as an open technology
  - Address various operators' services (residential, business, mobile backhaul…) in multi-vendor environments
  - Enable business models where the retail service provider may not operate the access network
- GPON interoperability status
  - GPON Physical and TC layers fully tested and interoperable
  - OMCI layer now mature in standards (ITU-T G.984 and G.988, Broadband Forum TR-156,TR-167, TR-142)
  - Operators now want a method to identify GPON equipment that is fully standard compliant and interoperable

Standards efforts for GPON interoperability

- Birth of a long term collaboration between BBF and FSAN on ITU-T PON technology (GPON, XG-PON1…)
  - FSAN *IOP Task Group* in charge of Physical and TC layers
  - Broadband Forum *Fiber Access Network Working Group* in charge of upper layers
- All ingredients for true interoperability are now specified
  - ***TR-156*** and ***TR-167*** specify architecture and minimum functionalities that OLT and ONT/ONU must implement respectively
  - ***TR-142*** specifies the boundary between OMCI and TR-069 domains for ONT management
  - ***OMCI Implementers' Guide*** *(G.Imp984.4)* defines how exactly the OMCI protocol must be used to manage TR-156 ONT/ONU

➔To allow plug and play interoperability, GPON systems MUST comply with the above standards!

Interoperability and Conformance Testing

- Need to verify standards compliance of GPON equipment: WT-247 “GPON Conformance Test Plan”
  - Working Text dedicated to testing OLT and ONU conformance to TR-156 and related part of OMCI Implementers’ Guide
  - Describes how to test each TR-156 requirement with the appropriate OMCI implementation
- Need to verify interoperability between GPON OLT and ONU: WT-255 “GPON Interoperability Test Plan”
  - Working Text dedicated to testing actual interoperability between OLTs and ONUs from different vendors
  - Assumes WT-247 compliance

GPON interoperability Plug-Fests

- Many GPON interoperability test events already organized by FSAN
  - Allowing GPON vendors to test and fix their implementations
  - Broadband Forum members are invited to join FSAN GPON test events
- Once WT-247 and WT-255 are finalized, these documents will serve as a basis for Broadband Forum GPON test events
- FSAN now starts interoperability work on XG-PON1 and will organize XG-PON PHY and TC layers test events

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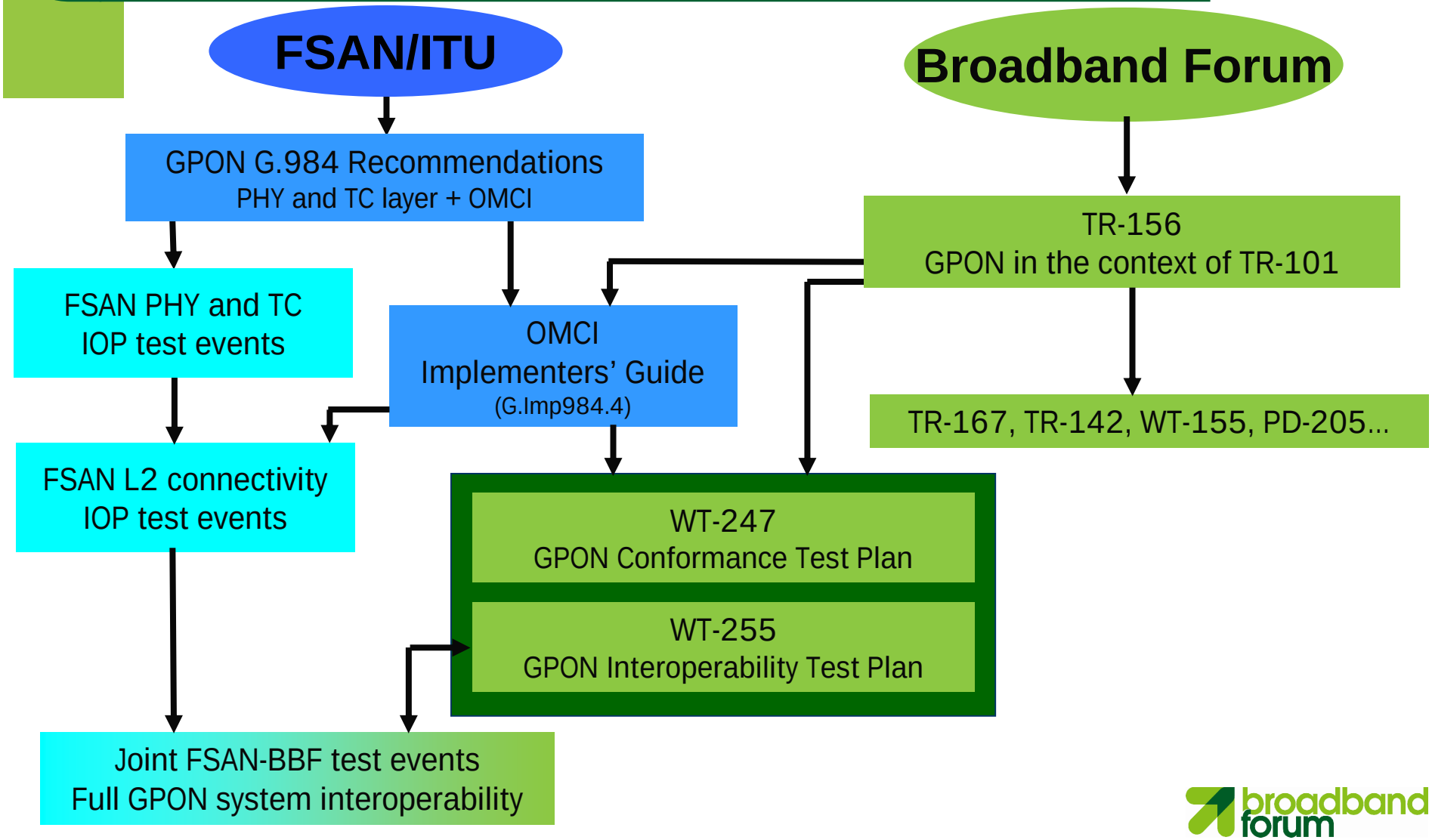
Collaboration on GPON Interoperability



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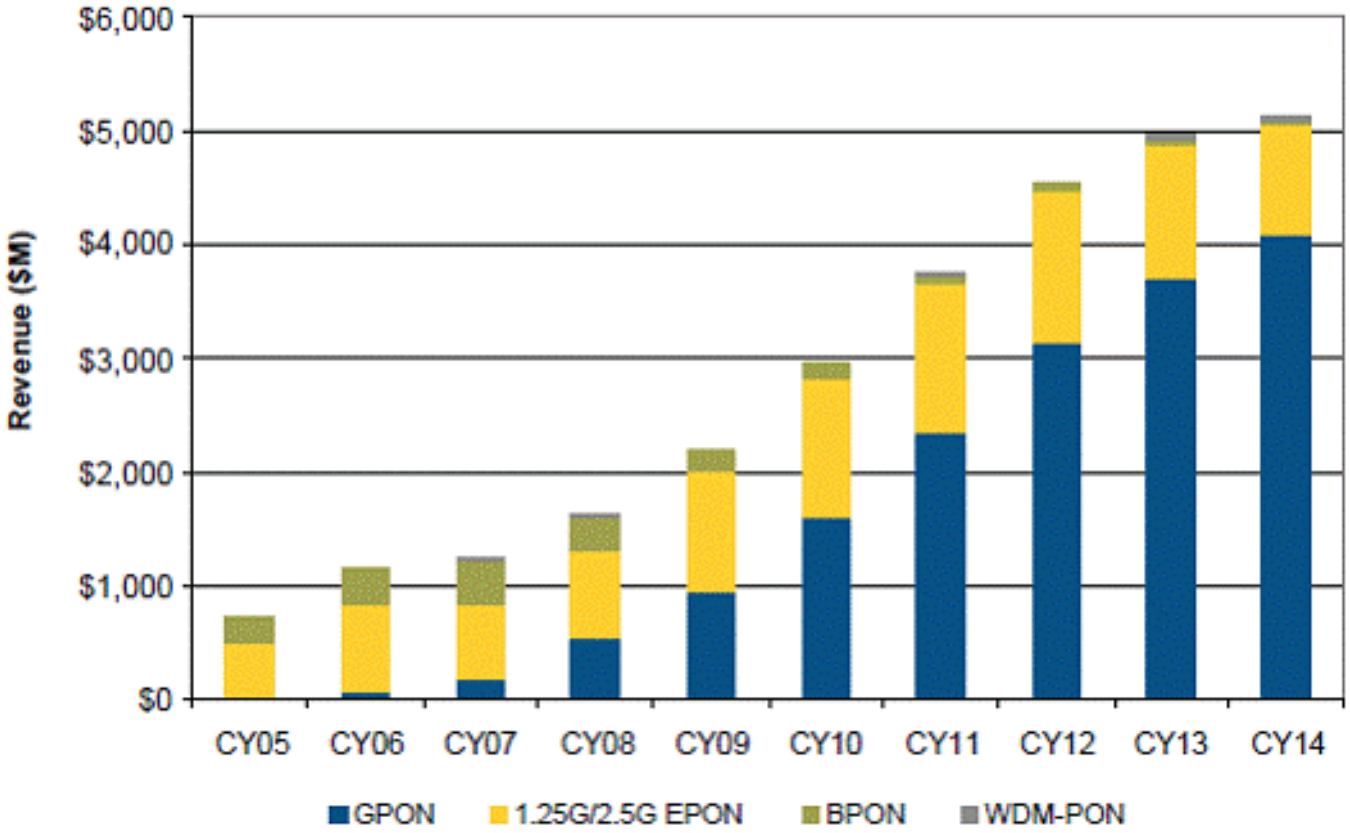
Market adoption and next issues

Market trends and future work

Market adoption

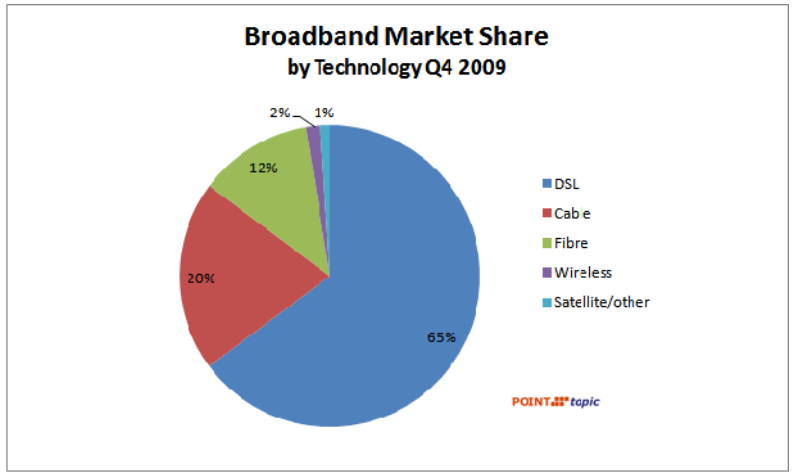
- GPON market is rapidly growing

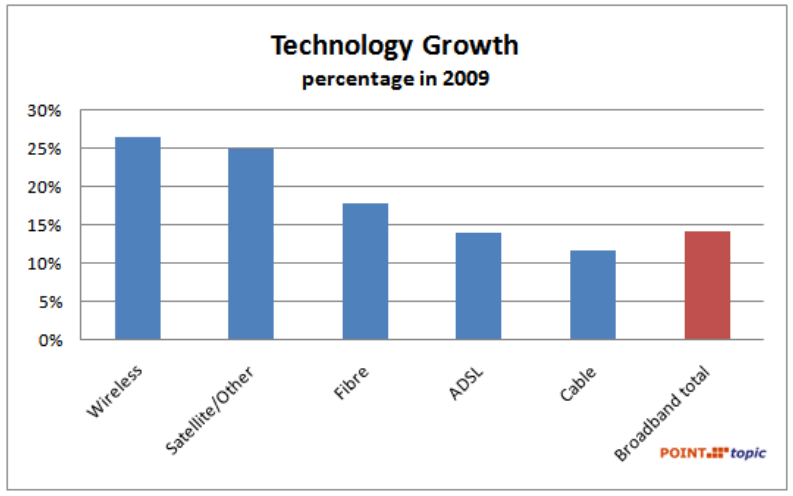


Source: Infonetics (March 2010)

Market adoption

- DSL continues as dominant broadband access technology, with 65% market share.
- Fiber experiences 18% annual growth.





broadband forum

More PON work is currently in progress at the Broadband Forum

- GPON work continues
  - WT-155 : Requirements for GPON RG
  - WT-247 : GPON Conformance Test Plan
  - WT-255 : GPON Interoperability Test Plan
  - PD-205 : GPON Management
- EPON work has started
  - WT-200: EPON in the context of TR-101
- Next generation PON technologies will be addressed as they develop
  - XG-PON1 is already covered by TR-142i2, TR-156i2 and TR-167i2 ☺☺☺

broadband forum

Partner organizations for PON related work

- FSAN: http://fsanweb.com
- HGI: http://www.homegatewayinitiative.org
- IEEE: http://www.ieee.org
- ITU-T: http://www.itu.int/ITU-T

Our doors are wide open

- All interested parties are encouraged to participate in our work!
- Broadband Forum Reports are freely available on our website:
  - http://www.broadband-forum.org

Thank you
for attending the GPON in FTTx Broadband Deployments Tutorial

For more information, visit us at

http://www.broadband-forum.org

Abbreviations

ACS – Auto-Configuration Server
ADSL – Asymmetric DSL
AES – Advanced Encryption Standard
AN – Access Node
AP – Access Point
ATM – Asynchronous Transfer Mode
BBF – Broadband Forum
BNG – Broadband Network Gateway
BPON – Broadband PON
BS – Base Station
BSC – Base Station Controller
COS – Class os Service
CPE – Customer Premises Equipment
CWMP – CPE WAN Management Protocol
DBA – Dynamic Bandwidth Allocation
DHCP – Dynamic Host Configuration Protocol
D/S – Downstream
DSL – Digital Subscriber Line
EMS – Element Management System
EPON – Ethernet PON
FITH – Fiber Into The Home
FTTH – Fiber To The Home
FTTO – Fiber To The Office
GEM – GPON Encapsulation Method
GPON – Gigabit Passive Optical Network
GTC - GPON Transmission Convergence
IGMP - Internet Group Management Protocol
IOP – Interoperability
IP – Internet Protocol
IWF – Inter-Working Function
LAN – Local Area Network
L2TP – Layer 2 Tunneling Protocol
MAC – Media Access Control
MEP – Maintenance End Point
MIB – Management Information Base
MIP – Maintenance Intermediate Point
MPLS – Multi-Protocol Label Switching
MR – Marketing Report

Abbreviations

OAM – Operations, Administration & Maintenance
ODN – Optical Distribution Network
OLT – Optical Line Termination
OMCI – ONU Management Control Interface
ONT – Optical Network Termination
ONU – Optical Network Unit
P2P – Point-to-Point
PCBD – Physical Control Block Downstream
PD – Proposed Draft
PLOAM – Physical Layer OAM
PMD – Physical Media Dependent
PON – Passive Optical Network
PPPoE – Point to Point Protocol over Ethernet
QOS – Quality of Service
RF – Radio Frequency
RG – Routing Gateway
RNC – Radio Network Controller
SIP – Session Initiation Protocol
SNMP – Simple Network Management Protocol
STB – Set Top Box
TC – Transmission Convergence
T-CONT – Traffic Container
TDM – Time Division Multiplexing
TDMA – Time Division Multiple Access
TR – Technical Report
TV - Television
UNI – User to Network Interface
U/S – Upstream
VDSL – Very high bit-rate DSL
VID – VLAN Identifier
VLAN – Virtual Local Area Network
VOD – Video on Demand
VoIP – Voice over IP
VPN – Virtual Private Network
vUNI – Virtual UNI
WAN – Wide Area Network
WDM – Wavelength Division Multiplexing
WT – Working Text