MARKETING REPORT

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Next Generation Broadband Access White Paper

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1 Executive Summary

Global demand for broadband Internet access is as strong as ever. A tough economy, rising energy costs, and flu epidemics often turn consumers and businesses to broadband as a cost-effective and green alternative for communication, collaboration, and entertainment. Service providers are not only working hard to expand service coverage and increase subscriber penetration rates, they are also asking how they can significantly improve interoperability and network performance, increase bandwidth, and lower latencies for demanding applications such as IPTV, interactive gaming, and video chat.

Broadband access has reached yet another generation, thanks to the continued advancements in DSL, introductions of passive optical networks (PONs), optical Ethernet fiber to the premises (FTTP), and wireless access via Worldwide Interoperability for Microwave Access (WiMAX) or Long Term Evolution (LTE) in the last mile. The landscape of broadband technologies has grown more capable and complex with the addition of these exciting alternatives. Decision makers and technologists alike are faced with choices on access technologies and network architectures that have long-term implications. The purpose of this white paper is to provide an overview of next-generation access technologies, and to show how these new technologies can both enable new services and still coexist with, and make use of, currently deployed broadband access infrastructure.

The Broadband Forum, successor of the DSL Forum, has recognized the need to shepherd new access technologies to market since 2005, and has been actively working on incorporating fiber and other alternative broadband access methods into its standardization work. In doing so, it strives to align future architectures with the existing global deployment of more than 400 million broadband lines, while meeting the demands of future applications.

2 State of Broadband Network Access

In the past five years, broadband access has grown greatly in terms of the number of customers serviced, the bit rates delivered, and the ability to support a larger set of services and applications. Global broadband subscribers rose 28% annually from 150 million in 2004 to beyond 400 million in 2008. IPTV subscribers rose even faster, exceeding 20 million in 2008. (Source: PointTopic, 2009).

Even during a time when the global economic landscape looks grim, the outlook for broadband access remains upbeat for several reasons. Broadband access into the home enables cheaper and greener alternatives to traditional entertainment, leisure travel, and job-related commutes. A broadband link to the world provides job opportunities farther away from home. A flu epidemic may put a brake on business travel, but it is nearly “business as usual” if you have broadband access. More people are using the Internet for multimedia and interactive applications such as entertainment video, interactive/multiplayer gaming, and video chat. Governments around the world are funding national broadband infrastructures much akin to developing physical infrastructures such as roads, bridges, schools, and hospitals.

Fueled by an increasing number of high bandwidth applications, the consumer’s appetite for speed is growing worldwide. By 2010, it is predicted that about 75% of U.S. households will have broadband service, and over 15% of households will subscribe to very high-speed broadband of at least 24 Mbps, according to a report from Technology Futures, Inc. (TFI)—*Transforming the Local Exchange Network: Fourth Edition*. The figure below shows history and projections for broadband penetration and technology migration in the United States. While the data is limited to the U.S. market, it demonstrates an enormous market momentum towards higher bandwidth access technologies.

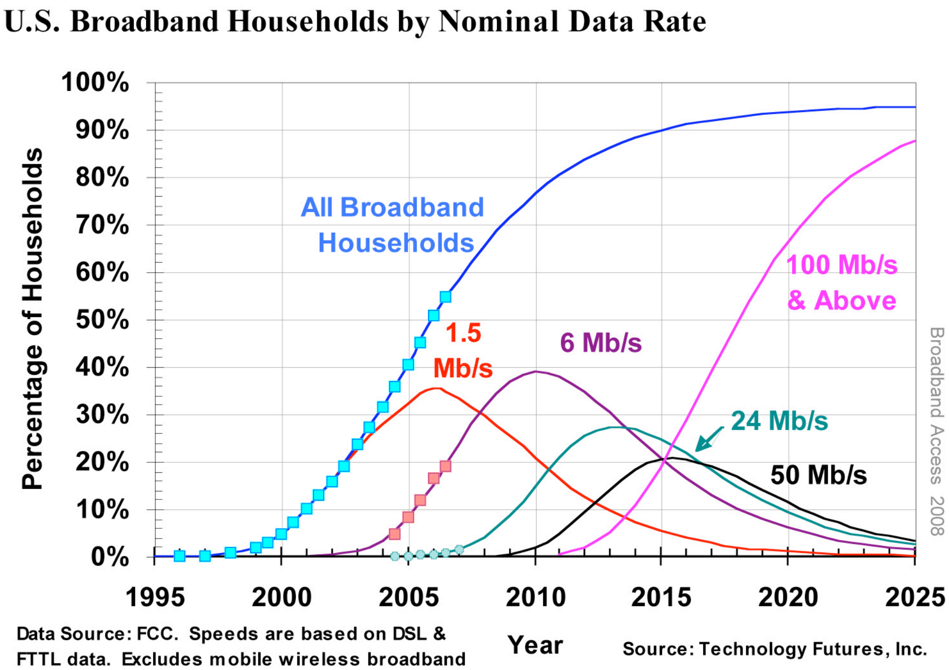

Figure 1. Household Broadband Bandwidth Growth (Source: TFI, 2008)

To take advantage of this opportunity, service providers are renewing their requirements for the broadband network of the future. The recent work from the Broadband Forum, TR-144 (*Broadband Multi-Service Architecture and Framework Requirements*), is an industry collaborative effort driven by the largest and most forward-looking broadband service providers who are active in the Broadband Forum, and serves as a basis for the broadband networks of the future.

As detailed in TR-144, there are a number of driving factors for broadband applications.

- More user appliances and devices require content to be delivered over broadband infrastructure on demand.
- There is an increasing trend towards multiple services per device, as well as towards services delivered to any device anywhere.
- The content delivery industry continues to grow and innovate.

As a result, there is a plethora of applications that drives network evolution. These include:

- Video applied to residential entertainment, business, and education
- Video calls and conferences
- Advertising
- Mass market Internet for both business and residential customers
- Gaming, both gaming download, and interactive and multiple-player gaming

For sure, today's consumer uses content or services in ways that were unimaginable before they were invented, and it is impossible to list them all. But we can distill the requirements on the broadband infrastructure down to three key aspects:

1. Higher bandwidth to deliver residential video and high-speed business applications. For example, demand for HDTV and multiple channel delivery will put bandwidth requirements above what is currently provided by first-generation asymmetric digital subscriber lines (ADSLs) (G.992.1).
2. Support for service-level agreements (SLAs) and quality of service (QoS). This is due to the fact that more people increasingly rely on broadband connections to run more applications simultaneously.
    a. Ability of some applications to take precedence over others
    b. Ability to guarantee minimum bandwidth and low latency per user or user application
    c. Service-level management
    d. High reliability and availability
3. Ability to deploy next-generation broadband access technology. The deployment of new technology must consider the following factors to reduce and control capital and operational expenditures (CapEx and OpEx).
    a. Network architecture alignment with existing broadband infrastructure
    b. Reuse of existing and expanded operational ability of operations support systems/business support systems (OSS/BSS) such as subscriber and remote management

3 Evolution of Access Options

DSL has been the most popular broadband technology, still accounting for two-thirds of all broadband deployments as shown in Figure 2.

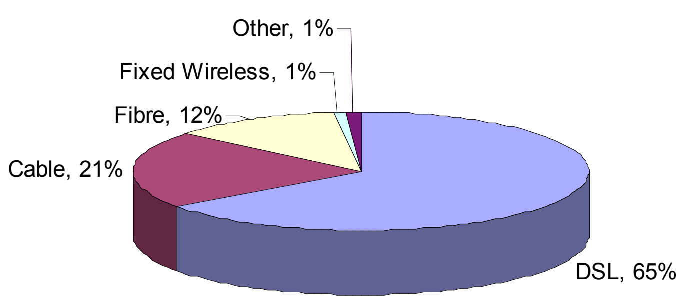

Figure 2. Broadband Deployment by Technology in Q4, 2008. Source: PointTopic.

The trends from PointTopic's deployment data also show an increased use of fiber and wireless technologies. As we discuss in the first three sections of this chapter, the broadband landscape of the foreseeable future will be characterized by:

- Continued evolution of copper-based DSL technologies
- An aggressive push for fiber optics to shorten or eliminate copper
- Deployments of alternative and complementary technologies such as wireless

We will summarize in Section 3.4 what this all means to broadband service providers.

3.1 Continued Evolution of DSL

Hundreds of millions of kilometers of copper have been deployed for connecting residential and business customers. Getting the most out of this infrastructure has been of key importance for network providers since the early 1990s.

New DSL deployment is still increasing at an astonishing rate. In 2008, worldwide DSL subscribers grew 16% annually to 266 million lines, according to data maintained by PointTopic. Figure 3 shows the sheer magnitude of xDSL subscriber counts, and Figure 4 shows that penetration rates can exceed 25% even for large countries like France and Germany.

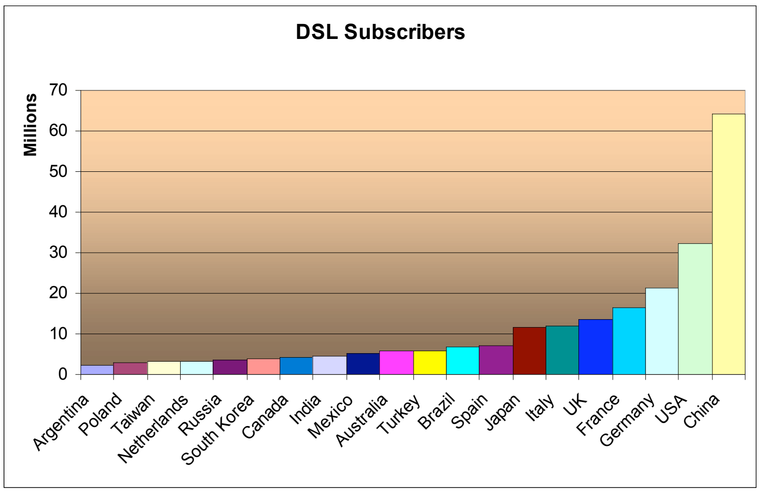

Figure 3. Top DSL Deployment Markets. Data Source: PointTopic, 2009

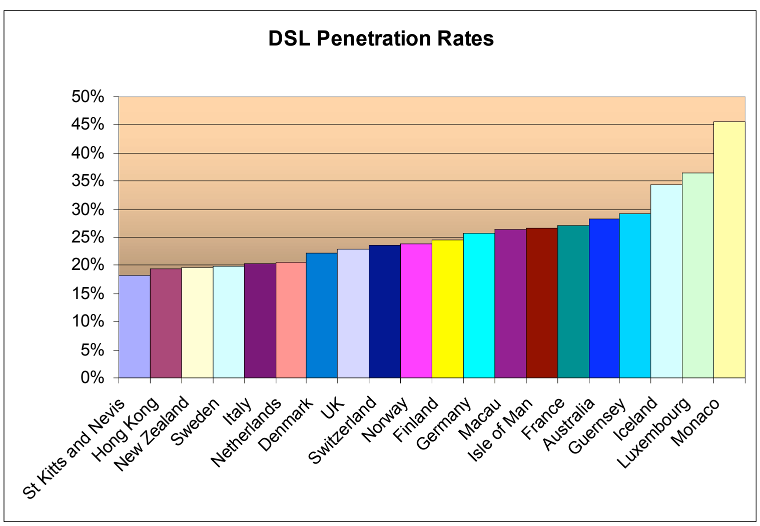

Figure 4. DSL Lines Per 100 Population. Data Source: PointTopic, 2008

Increase in bandwidth demand has driven the evolution of DSL. But other factors have also contributed to the evolution of DSL. These include end user requirements for symmetric services, service provider focus on operational simplicity, and the technology evolution in layer 2 transport from ATM to Ethernet layer 2.

From the beginning, bandwidth increases have driven the industry, particularly regarding DSL technologies for residential customers: from ADSL to bonded very-high-bit-rate digital subscriber line (VDSL2), enabling speeds in excess of 100 Mbps.

Supporting operational simplicity, significant improvements have been made to the quality and stability of services running atop DSL. Broadband Forum Technical Report,TR-176, *ADSL2Plus Configuration Guidelines for IPTV*, captures guidelines for provisioning the many parameters beyond bit rate available in ADSL2Plus in support of IPTV services such as Seamless Rate Adaptation (SRA) and impulse noise protection. SRA changes the bit rate of a given line without impacting service, enabling the technology to respond to changing environmental conditions with no user impact and no operator intervention. TR-176 optimizes impulse noise protection in the presence of Repetitive Electrical Impulse Noise (REIN).

For applications requiring the same bit rate upstream as downstream such as that needed for some business customers, symmetric high-speed DSL (SHDSL) technology can transmit up to 5.6 Mbps in both directions on a single line. With multi-line bonding, much higher symmetric bit rates can be provided.

VDSL is a very attractive technology alternative that provides high-speed performance for various deployment scenarios. The evolution of VDSL has led to the current flavor—VDSL2—which increases the bit rate from 20 Mbps to up to 100 Mbps. This improvement is possible with the use of power spectral density (PSD) shaping, which allows adaptation of the signal spectral density to the transmission channel and local noise conditions. PSD shaping tools provide the ability to adapt VDSL2 carrier power to maximize performance and compatibility with adjacent xDSL lines.

In order to increase coverage from a transmission perspective, countermeasure techniques are necessary to improve signal-to-noise performance. By their nature, transmission systems operating on copper pairs experience cross talk resulting from the signals transmitted on one pair of wires coupling into the other wires in the same cable, for example, NEXT (near-end cross talk) and FEXT (far-end cross talk).

The International Telecommunication Union Telecommunication Standardization (ITU-T) is completing work on G.vector. The G.vector standard describes methods for learning the cross talk characteristics of the cable plant and compensating with downstream transmission signals to effectively eliminate digital subscriber line access multiplexer (DSLAM)-generated FEXT. Multi-pair, advanced signal processing techniques potentially provide significant upstream improvement on short loops. Figure 5 shows representative performance characteristics of VDSL2 and the potential gain from G.vector. The G.vector VDSL2 performance shown in the graph assumes that all broadband lines in the cable are included in the group of vectored lines, i.e., there is no out-of-domain cross talk.

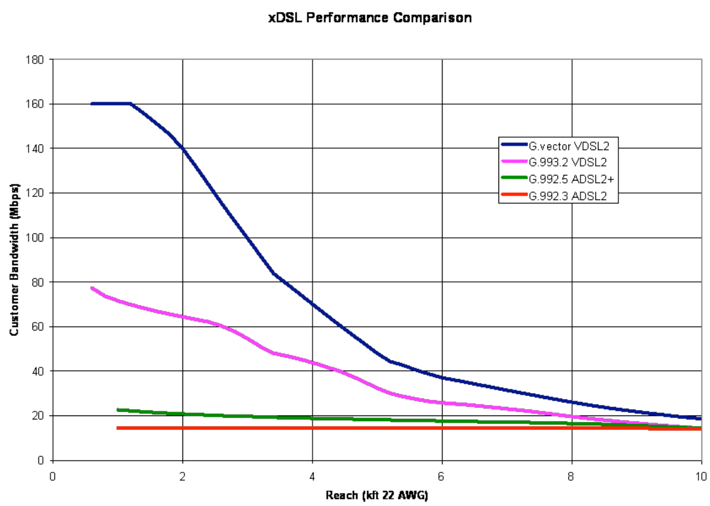

Figure 5. xDSL Performance Comparison. Source: ADTRAN

DSL technology continues to evolve, and its performance continues to improve. Where feasible, the introduction of fiber in the access network is already happening, providing much higher bandwidth over longer access loops.

3.2 Fiber Optic Push

In fact, to satisfy the increasing demand for bandwidth intensive applications, the deployment of optical fiber systems in access networks is straightforward, and it is already happening in many countries.

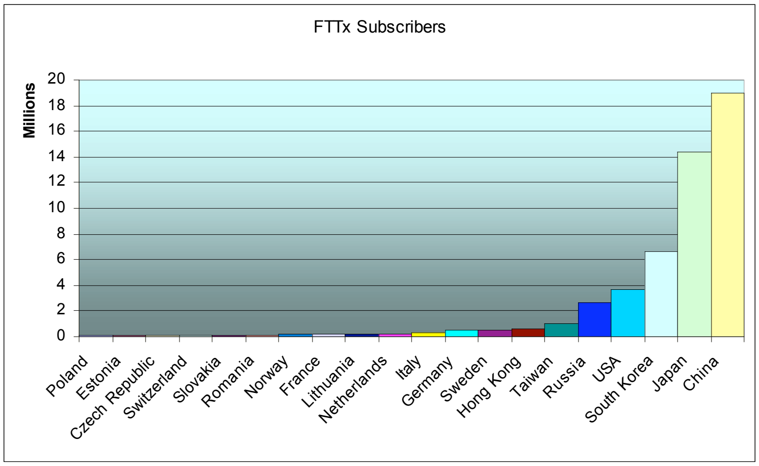

Figure 6. Top FTTx Markets. Data Source: PointTopic, 2008

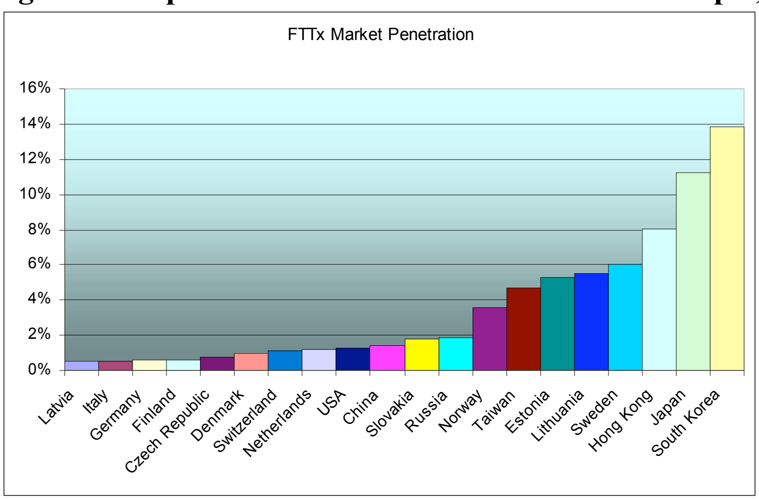

Figure 7. Top FTTx Markets. Data Source: PointTopic, 2008

In the past, point-to-point optical fiber systems were deployed for business customers. But today, the market is mainly driven by residential demand and from that perspective, passive optical network (PON) technologies are perceived as a suitable approach where the infrastructure (fiber) and bandwidth is shared between several customers.

Depending on the fiber deployment strategy, several alternatives are available, using all fiber or a combination of fiber and copper.

- FTTCab: Fiber to the cabinet
- FTTC: Fiber to the curb
- FTTB: Fiber to the building
- FTTH: Fiber to the home

As an example,

Figure 8 shows a gigabit passive optical network (GPON) architecture. The optical line termination (OLT) is typically located in the central office, while the optical network units (ONUs) and optical network terminals (ONTs) are typically located near or at the customer's premises.

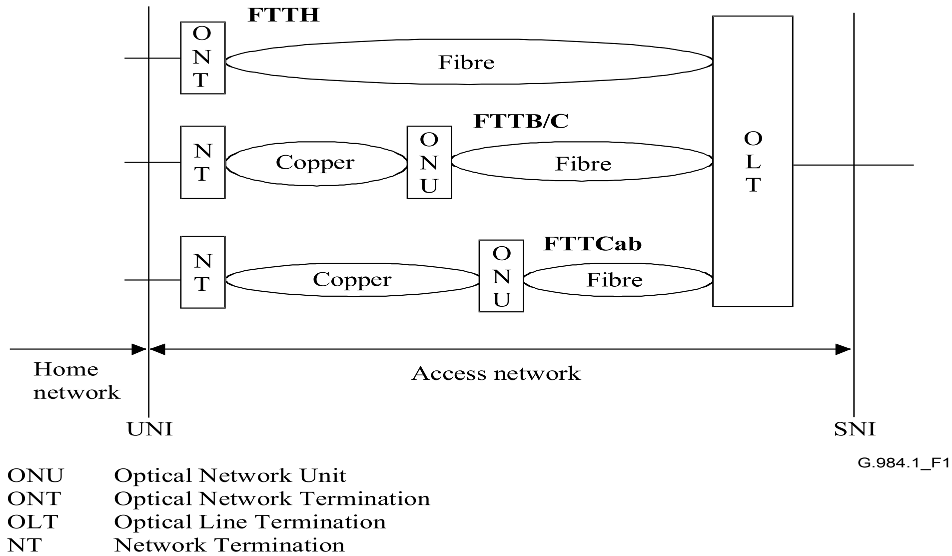

Figure 8. Rec. G.984.1 Networks Architecture. Source: ITU-T Rec. G.984.1 (2008/03)

In PON, the optical signal is shared between customers using passive optical splitters combined with time-division multiplexing (TDM) techniques for downstream and upstream directions.

Two PON variants are standardized today:

- ITU-T GPON (Rec. G.984 series) providing up to 2.5 Gbps downstream and 1.2 Gbps upstream accommodating split ratios up to 1:64.
- IEEE EPON (former P802.3ah, now part of IEEE 802.3-2008) providing symmetric 1 Gbps data rate, accommodating split ratios above 1:16. Note that this system is also referred to as 1G-EPON.

One of the key benefits of GPON, is its interoperability capability which has benefited from the Broadband Forum TR-156, *Using GPON Access in the context of TR-101*, specification that defines architectural aspects of the broadband network and leverages the ONT management control interface (OMCI) defined by ITU. OMCI is the protocol that allows OLT to manage the GPON physical layer and Ethernet layer in the ONT.

Both GPON and EPON systems have been deployed around the world, and these technologies are now poised for higher bandwidth and wider coverage. The industry is looking at next-generation (NG) technologies to provide higher bandwidth, or higher split ratio, or both, to support residential, business, and mobile backhaul.

In regards to this evolution, ITU-T is studying NG-PON systems (future Rec. G.987 series) which must be capable of coexisting with already deployed GPON systems. This has an impact on the use of DS/US wavelengths and optical budget. Higher bit rates are considered and the first NG-PON system is targeting 10-Gbps/2.5 Gbps for 20 km coverage XG-PON1.

Within the IEEE, 10G-EPON is currently under development in IEEE P802.3av, with the completion date slated for September 2009. 10G-EPON takes into account a new, higher speed EPON system under standardization in the P802.3av project providing symmetric (10 Gbps downstream/downstream) or asymmetric (10 Gbps downstream and 1 Gbps upstream) data rates, referred to as 10/10G-EPON and 10/1G-EPON, respectively.

The alternative optical broadband technology to PON is point to point (P2P)/active Ethernet FTTP. P2P is defined in the former IEEE P802.3ah standard (now part of IEEE 802.3-2008) that defines 1G-EPON. However, it represents an alternative access architecture when compared to point to multipoint (P2MP) in that dedicated facilities are devoted to individual subscribers. P2P optical architectures have been widely deployed in the APAC and EMEA regions with relatively small deployments in the North American market.

P2P solutions are comparable to PON alternatives in their ability to deliver anywhere from 100 Mbps to 1 Gbps worth of bandwidth to end users. The contrasting difference between P2P and P2MP solutions is found in the architectural design. P2P optical access leverages a dedicated optical facility between the OLT and the ONT and does not share the last mile bandwidth among multiple subscribers. Therefore, it is viewed as an attractive alternative in deployments where subscriber growth can be unexpected or where bandwidth consumption rates are unpredictable.

Another contrasting difference between P2MP and P2P optical access is in the ability to support radio frequency (RF)-based video signals natively through the use of optical triplexers. P2MP PON architectures support RF overlay of video signals for distribution to residential consumers. As P2P access has not standardized a method of supporting RF overlay, it is only suited to deliver IP-based entertainment content.

While GPON is still relatively new to the broadband landscape, the IEEE specifications for EPON and P2P Ethernet have been widely deployed for over six years.

From an architectural perspective, the Broadband Forum has also recently opened two new documents for consideration:

- Generic Requirements for Shared Media Ethernet Access System, including EPON, in the context of TR-101
- Point-to-point Ethernet in the context of TR-101. This is often referred to as point-to-point Ethernet-to-the- home/premises (P2PETTx).

So, apart from existing deployments, various efforts are under way considering both optical schemes and also architectural features. And these represent promising and challenging issues for the near future.

3.3 Wireless Broadband Alternatives

Wireless broadband systems represent an interesting alternative to wireline systems for deployment of broadband services. These technologies can provide a variety of bit rates, along with high coverage and various frequency bandwidths. In addition, mobile broadband supports high bandwidth services anytime and anywhere. As shown in the following figure, there are two promising technologies:

- One originating from the fixed network based on the wireless LAN (WLAN) family
- One originating from the mobile telecommunication world

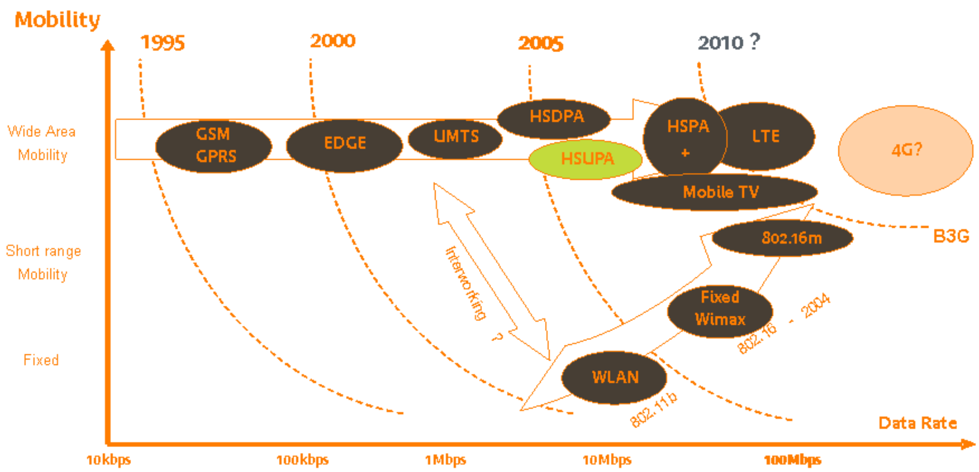

Figure 9. Wireless Broadband Landscape

WiMAX (Worldwide Interoperability for Microwave Access) is a technology that provides broadband services for both fixed and mobile customers using different kinds of applications:

- Fixed, as a broadband access network like DSL or as a backhaul network for WiFi hot spots
- Mobile, as a broadband mobile network with high coverage and connected to mobile terminals such as PCs, tablets, mobile phones, note books, etc.

As such, WiMAX as defined in the IEEE 802.16 series based on common media access control (MAC) layers and an orthogonal frequency-division multiplexing (OFDM) modulation scheme. It is still evolving in order to:

- Support better mobility management and QoS
- Support better high transmission speeds
- Support scalable channel bandwidth, multiple-input and multiple-output (MIMO), and smart antenna systems
- Introduce new functions such as multi-hop mesh, better handover, etc.

The recent increase in mobile data usage has lead to the development of LTE (Long Term Evolution) network, also called E-UTRAN (Evolved UMTS Terrestrial Radio Access Network), coming from the previous GSM and universal mobile telecommunications system (UMTS) mobile network technologies. The Third-Generation Partnership Project (3GPP) is working on this specification in order to improve customer bit rate with the support of IP-based traffic and end-to-end QoS. To support the E-UTRAN, this work is considering:

- A new packet core, the Evolved Packet Core (EPC) network
- A reduction in the number of network elements
- Simpler functionality and improved redundancy
- Connections and handovers to other fixed line and wireless access networks (UMTS, WiFi, WiMAX, etc.).

LTE has set aggressive performance requirements that rely on physical layer technologies such as OFDM and MIMO systems, as well as smart antennas to achieve these targets. It will also allow flexible spectrum deployment in existing or new frequency spectrums and enable coexistence with other 3GPP radio access technologies.

Wireless networks represent alternative ways to deliver broadband content as "the total number of 4G subscribers worldwide, including both LTE and WiMAX, is expected to exceed 90 million in 2013" (ABI Research).

3.4 Summary of Broadband Access Options

We have surveyed the broadband access options: DSL, fiber, and wireless. All of these options have significant deployments and are being enhanced with technology enhancements. DSL deployments continue to leverage the near ubiquitous copper infrastructure of telephone lines in many countries, while DSL technology continues to evolve to meet growing bandwidth and other requirements. PON pushes fiber further and further towards the subscribers, and brings enormous bandwidth potential. Fiber is used either in combination with copper as in FTTCab/FTTC/FTTB, or to completely replace the copper loop as in FTTH. The wireless alternatives are especially attractive in a "green field" deployment where new fiber infrastructure is not cost effective.

What does all this mean to broadband service providers? Are all options readily available? What does the network architecture look like? How will it affect existing deployments? Will it change network operations? The answers to these can greatly affect CapEx and OpEx, and are the subject of discussion in the next chapter.

4 Future Proofing Broadband Network Infrastructure

As we can see from the previous chapter, existing access technologies are evolving, and new technologies are becoming available. How can service providers be sure that their network infrastructures will allow them to take advantage of the new broadband access technologies?

4.1 Common Elements

If you want to build an architectural framework for broadband service delivery, you want it to look the same regardless of what the access option is—copper, fiber, or wireless. The key elements are always the same:

- Network termination ((residential gateway (RG), ONT, base transceiver station (BTS)) at the customer side
- First node for last mile drop (access node, aggregation switch)
- First IP edge ((Broadband Remote Access Server (B-RAS), Broadcast Network Gateway (BNG))

Once the common elements are identified, a common architecture framework may be formed. That is in essence what the Broadband Forum has done. Its specifications can be extended to take into account not only the necessary convergence of existing networks and services, but also the next generation of broadband access technologies.

Recognizing the technology trends early on, the Broadband Forum began broadening its focus beyond DSL to include fiber optics technologies such as GPON back in 2005. Efforts of this strategic move have created the following value for service providers and the broadband industry at large.

- A full set of fiber-related work items to complement the continued DSL work items, including TR-156 for GPON released in 2008
- An evolutionary architecture (TR-101 and beyond) that is agnostic to the access technologies, so that service providers have the freedom to choose the next-generation broadband access that best suits their needs
- A standardized customer premises equipment (CPE) remote management infrastructure based on the TR-069 (*CPE WAN Management Protocol*) protocol

4.2 The BroadbandSuite—An Evolutionary Approach

To put the architectural work in proper context, we need to take a side trip to look at the scope of the Broadband Forum's work. The good news is that the Broadband Forum has been working to meet this challenge for some time now, having started a systematic effort on broadband network infrastructure and architecture in the early 2000s. Above and beyond its legacy work to facilitate DSL deployment, the Broadband Forum developed a comprehensive set of network architecture specifications for broadband service providers. As the industry gets ready to migrate to the latest technologies, the Broadband Forum offers a comprehensive solution in the form of BroadbandSuite releases, with each release being a collection of approved forum specifications.

- **BroadbandSuite Release 1.0**, completed in 2005, enabled Internet access via ADSL or SHDSL over a QoS-enabled ATM architecture, VoIP transport, and VoDSL.

- **BroadbandSuite Release 2.0**, completed in 2006, enabled triple play access via ADSL2plus over a QoS-enabled Ethernet architecture, as well as full support for multicast to enable IPTV streaming.
- **BroadbandSuite Release 3.0**, completed in 2008, enables triple play augmented via GPON or bonded DSL over a QoS-enabled Ethernet architecture; full support for multicast to enable IPTV streaming; and integrated remote management of set-top box and attached storage devices.

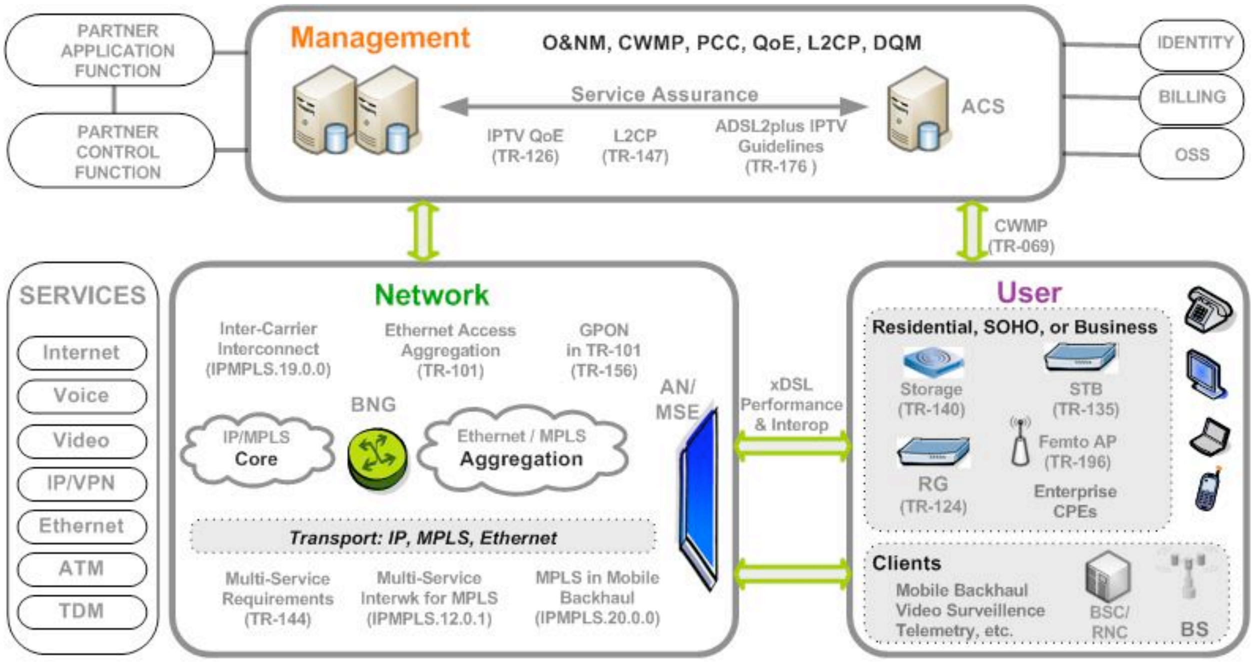

Figure 10. BroadbandSuite—Current Scope of Work at the Broadband Forum

This overarching approach has led to two major areas of work that are applicable regardless of the access technology in use: a multi-service aggregation architecture and a CPE auto-configuration framework.

4.3 Multi-Service Aggregation Architecture

Back in 2003, the Broadband Forum took a systematic approach in defining the market requirements of service providers in TR-058, *Multi-Service Architecture & Framework Requirements*. These market requirements were the basis for the architectural and technology-specific specifications in BroadbandSuite releases 1.0, 2.0, and 3.0.

From the requirements of TR-058 came architectural specifications such as TR-059, *DSL Evolution - Architecture Requirements for the Support of QoS-Enabled IP Services* and TR-092, *Broadband Remote Access Server (BRAS) Requirements Document*. As aggregation of choice evolved from ATM to Ethernet, TR-101, *Migration to Ethernet Based DSL Aggregation*, was developed. This work has further applied PON *Using GPON Access in the context of TR-101* (TR-156) and *GPON-fed TR-101 Ethernet Access Node* (WT-167).

TR-156 allows service providers to deploy GPON in their existing Ethernet-based xDSL network infrastructure. Requirements from subscriber management to QoS, from IPv4 and IPv6 to multicast, from routing and provisioning to operations and diagnostics, are all supported in the same manner as with DSL subscribers.

Market requirements change over time. In 2008, five years after TR-058 was published, a revised set of market requirements were defined in TR-144, *Broadband Multi-Service Architecture & Framework Requirements*. This specification defines a new basis and sets the stage for a set of specifications led by WT-145, the next-generation multi-service architecture. The recent union with the IP/MLS Forum will further enrich the future Broadband Suite releases.

4.4 TR-069 CPE WAN Management Protocol (CWMP)

In 2004, the Broadband Forum released a widely influential specification, the CPE WAN Management Protocol, better known as TR-069. This specification defines a common communication mechanism to auto-configure and remotely manage CPE devices. It is largely access technology independent and is extensible to accommodate the needs and characteristics of new access technologies. For example, the TR-142 framework for TR-069-enabled PON devices allows the TR-069 auto-configuration server (ACS) to be used to remotely manage, monitor, and diagnose PON CPE devices.

5 Conclusions and Next Step

The broadband landscape is full of access options as well as market potentials. Standardization, especially in network infrastructure and architecture, brings enormous benefit to service providers, their end users, and equipment suppliers alike. While collaborating with other standards development organizations (SDOs), the Broadband Forum continues to focus on end-to-end network architecture solutions. Access technology-related work to be completed in the near future includes VDSL2, evolutions of PON and wireless technologies. Architectural framework specifications such as WT-145 and WT-134 and continued proliferation of TR-069 data models for CPE devices will facilitate next-generation services of broadband networks such as IPTV and fixed/mobile convergence.

6 Appendices

A.1 Other Broadband Related Standards Development Organizations

Many SDOs are involved in standardizing next-generation technologies for broadband access. The Broadband Forum has a formal liaison program that seeks to align industry efforts by reducing overlaps or gaps, and coordinating and expediting work done by the Broadband Forum or other organizations. The following is a non-exhaustive list of areas of coordination related to this white paper;

- ITU Study Group 15 and their work for xDSL and GPON (along with FSAN, a group related to SG15 that has worked on GPON)
- IEEE and their work on WiMAX (802.16) and EPON (802.3ah)
- 3GPP and their work on LTE

A.2 VDSL2

The high data rates of VDSL2 are made possible mainly with the use of power spectral density (PSD) mask as shown in the figure below. For more information, please refer to ITU-T G.992.1 (ADSL), G992.5 (ADSL2plus) and G993.2 (VDSL2).

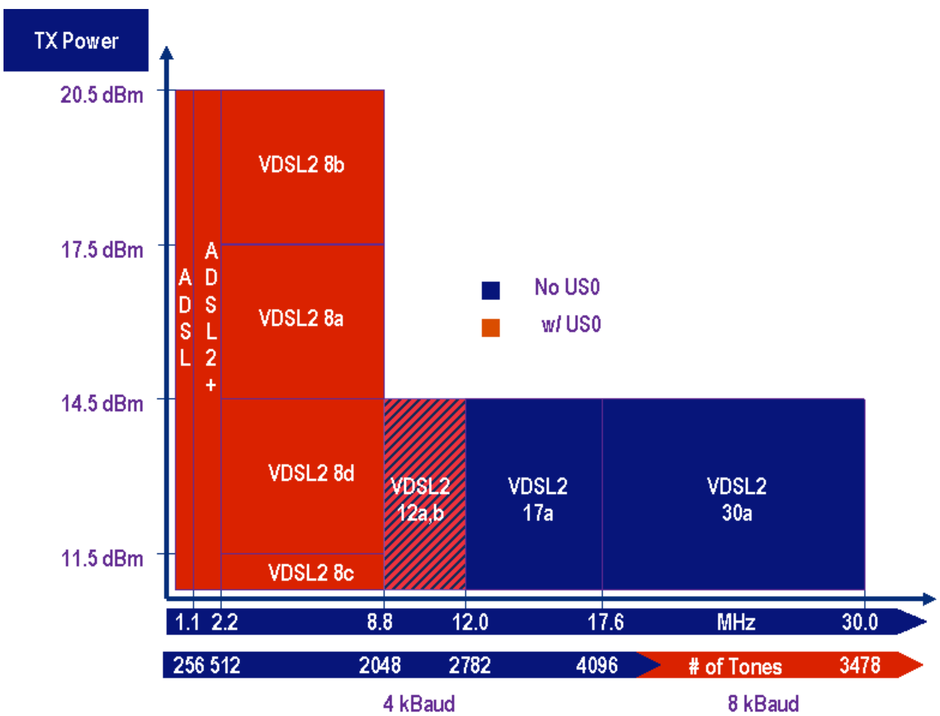

Figure 11 VDSL2 with PSD Mask

A.3 LTE

The following are LTE performance requirements.

Metric	Requirement
Peak data rate	DL: 100 Mbps UL: 50 Mbp (for 20 MHz spectrum)
Mobility support	Up to 500k mph but optimized for low speeds from 0 to 15k mph
Control plane latency (transition time to active state)	< 100 ms (for idle to active)
User plane latency	< 5 ms
Control plane capacity	> 200 users per cell (for 5 MHz spectrum)
Coverage	5 – 100 km with slight degradation after 30 km
Spectrum flexibility	1.25, 2.5, 5, 10, 15, and 20 MHz

Table 1. LTE Performance Requirements (Source: Motorola)

A.4 WiMAX

The following are the WiMAX standard specifications defined by IEEE.

WiMAX	802.16	802.16a	802.16-2004	802.16e-2005
Frequency	10-66 GHz	2-11 GHz	2-11 GHz	2-6 GHz
Exploitation	Loss of signal (LOS)	No loss of signal (NLOS)	NLOS	NLOS and mobility
Bit rate	32-134 Mbps	Up to 75 bps	Up to 75 Mbps	Up to 15 Mbps

Table 2. WiMAX

A.5 Acronyms and Terminology

1G-EPON	1 Gbps EPON, based on former IEEE P802.3ah (now part of IEEE 802.3-2008)
10G-EPON	10 Gbps EPON, based on IEEE P802.3av
3GPP	Third-Generation Partnership Project
ADSL	Asymmetric digital subscriber line, based on ITU G.992.1 family of Recommendations
ADSL2	Based on ITU G.992.3 family of Recommendations

ADSL2+	Based on ITU G.992.5 family of Recommendations
BNG	Broadcast Network Gateway
BTS	Base transceiver station
CWMP	CPE WAN Management Protocol
DSL	Digital subscriber line, also referred to as xDSL
DSLAM	Digital subscriber line access multiplexer
EPON	Ethernet passive optical network
ETTx	Ethernet to the premises/home
EPC	Evolved Packet Core
E-UTRAN	Evolved UMTS Terrestrial Radio Access Network
FTTx	FTTN/FTTC/FTTB/FTTP/FTTH, i.e., Fiber to the node/cabinet/curb/building/premises/home
GPON	Gigabit PON, based on ITU-T G.984 series of Recommendations
GSM	Global System for Mobile Communications
HDTV	High-Definition Television
IPTV	IP television
ITU-T	International Telecommunication Union Telecommunication Standardization
LOS	Loss of signal
LTE	Long Term Evolution, from 3GPP
MAC	Media access control
OFDM	Orthogonal frequency-division multiplexing
OLT	Optical line termination
OMCI	ONT management control interface
ONT	Optical network terminal
ONU	Optical network unit
OSS/BSS	Operations support systems/business support systems
P2P	Point-to-point
P2MP	Point to multipoint
PON	Passive optical network
PSD	Power spectral density shaping
QoS	Quality of service
RG	Residential gateway
SHDSL	Symmetric high-speed DSL technology
SLA	Service-level agreement
TDM	Time-division multiplexing
UMTS	Universal mobile telecommunications system
UTRAN	UMTS Terrestrial Radio Access Network
VDSL	Very-high-bit-rate digital subscriber line, based on Nov. 2001 ITU standards
VDSL2	Very-high-bit-rate DSL 2, based on ITU-T G.993.2
WLAN	Wireless local area network
WiMAX	Worldwide Interoperability for Microwave Access, based on IEEE 802.16

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