MARKETING REPORT

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Multi-Service Broadband Network Architecture Evolution

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Executive Summary

This white paper aims at describing the evolution of the Multi-Service Broadband Network Architecture, highlighting the key topics defined in the published BBF Technical Reports and explaining the relationships among the different BBF documents, in the context of the Multi-Service Broadband Network Architecture.

Starting from the challenges Service Providers have been facing, this document explains how the Multi-Service Broadband Network Architecture is able to fulfill the Service Providers' business requirement enabling the convergence of different types of services, residential and business, fixed and mobile, retail and wholesale, on a common network infrastructure. The document also highlights the flexibility of the Multi-Service Broadband Network Architecture in order to support emerging cloud and virtualized services.

1 Introduction

The Broadband Forum has been driving the evolution of Broadband Network Architectures for the last 12 years. During this timeframe Broadband Network operators have been facing several challenges and additional technical options have been introduced:

- the evolution from ATM to Ethernet to connect subscribers to their edge nodes;
- The evolution towards using MPLS as a virtualization technology in access and aggregation networks;
- the introduction of IPoE and Ethernet Sessions to complement PPPoE sessions;
- the deployment of IP multicast to support IPTV services;
- the migration from IPv4 to IPv6;
- the Interworking between next generation fixed and wireless access;
- the introduction of Cloud and virtualized services

The Technical Reports published by Broadband Forum in order to address Service Providers' business requirements and use cases, have been playing a critical role in helping the industry to face these challenges.

The goal of this white paper is to familiarize readers with the evolution of Multi-Service Broadband Network Architectures. It describes the major issues faced by the Service Providers in moving from legacy networks (ATM/TDM); to today's networks (capable of handling triple-play traffic); to future networks (capable of handling not-only Machine-to-Machine and Internet-of-Things traffic, but also supporting a variety of services in the Cloud).

This white paper provides an overview of ongoing and past work in the Broadband Forum in this area.

As to Broadband Forum work, this document highlights the key topics contained in each document, and explains the relationships among the different BBF documents in the context of the Multi-service Broadband Architecture defined in TR-144 [3], TR-145 [4] and WT-178 [9].

2 Main Challenges for the Network Operator

2.1 Introducing Multi-Service support

During the early 2000s the obsolesce of ATM, as aggregation technology, together with the desire to offer triple play residential services (data, voice, video/IPTV) led the operators to start defining a new aggregation network based on Ethernet technology. This architecture is defined in TR-101 [2], and the TR-101 Service Model is still the basis for the current broadband architectures.

The introduction of video services not only required the creation of a new aggregation network, but also introduced new requirements in terms of forwarding models and Subscribers Sessions. One of the key differences of the IPTV service compared to traditional services, like data and voice, is the requirement for Multicast forwarding. The use of multicast forwarding reduces utilization of network links between the video server and the customer by sending only a single copy of a media stream into the network.

Handling Multicast together with PPPoE sessions can be seen as complex, thus a requirement for a simple construct of Sessions came up. The DHCP protocol was introduced as an alternative to PPP for IP address configuration and service provisioning.
The use of DHCP in Broadband Networks started getting popular and DHCP based Sessions (defined in BBF terminology, IP Sessions) became an alternative to PPPoE Sessions for residential services, in scenarios where “always on” connectivity and simple IP based architecture were/are important requirements.

Augmenting the support of PPPoE Sessions with IPoE Sessions introduced additional challenges, mainly related to define new concepts for IPoE that were traditionally available for free with PPPoE, like authentications and monitoring of the session state. Not all the Service Providers have the same set or the same level of requirements in terms of Subscribers Sessions, thus different models have been defined. In addition in such environment a new type of Session, Layer2/Ethernet Sessions, came up.

After starting designing a new aggregation network for IPTV and triple play residential services, the Service Providers immediately saw the opportunity to use this new network to carry not only the traffic of residential customers but also traffic coming from business and wholesale clients. The next step in the evolution of the Multi-Service architecture was the possibility to transport fixed and mobile traffic over a common network architecture: this opened up for Mobile Backhauling initially of 2G/3G traffic, more recently of LTE/4G.

2.2 Migrating from IPv4 to IPv6

The Internet Assigned Numbers Authority (IANA) ran out of IPv4 addresses in February 2011: the world is now facing the fundamental problem of IPv4 address space exhaustion. There is a huge demand for IP addresses resulting from the explosive growth of mobile devices, including smart phones, portable gaming consoles, tablets, laptops and netbooks, and machine-to machine modules. The IPv6 protocol is designed to meet these requirements and to enable a global environment where network addressing is again transparent to the applications.
Continuous growth of the Internet requires the overall network architecture to evolve: Broadband network architectures are deeply impacted by the introduction of the IPv6 support not only in terms of migration towards IPv6, but also in terms of co-existence of IPv4 and IPv6 in Service Providers networks.

Broadband Forum started working on IPv6 migration back in 2008, defining the evolution of the Broadband network architecture from an IPv4 only network to a dual-stack IPv4/IPv6 network. As the IPv6 protocol is not backward-compatible with IPv4, a lot of work has been done on different IPv4 to IPv6 migration technologies in order to allow a smooth migration from IPv4 to IPv6; section 3 will explain in more details the Technical Reports that define this key topic.

2.3 The Usage of MPLS in the Multi-Service Broadband Network

IP/MPLS is a standard and mature technology widely deployed in several multi-vendors networks all over the world. IP/MPLS was initially deployed in core/backbone networks, given its flexibility to simply address different scenarios; it then became also very popular in the aggregation networks for delivering residential, business and mobile backhauling services, as a supporting technology for the TR-101 Ethernet Service Layer that interconnects CPE equipment with the IP Service Nodes. This model leverages Ethernet Access Nodes.

Extending IP/MPLS to the access network appears, for some Service Provides, the natural next step in building a single network architecture based on a common technology.
Using the same technology end-to-end in different network segments, from core to aggregation towards the access, introduces several benefits:

- Simplifies the provisioning chain by minimizing the provisioning points;
- Allows for flexible Service Node placement in the network;
- Improves the network scalability;
- Removes the need for a legacy (ATM, TDM) aggregation and access network.

Different Service Providers may have different visions in terms of how much complexity and which functionality is needed and/or can be supported on the Access Node (AN). These different views led to the definition of two different approaches for extending IP/MPLS to the access network:

- Seamless MPLS model
- Full MPLS model

In case of Seamless MPLS model the MPLS functionalities are extended to the AN minimizing the impact on the nodes themselves. In particular IP Routing is introduced in its simplest form by only using *static routes* from the AN to the aggregation nodes, while in order to achieve high scalability MPLS label distribution is performed by using the LDP Downstream On Demand model.
The Full MPLS model represents the complete extension of all the IP/MPLS and Layer 3/ dynamic routing functionalities to the AN. In this case the AN becomes functional equivalent to an aggregation node and in some cases can also host Broadband Network Gateway (BNG) functions.

For several different business reasons not all the Service Provides may be ready or willing to jump from Ethernet access network to an MPLS based access network. The choice amongst an Ethernet access network or a MPLS based access network using Seamless or Full MPLS functions, depends on the Service Provider's requirements and his current network architecture. All the three possible options are still considered valid and defined in BBF Technical Reports.

2.4 Interworking between next generation fixed and 3GPP wireless access

Service providers demand for the interworking and, in some cases, convergence between Broadband Forum and 3GPP networks. The Broadband Forum responds to these demands by working towards aligning the telecom industry by defining the interworking requirements between 3GPP Evolved Packet Core architecture and the Broadband Forum architectures.

The main convergence aspects addressed by the BBF – 3GPP interworking activities are:

- Converged business and services
- Converged network and infrastructure
- Converged user management and terminals

The main interworking use cases driving such technology developments, and the architectural frameworks devised to enable them are presented in TR-203 [11]. This document presents several technical evolution steps that can be taken from the present non-converged fixed and mobile networks towards a Fixed/Mobile Converged network. The nodal requirements derived from such architectures are specified in WT-291 [17].

Industry trends and business opportunities driving Fixed/Mobile Convergence are highlighted in . In there, it is also included an overview of the standardization organizations active in defining the open-standards that are an essential component to build a profitable and sustainable converged network, enabling feature rich, interoperable solutions and smooth deployment of novel customer services.

2.5 Introducing Cloud and Virtualized Services

Service providers are struggling with the constant need to increase market share, pressures around average revenue per user (ARPU) and service pricing, low and declining margins on hosted and co-located services, increasing capital and operating expenses, infrastructure complexity, speed of provisioning, and the demand for constant service innovation.

In most IT organizations, the process for data center application and infrastructure service requests is complex and expensive. Each request is often treated as a separate project, requiring approvals and exceptions. The result is a time-consuming and inefficient series of manual steps, involving requirements validation and architecture reviews. Optimizing IT operations in order to speed up this process is clearly becoming an urgent need for several organizations.

The concept of Cloud computing as a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort is becoming a dominant paradigm in today's networks. Cloud computing can be seen as the next step in the evolution of the Internet. Clouds are fundamentally changing the way that businesses and people consume services: enabling IT to be delivered as a service. Cloud has the potential to have a massively positive impact on Capital Expenditure and Operational Expenditure.

In such environment Broadband Service Providers have a unique reach to customers: being able to leverage and improve current network architectures to offer Cloud and virtualized services is a key goal for Service Providers that see the Cloud computing as an innovative source for revenues. Cloud Computing will play a key role in generating new business as Broadband Service Providers can break into the IT services market using their existing assets. Cloud computing will have a significant impact on broadband networks going forward.

Network Function Virtualization (NFV) is next logical step towards virtualization. NFV attempts to offload (some of the) network embedded functions onto x86-based computing platforms, allowing tighther integration into datacenter/cloud based orchestration systems. NFV is currently one of the main forward looking topics discussed at the Broadband Forum.

3 Roles played by BBF Technical Reports

The core of the Multi-Service Broadband Architecture is made up of three fundamental documents:

- TR-144 “Broadband Multi-Service Architecture & Framework Requirements” [3]
- TR-145 “Multi-service Broadband Network Functional Modules and Architecture” [4]
- WT-178 “Multi-service Broadband Network Architecture and Nodal Requirements” [9]

However the building blocks necessary to create a complete Multi-Service Broadband Network Architecture are defined in several Technical Reports, each of them focuses on a specific topic/key issue and it explains the use-cases and the technical requirements necessary to support them. Section 3 summarizes the roles played by the Technical Reports and their relationships with the Multi-Service Broadband Architecture; the following sub-sections will details the content of each document.

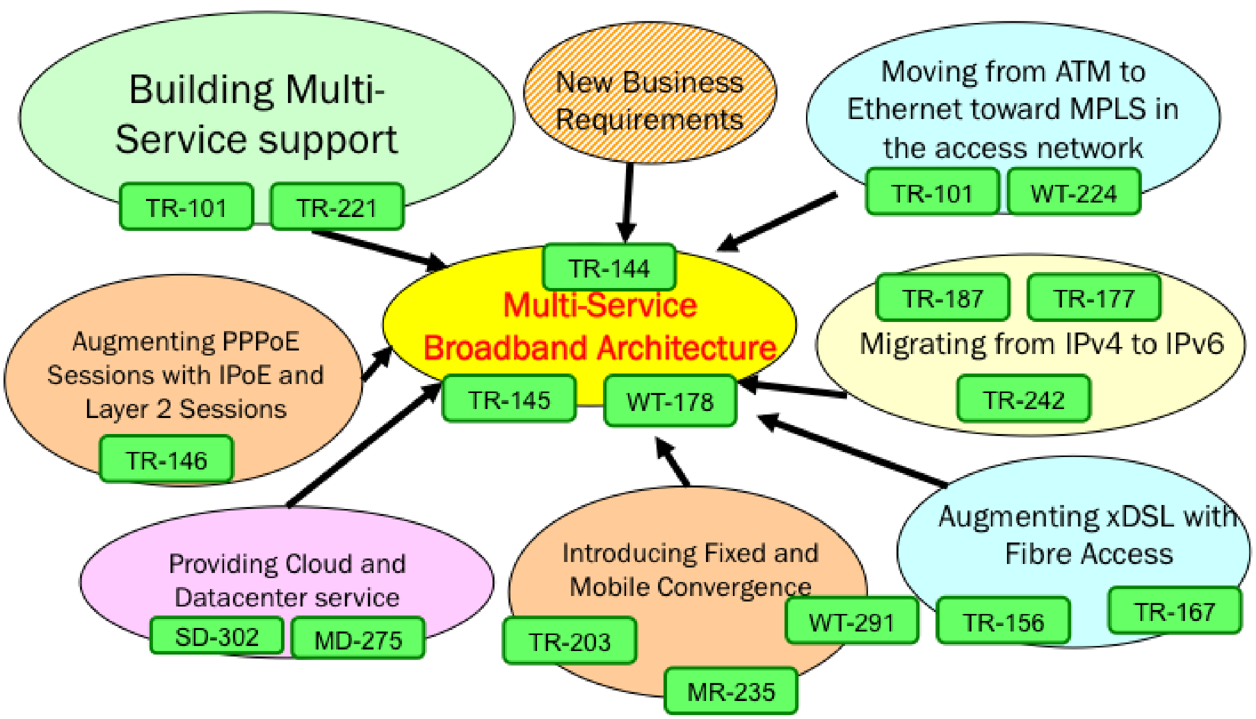

Figure 1 : Roles played by BBF Documents

3.1 The Core of the Multi-Service Architecture

3.1.1 Business Requirements

The first published Technical Report belonging to the Multi-Service Broadband Network Architecture is TR-144 [3]. This document describes the drivers and requirements for the Broadband Multi-Service Architecture.
The key motivations that triggered the definition of the Multi-Service Broadband Network Architecture can be summarized as following:

- *Simplification of network architecture*: for new deployments free from migration constraints, an end-to-end architecture that is a combination of an IP/MPLS and Ethernet;
- *Seamless connectivity*: Integration of access, aggregation and core networks;
- *Multi-service support* for residential, business, retail, wholesale, fixed, mobile, emerging cloud/virtualized services over a common network architecture;
- *Operational enhancements*: migration to a converged packet based access and aggregation network to minimize the number of operational touch points and to simplify and improve the end-to-end provisioning process;
- *Service independence*: support for separation of the client service and transport network;
- *Multipoint services* (e.g. for business connectivity): the network must provide the appropriate packet layer functionality in both control and data planes, typically based on Ethernet or IP/MPLS;
- *Multi-Edge support*: the ability to source traffic to an individual subscriber from multiple Service Edges;
- *Enhanced availability with resiliency*: use of OAM and an appropriate control plane for automatic convergence protection and/or restoration in case of a network link or a network node failure or maintenance activity;
- *Enhanced Scalability*: each IP Edge Node has a finite ARP table, and each Ethernet switch also has limited MAC table size. Distributing IP Edge Nodes closer to customers allows the connection of more customers through an aggregation network.

3.2 Functional Modules and Architecture

After identifying the key business requirements BBF started working on the Multi-service Broadband Network Functional Modules and Architecture, **TR-145** [4].
The goal of this document is to define the Multi-Service Broadband Network Architecture able to support the emerging and the legacy services and that it is flexible enough to allow the deployment of new services like Cloud Computing. This document defines reference architectures for multi-service broadband networks and it specifies several functional modules necessary to meet the Service Providers' business requirements. The functional module decomposition adopted in TR-145 enables a variety of deployment options and different distributions of functions.
Convergence of all services over common network architecture is a key objective TR-14: this TR specifies a converged broadband network architecture supporting many types of services, access and transport technologies, and deployment scenarios envisioned by service providers.

3.2.1 Service Layers

The Multi-Service nature of TR-145 implies the capability to offer services at different layers. One of the key concepts of TR-145 is the use of Service Layers, which can be classified as:

- **IP Service Layer**: these are the services seen by subscribers at the IP layer e.g. L3-VPNs or Residential Internet Access.
- The **Ethernet Service Layer**: these are the services seen by subscribers as Ethernet Services (MEF Services) as well as the (emulated) Ethernet constructs to connect IP RGs or CPE to their IP Service Edges. The Ethernet Service Layer will perform 802.1ad Ethernet Aggregation, very much like the model deployed in TR-101 [2].
- The **Supporting Aggregation Layer**: this is the layer that emulates the Ethernet Service layer on top of a different technology (e.g. IP/MPLS).

An important piece of the TR-145 architecture is the concept of ***Infrastructure Virtual Circuit (IVC)*** that is the basic building block for constructing end-to-end Ethernet Service Layer connectivity. An Infrastructure Virtual Circuit (IVC) can be from either user to user or from user to service edge. An end-to-end IVC consists of one or more IVC segments. For instance, an end to end multipoint IVC can be built from the combination of a simple point-point (E-LINE) IVC segment in the access network (IVC1a in Figure 2 and a multipoint IVC (IVC1b in Figure 2) in the Regional network that supports E-LINE, E-LAN, and E-TREE services. This example IVC extends the E-LINE, E-LAN, and E-TREE services all the way to the end user.
A pair of IVCs can be used to provide redundancy, which is especially important for the RNC/GW in mobile network and core network for mobile backhaul. This can be achieved with or without geographical diversity in the network.
A particular logical interface could be shared by multiple virtual connections; therefore there is a need distinguish a single virtual connection, such as an IVC on a logical interface. The instantiation of an IVC at a given logical interface is called the ***Ethernet Flow Point (EFP)***. By defining the functions and attributes at the EFP level, one can model how packets traverse a certain function and get encapsulated/conditioned/ filtered/etc.

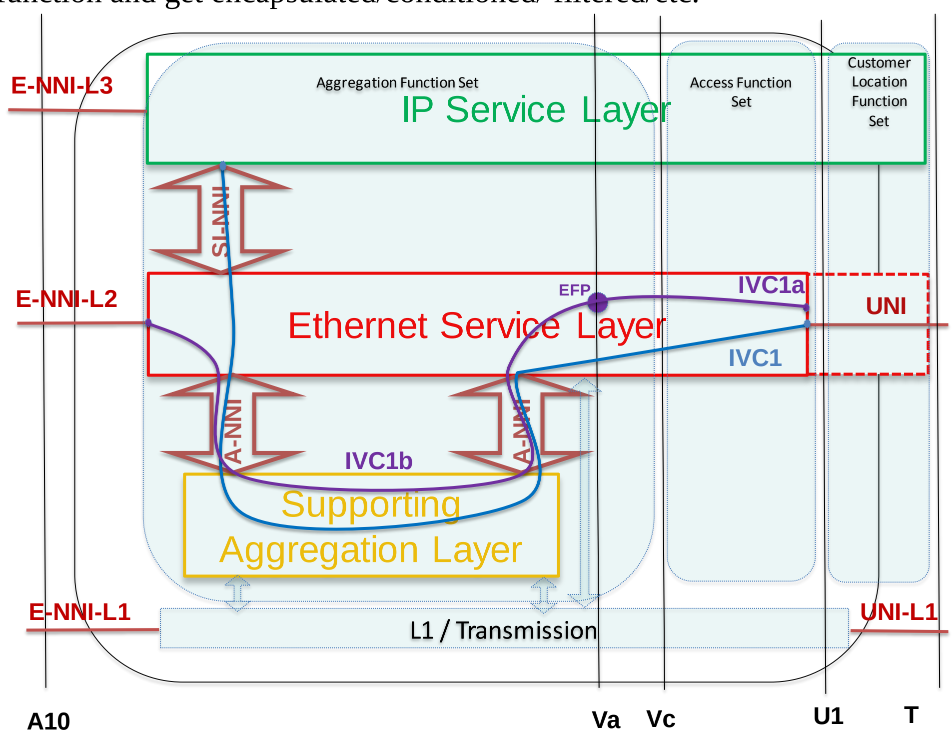

Figure 2 : IVC Example

TR-145 [4] specifies the functional requirements for the Ethernet Service Layer (at IVC and EFP level) and IP Service Layers in terms of support for QoS, Multicast, resiliency, geo-graphic redundancy, OAM and security.

3.2.2 Nodal Distribution and Architectural Models

Multiple Services are supported by the TR-145 architecture. Therefore most nodes will have to carry traffic for different service types, often received on the same interface. As different Service types might need a different logical topology, a node will have to incorporate different functions, on a per service (or set of aggregated or similar services) basis.

How far the Infrastructure Virtual Circuit (IVC) reaches into the topology and where it terminates into the L3 aggregation functionality depends on various factors, such as:

- Subscriber density and concentration;
- Whether a high amount of per subscriber/customer control is needed and or the Service Type; In typical scenarios a high amount of per subscriber state calls for greater centralization; Where Qos is only needed on a per service basis this can be more easily distributed (e;g; some Video deployments);
- Failure Domain: distributed Service Edges have a smaller failure domain;
- Ease of provisioning: distributed Service Edges need 'very short' IVCs, thus making the IVC provisioning easier and the stitching of individual segments of the IVCs may be unnecessary; However this places a greater provisioning load on the Service Edges themselves;
- Distribution of Application and Caching Servers (VoD, I-frame, etc), as they need to be placed behind the relevant service edge;
- The opportunity to reduce backhaul over subscription;
- Providing low latency services might require more distribution of Service Edges;
- Organizational structure of the Service Provider;
- IVC/aggregation technology used: if an IVC technology is used that can leverage an IP based control plane, Service Edge placement is very flexible, as a node can leverage that control plane to built IVCs for service X, as well as being a Service edge for Service Y;
- Regulatory requirements like legal intercept and regulated interconnect points;

The functional disposition and topology may be service specific and require a variety of technologies, such as:

- Ethernet 802.1ad Based Forwarding
- Point-to-point, point-to-multipoint and multipoint L2VPNs, to build business and wholesale services with Ethernet based handoffs. For IP Services the same technologies can be deployed to build IVCs interconnecting users to Service Edges.
- Multicast and Unicast IP based aggregation, e.g. to build Video and Internet Access Services.
- L3 VPNs for IP business services and for virtualization of IP services.

A node may need to support more than one of the above technologies at the same time.

All these considerations lead to several possible network architectures; the functional modules defined in TR-145 are flexible enough to allow building different architectural models. The disposition of the functional modules into the physical network node depends on the service and on the operator's requirements and constrains. The key elements to be considered to build the different architectures are the following:

- use of **Ethernet** or **IP/MPLS** in the **aggregation** network;
- use of **Ethernet** or **IP/MPLS** in the **access** network;
- deployment of **Centralized** versus **Distributed BNGs**;
- The concept of **BNG hierarchies**: the BNG can be split in Edge and Service BNG. An Edge BNG is the IP aggregation point for some services/Service VLANs. A Service BNG has similar requirements to an Edge BNG, but can be specialized with regard to service offerings such as Ethernet Services, Mobility, IPv6, and CGN.
- The possibility to embed advance functions in the Access Node (for example **BNG embedded AN**).

By combining all these elements different network models can be built; here there are some examples of network architectures supported by TR-145 [4]:

1. **Ethernet based Architecture** (TR-101 model) where Access and Aggregation network are Ethernet based and the supporting aggregation layer (IP/MPLS) is absent;
2. **Ethernet Access, MPLS Aggregation based architecture:** supporting aggregation layer (IP/MPLS) is present only in the aggregation nodes (commonly used today);
3. **MPLS Access, MPLS Aggregation based architecture:** supporting aggregation layer (IP/MPLS) is extended to the access nodes
4. **Combination of architectures 2 and 3 with Hierarchical BNGs (**Edge/Service BNG**)**
5. **MPLS and IP Aggregation in the Access Node:** supporting aggregation layer (IP/MPLS) is extended to the access nodes and BNG functionalities are embedded in the AN.

Figure 3 shows an **example** of architecture 4 where TR-101 [2] Ethernet Access Nodes are re-used. However, the node performing the second level of aggregation can perform both IP/MPLS aggregation as well as IP Aggregation depending on the services. In other words it is a full-blown BNG called Edge BNG or BNG_{EDGE}. It will be the IP aggregation point for some services/Service VLANs, whereas it will also perform MPLS tunneling towards more centralized Service Edges Service BNGs ($BNG_{SERVICE}$). See section 6.4 of TR-145 for more examples.

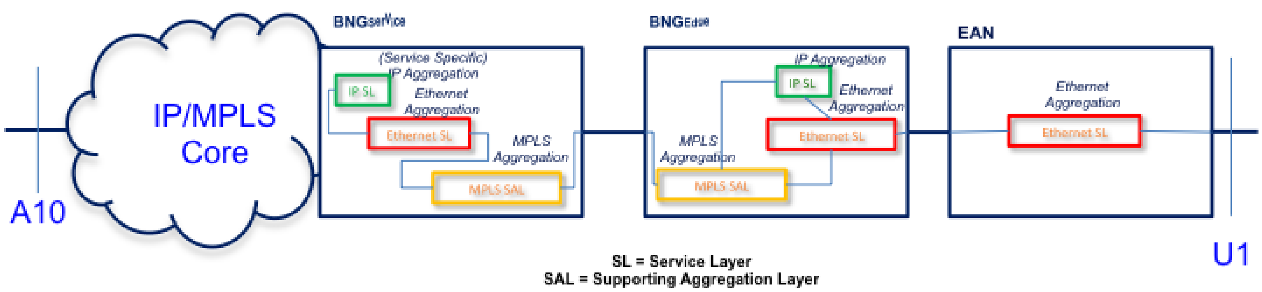

Figure 3 : BNG Hierarchies, High Level Functional Distribution

3.3 Nodal Requirements

WT-178 defines the next step in moving from Architecture and Functional Modules towards nodal requirements. This document describes a set of architectures for broadband multi-service network, re-using the functional modules provided in TR-145 [4].
Starting from such architectural models WT-178 defines the specific nodal requirements necessary to support the addresses typical infrastructures, topologies and deployment scenarios, and it specifies associated nodal requirements in order to fulfill the business requirements defined in TR-144 [3].
The main changes introduced in the WT-178 architectures compared to the legacy TR-101 [2] model are:

- The emulation of the TR-101 Ethernet Service Layer on top of IP/MPLS
- the optional extension of IP/MPLS to the access network;
- the introduction of BNG hierarchies concept with the definition of Edge and Service BNGs;
- the possibility to embed BNG factions in the Access Node, effectively turning the Access Node into an Edge BNG.

WT-178 [9] tackles all these possible deployment scenarios based focusing on these new elements and it defines the details nodal requirements for these scenarios.

Regarding the extension of IP/MPLS to the access network the document specifies two different approaches, (Seamless MPLS model, Full MPLS model) and for both of them it defines a set of requirements for the Access Nodes.

The concept of BNG hierarchies introduces a large set of requirements mainly related to QoS and OAM handling and the possible need for coordination between Edge and Service BNGs.

Finally BNG embedded AN represents an alternative that some Service Providers are currently considered allowing them to distribute the BNG functionalities even more closer to the customers. WT-178 describes requirements for this scenario too.

Specific nodal requirements derived for the fixed mobile interworking use cases presented in TR-203 [11] are specified in WT-291 [17].

3.4 The Key Technical Building Blocks

This section describes the key technical solutions defined by BBF to tackle the challenges faced by the Service Providers; all the documents described in the following sub-sections are necessary to complement the core documents (TR-144, TR-145, WT-178) for the definition of the Multi-Service Broadband Network Architecture.

3.4.1 IP/MPLS in Broadband Networks

IP/MPLS is a key technology widely used in the Multi-Service Broadband Network Architecture to achieve support for residential, business, fixed and mobile services over common network architecture.
The requirements for introducing IP/MPLS in broadband networks are described in several BBF documents: TR-145, WT-178 , TR-221 [12] and WT-224 [13] deal with MPLS requirements.

TR-145 [4] talks about IP/MPLS when introducing the *Supporting Aggregation Layer*. As already described in section 3.2.1, IP/MPLS is the constitutional element of the Supporting Aggregation Layer used to emulate the Ethernet Service layer on top of a different technology. TR-145 describes several architectural options according to the network segments (access, aggregation or both) where IP/MPLS is deployed.

WT-178 [9],as introduced before, specifies nodal requirements to introduce IP/MPLS into the aggregation and extend IP/MPLS towards the Access network.

TR-221 [12]provides technical architecture and nodal requirements for MPLS based mobile backhaul networks. TR-221 focuses on the application of MPLS technology in these networks with regards to encapsulation, signaling and routing, QoS, OAM, resiliency, security and synchronization. TR-221 approaches the mobile backhaul architecture from the point of view of the transport network. Mobile traffic is considered as application data of the respective Transport Network Layer (TNL) and is transparent to the transport network. Different MPLS solutions can be used to transport the TNLs of mobile networks: L2VPN, (e.g. VPWS, VPLS, H-VPLS), L3VPN (e.g. BGP L3VPN), and IP routing over MPLS (e.g. IP over LSPs).

WT-224 [13] provides the technical architecture and nodal requirements for implementing Carrier Ethernet Services over an MPLS network. This document defines requirements for Carrier Ethernet Services using Layer 2 VPN mechanisms:

- Ethernet point to point (E-Line) and multipoint to multipoint (E-LAN)
- A subset of point to multipoint (E-Tree*- defined elsewhere in this document)
- Control, OAM, QoS, reliability and scalability for the MPLS network

3.4.2 IPv6 and IPv4/IPv6 migration mechanisms

In the migration from IPv4 to IPv6 the Dual-Stack model remains the simplest and most well understood approach today. **TR-177** [8] and **TR-187** [10] describe respectively IPoE and PPPoE Dual-Stack architectures that can be deployed by operators to provide IPv6 unicast services in addition to existing IPv4 services, leveraging TR-101 [2] based broadband network architecture. These documents, by describing in details use cases and nodal requirements, serve as a guideline to help the Service Providers in building a Broadband dual-stack IPv4/IPv6 network architecture.

Unfortunately the classic Dual-Stack alone does not help with the IPv4 address depletion problem. In addition this model may not be directly applicable to some operators' networks either because the Service Providers do not have any more enough IPv4 addresses left to provision the new subscribers, or because this model would require upgrading different existing network equipment which may include the Residential Gateway (RG), Broadband Network Gateway (BNG) and Access Node (AN).

There is a variety of coexistence or translation techniques being proposed at the IETF to allow continued expansion of the current Internet: the adoption of a specific mechanism in the BBF's architecture may depend on different factors and at the end of the day it is the Service Provider's choice.

TR-242 [15] specifies the nodal requirements necessary to support selected transition IPv6 mechanisms enabling operators to handle the operational and deployment challenges related to IPv4 address exhaustion, IPv6 introduction and IPv4/IPv6 co-existence. TR-242 describes different techniques, which enable different migration paths:
Techniques that deal with IPv4 address exhaustion do not simply depend on the introduction of IPv6. These techniques involve some kind of IPv4 address sharing;

- Techniques that ease the introduction of IPv6 by not requiring dual stack End-to-End;
- Techniques that maintain IPv4 service continuity for IPv4 only hosts and/or applications by not requiring dual stack End-to-End.

3.4.3 Interworking between Next Generation Fixed and 3GPP Wireless Access

Enabling interworking between next generation fixed and 3GPP wireless networks requires the introduction of interworking functions from the perspective of the BBF fixed access network. These functions include both the user plane and control plane.

TR-203 [11] has specified an interworking framework that illustrates this, see Figure 4:

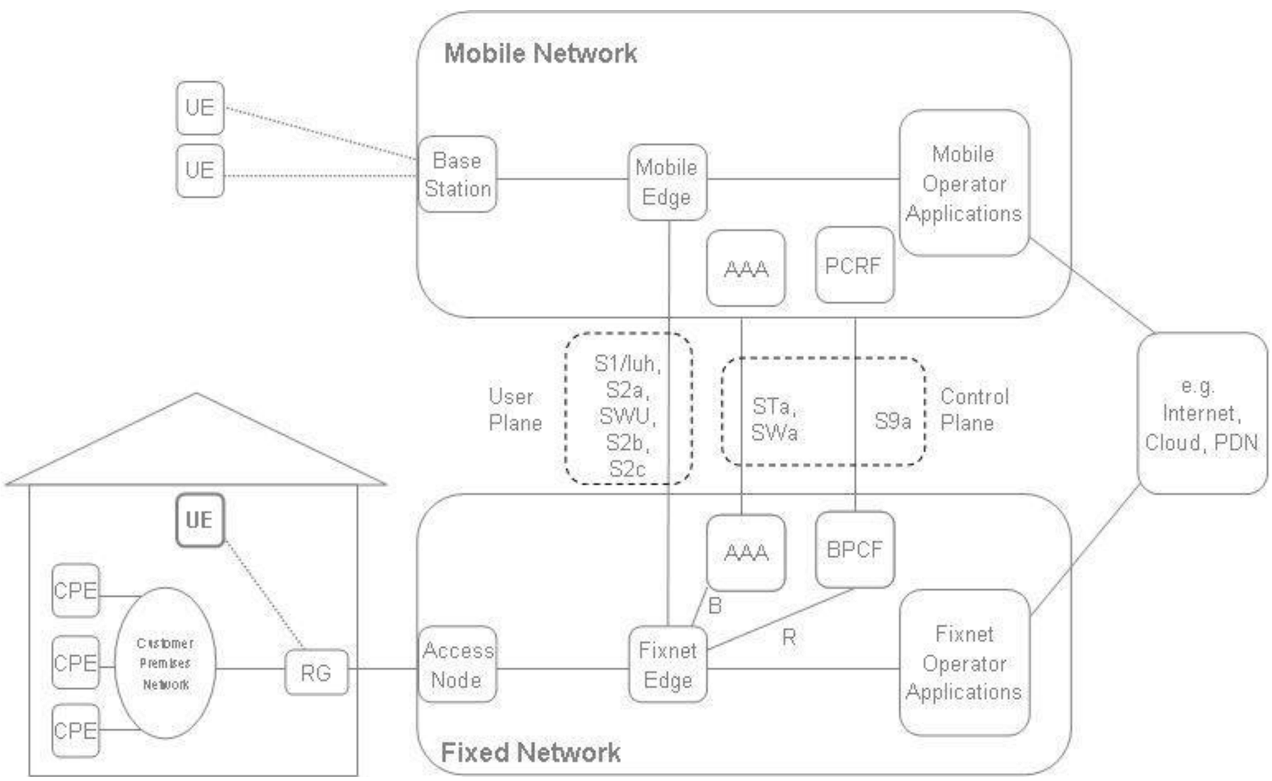

Figure 4: TR-203 interworking framework

This framework enables three different interworking architectures, which are:

- Trusted WLAN Interworking Reference Architecture
- Untrusted WLAN Interworking Reference Architecture
- Femto interworking reference architecture

The three reference architectures are described in detail in TR-203 [11] while the nodal requirements derived from such architectures are specified in WT-291 [17]. These architectures satisfy the interworking use cases identified by both BBF and 3GPP. These interworking use cases are:

- Internet access with parental control and personal firewall
- Voice / multimedia and charging
- Video
- 3G femto
- Application mobility
- Dual-WAN connected device

The use cases are for the interworking between next generation fixed and 3GPP wireless networks for 3GPP UE devices only. These use cases include public and enterprise network fixed access types and a reasonable set of permutations of fixed access types. These include WiFi provided by non-3GPP SP's, fixed access such as Ethernet and H(e)NB for 3GPP UE devices to move between the different access types and service providers. These are deployed in a variety of fixed served access locations such as broadband Home Networks, public Hot Spots, community WiFi, Business Intranets and Public Zones.

3.4.4 IPoE and Layer 2 Ethernet Sessions

TR-146 [5] describes Subscriber Sessions as an evolution of broadband access networks from PPP-based to Ethernet/Layer 2 and IPoE-based networks. TR-146 describes Subscriber Session Management for Ethernet, IPv4 and IPv6 Subscriber Sessions. In particular this document describes how to perform authentication, authorization, accounting and IP address/prefix allocation of IPoE connected endpoints to provide specific Subscriber profile management for these endpoints.

TR-146 defines Subscriber Sessions and Flow classifiers, along with Session authentication and management applicable to a broadband access environment. This allows service providers to provide a diversified set of Ethernet and IP services, whilst still having the network tools to control and account for them.

3.4.5 Cloud Services and Virtualization Support

A cloud is a powerful combination of computing, networking, storage, and management resources, enabling a new generation of consumer and enterprise IT services that are available on demand and delivered economically to any device anywhere in the world without compromising security or function.

SD-302 [18] provides a framework to support cloud services in multi-service Broadband Networks. It contains use cases of Cloud Services as a new kind of networking function in the context of Multiservice Broadband Networks.

Key requirements of the Cloud Services include:

- "***On-demand"*** means that resources can be provisioned immediately when needed, released when no longer required, and billed only when used;
- ***"At-scale"*** means the service provides the illusion of infinite resource availability in order to meet whatever demands are made of it;
- ***"*Elasticity**" means that resources are scalable according to demand;
- **"Broad network access"** means that resources can be accessed from different places and using any device;
- ***"Multitenant environment"*** means that the resources are provided to many consumers from a single infrastructure, saving the provider significant costs;
- ***"Measured service"*** means that the resource usage can be metered

Cloud services offered by broadband networks can be architecturally categorized as a new set of services under the multi-service umbrella defined by TR-145 [4], where the architecture, its components and access model can be leveraged to offer Cloud Services.

The Multi-Service Broadband Network Architecture defined in TR-145/WT-178 already contains some important elements necessary to address some of the Cloud Services requirements.
For example the capability to scale and growth on demand in elastic way is a key characteristic of TR-145 architecture where nodes can be grouped in virtual clusters and functions can be moved from centralized to distributed nodes in order to be able to handle the growth in terms of both subscriber's population and required bandwidth. The "on-demand" configuration and provisioning of new services is another important piece already specified in TR-145/WT-178 for both layer 2 and layer 3 services.

Further more the concept of the Ethernet Service Layer can simply be re-used to embrace Data-Center interconnection: there are techniques such as VPWS and VPLS, and newer technologies such as E-VPN and PBB-EVPN that leverage IP/MPLS technology as Supporting Aggregation Layer to provide scalable Data-Center interconnection. These options are described in the tutorial MR-275, "Enhancing IP/MPLS based Carrier Services to address the Data Center Interconnection Market".
Regarding Multi-tenant support, different options are still under discussion in IETF, some are layer 2 , some are layer 3 based; once a set of option is selected it won't require major changes to the Multi-Service Broadband Network Architecture in order to provide Multi-tenant support.
The work done in the TR-145/WT-178/WT-224 on Ethernet OAM (IEEE 802.1ag and Y.1731) and MPLS OAM could be leveraged to monitoring emerging services.

4 Conclusions

The architectural models defined in TR-145/WT-178 documents together with the technical options covered in the other described Technical Reports provide to the Service Providers a complete set of solutions able to truly fulfill different operator's needs in terms of deploying traditional and emerging services over a common, scalable network architecture.

5 Terminology

5.1 References

The following references are of relevance to this Marketing Report. At the time of publication, the editions indicated were valid. All references are subject to revision; users of this Marketing Report are therefore encouraged to investigate the possibility of applying the most recent edition of the references listed below.
A list of currently valid Broadband Forum Technical Reports is published at www.broadband-forum.org.

Document		Title	Source	Year
[1]	RFC 2119	*Key words for use in RFCs to Indicate Requirement Levels*	IETF	1997
[2]	TR-101	*Migration to Ethernet-Based Broadband Aggregation*	Broadband Forum	2011
[3]	TR-144	*Broadband Multi-Service Architecture & Framework Requirements*	Broadband Forum	2007
[4]	TR-145	*Multi-service Broadband Network Functional Modules and Architecture*	Broadband Forum	2012
[5]	TR-146	*Subscriber Sessions*	Broadband Forum	2013
[6]	TR-156	*Using GPON Access in the context of TR-101*	Broadband Forum	2012
[7]	TR-167	*GPON-fed TR-101 Ethernet Access Node*	Broadband Forum	2011
[8]	TR-177	*IPv6 in the context of TR-101*	Broadband Forum	2010
[9]	WT-178	*Multi-service Broadband Network Architecture and Nodal Requirements*	Broadband Forum	N/A
[10]	TR-187	*IPv6 for PPP Broadband Access*	Broadband Forum	2013
[11]	TR-203	*Interworking between Next Generation Fixed and 3GPP Wireless Networks*	Broadband Forum	2012
[12]	TR-221	*Technical Specifications for MPLS in Mobile Backhaul Networks*	Broadband Forum	2011
[13]	WT-224	*Technical Specification for MPLS in Carrier Ethernet Networks*	Broadband Forum	N/A
[14]	MR-235	*Considerations in Broadband Architecture Moving to FMC*	Broadband Forum	2011
[15]	TR-242	*IPv6 Transition Mechanisms for Broadband Networks*	Broadband Forum	2012

[16]	MR-275	*Enhancing IP/MPLS based Carrier Services to address the Data Center Interconnection Market, Tutorial*	Broadband Forum	2011
[17]	WT-291	*Nodal Requirements for Interworking between Next Generation Fixed and 3GPP Wireless Access*	Broadband Forum	N/A
[18]	SD-302	*Framework for Cloud Services in Broadband Networks*	Broadband Forum	N/A

5.2 Abbreviations

This Marketing Report uses the following abbreviations:

TR	Technical Report
WG	Working Group
WT	Working Text
BBF	Broadband Forum
ATM	Asynchronous Transfer Mode
MPLS	Multi Protocol Label Switching
PPPoE	Point to Point Protocol over Ethernet
IPTV	Internet Protocol Television
TDM	Time Division Multiplexing
DHCP	Dynamic Host Discovery Protocol
IPoE	Internet Protocol over Ethernet
LTE	Long Term Evolution
IANA	Internet Assigned Number Authority
AN	Access Node
EAN	Ethernet AN
LDP	Label Distribution Protocol
BNG	Broadband Network Gateway
3GPP	3rd generation partnership project
ARPU	Average Revenue per User
NFV	Network Function Virtualization
OAM	Operations and Management
ARP	Address Resolution Protocol
MAC	Media Access Control
IVC	Infrastructure Virtual Connection
EFP	Ethernet Flow Point
QoS	Quality of Service
VOD	Video on Demand
L2VPN	Layer 2 Virtual Private Network
L3VPN	Layer 3 Virtual Private Network
VLAN	Virtual Local Area Network

WiFi	Wireless Fidelity	E-VPN	Ethernet VPN
UE	User Equipment	PBB-EVPN	Provider Backbone Bridging E-VPN
VPWS	Virtual Private Wire Service		
VPLS	Virtual Private LAN Service		

End of Broadband Forum Marketing Report MR-316