Technological Advances in DSL

by Naresh Kurada MSEE
IEEE Toronto Section

Abstract

The deregulation of Telecommunication in the 1990s has unleashed the Broadband Access technology epitomized by the service provided through the cable networks as well as that provided by DSL through POTS. Furthermore, the rising demand by Internet users for feature rich high bandwidth applications has fuelled the adoption of those technologies – not only by households but also by Small and Medium Enterprises as an economical alternative to expensive leased lines. These obvious business drivers have led broadband access providers to turn copper into gold. The purpose of this paper is to try and put into perspective the DSL technology and its future.

Sommaire

La déréglementation des télécommunications dans les années ’90 a permis la diffusion de technologies d’accès à large bande telles celles fournies par les réseaux câblés et par les réseaux DSL via service téléphonique ordinaire. De plus, la demande croissante provenant des usagers de l’internet pour des applications riches et à large bande a stimulé l’adoption de ces technologies – non seulement par les ménages mais aussi les petites et moyennes entreprises comme alternative économique aux coûteuses lignes dédiées. Ces facteurs commerciaux déterminants ont mené les fournisseurs d’accès à large bande à transmuter le cuivre en or. Le but de cet article et de mettre en perspective la technologie DSL et son avenir.

1.0 Introduction

The deregulation of the telecommunication in the 90s brought about a competitive environment for broadband technology. Although DSL, *Digital Subscriber Line*, has been late to enter the market compared to cable networks, it has made progress in capturing market share - capitalizing on cost as well as bundling with other services. Figure 1 represents the Top 20 countries in terms of DSL users.

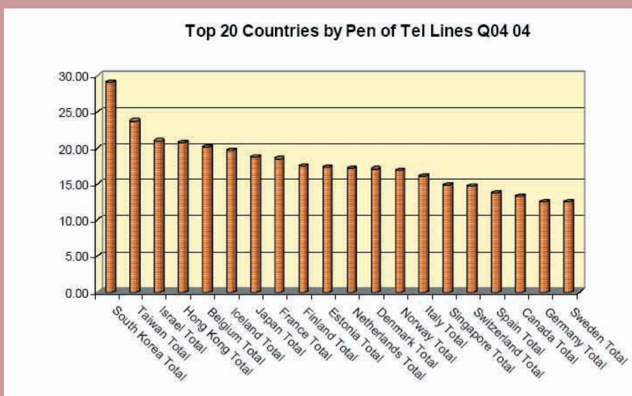

Figure 1 [1]

DSL access technology providers believe that it is the bundling of services such as IP Video over DSL and Voice over IP over DSL to become a Full-Service Network which will give it a competitive edge. These services demand higher bandwidths than those present today. As a result DSL access technology is evolving rapidly, as well as its implementation.

2.0 DSL basics

The premises of DSL technology are:

i. Copper wire can carry a wide range of frequencies well into the MHz range, with limitations only due to the physical characteristics of the wire (IEEE specs rely on testing a UTP category 5 cable to withstand 100MHz)

ii. The maximum information in bits/sec is described by Shannon theorem. This ideally implies that a UTP category 5 cables can carry 100 Mbps.

Although a few MHz of frequencies can be transmitted, only frequencies in the range of (0~4000) Hz are used by telephone lines for voice communications; the rest of the frequencies are not used. It is these unused frequencies that DSL exploits for Broadband Technology. A typical DSL access technology deploys either FDM (*Frequency Division Multiplexing*) or *Echo-Canceling* techniques to transmit and to receive data on a pair of copper wires. The Echo Cancelling technique not only requires sensitivity of Transmitter and Receiver to signals deemed useful but also requires advanced DSP circuitry to achieve good results and is therefore not popular. It is most often superseeded by FDM wherein the entire available frequency bandwidth is divided into 3 or more bandwidths. The 3 basic bandwidths are the following:

1. (0~4) KHz for voice
2. (20~138) KHz Upstream
3. (140 -1100) KHz Downstream.

Based on the upstream and downstream speeds, bit-rate, symmetry factor and number of copper pairs used, DSL is classified as in Table 1. The transmission rates are a function of the thickness and distance of the copper wire being used [9].

ATU C/R are the *ADSL Transmission Units* at the *Central* office and *Receiver* ends (also known as the DSL Modem or CSU/DSU), see Figure 2. The splitter is basically a filter used to separate out frequencies in the range of (0-4) KHz, which are used by the telephone lines. The ATU C/R also consists of transmitter and receiver filters. Depending on the type of DSL the transmitter and receiver filter out frequencies consistent with the DSL upstream and downstream bandwidths. Further, the DSL CSU/DSU also performs framing and line coding functions. This system reference model offers the features of interoperability as well as those of scalability for providing Voice-over-IP telephone services.

XDSL	Upstream	Downstream	Bit-Rate	Symmetry	Copper pairs
ADSL	~2Mbps	~640Kbps	N/A	Asymm.	1
HDSL	~1.544 Mbps	~1.544 Mbps	High	Symm.	2
HDSL2	~1.544 Mbps	~1.544 Mbps	High	Symm.	1
RDSL	N/A	N/A	Adaptive	Asymm.	1
SDSL	~1.544 Mbps	~1.544 Mbps	N/A	Symm.	1
VDSL	~2.3 Mbps	~52 Mbps	Variable	Asymm.	1

Table 1: DSL Classification [9]

3.0 DSL and the OSI reference Model

Digital subscriber line is a physical layer technology. However, as with any access technology - The DSL CSU/DSUs i.e. ATU-R and ATU-R performs

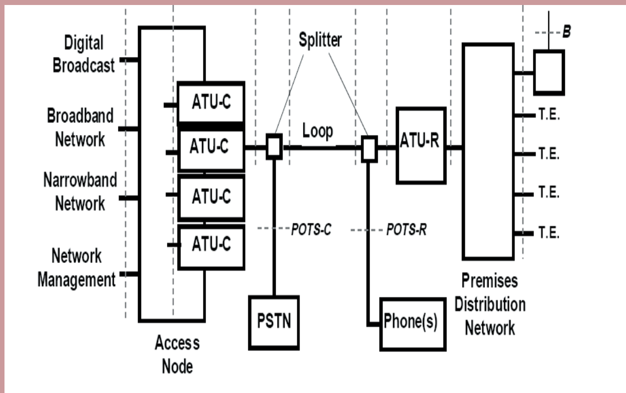

Figure 2: DSL System Reference Model [2]

framing and signaling functions. The framing functions are usually referenced to the Data Link Layer (Layer 2) of the OSI reference model and the DSL line itself is referenced to the physical layer of the OSI reference model. The Layer 2 function of the ATU-R and ATU-C differ in nature since the DSLAM (*DSL Access Multiplexor*) /ATU-C is connected to the Broadband Service provider through an ATM (*Asynchronous Transfer Mode*) network. However the ATU-R and ATU-C communicate in accordance to the implementation of the PPPoE (*Point to Point Protocol over Ethernet*). Being a physical layer technology the ATU C/R provide service to the Data link layer i.e. PPPoE.

Figure 3 illustrates a typical DSL network. The DSLAM/ATU-C is connected to the Broadband Services through the ATM network. The ATU-R relies heavily on the Internet Engineering Task Force Request for Comments (IETF RFC) document RFC 1662 "PPP in HDLC-like Framing" [3].

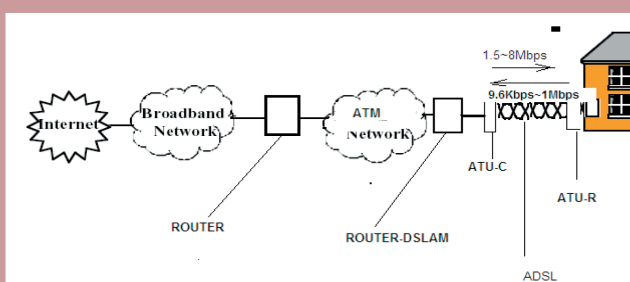

Figure 3: Typical DSL Network [11]

However, depending on the requirements of interfacing a variation to this RFC is often used in accordance to RFC 2516 PPPoE [4]. This is essentially because the user in most cases connects to the ATU-R through the Ethernet. Once these PPPoE frames reach the ATU-C and the DSLAM, the overlay network model as described in RFC 1483 is implemented [3]. The data undergoes the SAR (*Segmentation And Re-assembly*) functions of the ATM following the ATM Frame UNI Format (FUNI) [3]. The ATM FUNI frame format is as illustrated in Figure 4 [3].

This framing conforms to multiplexing techniques defined in RFC 1483 "Multi-Protocol Encapsulation Over ATM AAL5"[3][5]. It is important to note that the PPP connection must be made to Broadband network (server) and not to the DSLAMs. In this way there will be a mechanism to obtain user information for Operation, Administration and Maintenance (OAM). The Network Topology shown in figure 3 widely addresses the current needs of a Home user. However, to address the needs of business users such as those requiring a Branch network, provisions for establishing a VPN (*Virtual Private Network*) tunnel must be made accordingly.

Line Coding

Once the data is framed in the Data Link layer it has to coded into digital signals as well as modulated. A variety of coding and modulation techniques can be deployed. The most popular ones as described by the DSL Forum are the *Discrete Multi Tone* (DMT) and CAP (*Carrierless Amplitude and*

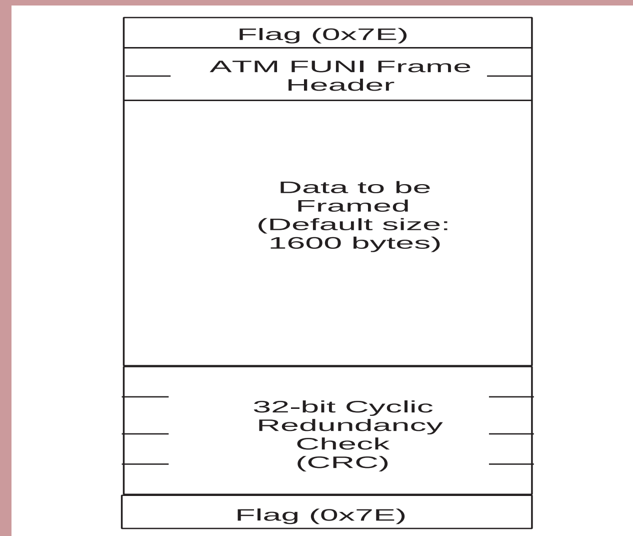

Figure 4: ATM Frame UNI Format [3]

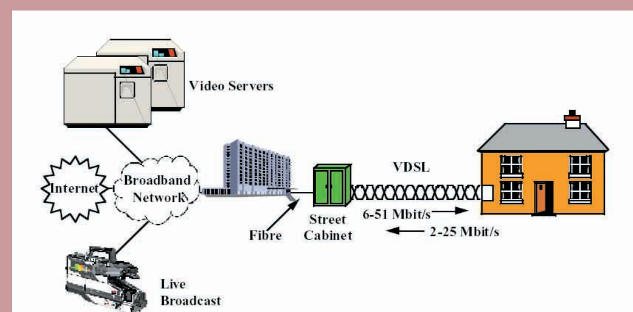

Figure 5: Full-Serviced Network [11]

Phase). DMT is a multi carrier technique. The DMT/ ANSI Standard T1.413standard calls for 256 sub bands of 4 KHz each, wherein the data link frame is encoded using a coding technique such as Reed-Solomon, QAM (*Quadrature Amplitude Modulation*) etc. which results in symbols. These symbols are transmitted on multiple carrier frequencies [6]. Unlike DMT, CAP line-coding uses a single pass band. The Data Link frames are encoded using trellis coding [7][8]. DSL signaling conforms to ITU G.992.1, G.992.2, and ANSI T1.413-Issue 2.The DSL frame in the time domain is recognized by the respective line coding at the beginning and end of the data identifier.

4.0 Future of DSL and the evolution of VDSL

Figure 5 is a typical Full Serviced Network encompassing the goals of Triple Play (convergence, of voice, data and video). The DSL access technology that can cater to these bundling of services is VDSL (*Very high bit rate DSL*). VDSL has been viewed as providing the "last mile" access to the home. A logical approach for VDSL is that the access multiplexer (DSLAM) will now reside at a flexibility point in the network, such as at a FDI/SAC, or in the basement of a multiple-dwelling unit. Therefore, in this instance, it is not possible to migrate CO-based ADSL to VDSL [11].

Further, for the support for QoS (*Quality of Service*) Enabled IP Services for evolving DSL deployment and interconnection, BRAS (*Broadband Remote Access Server*) outlines a common methodology for delivering QoS-enabled applications to DSL subscribers from one or more Service Providers [12]

Figure 6 illustrates the access network incorporating BRAS. The BRAS provides for the aggregation of various services such as ATM, IP, L2TP, and Ethernet etc. Thus, it acts to streamline as well as to provide a common architecture for the access network. BRAS will provide a congestion management function that will allow the synthesis of IP QoS through downstream elements that are not QoS aware, which enables DSL providers to support enhanced IP applications [12].

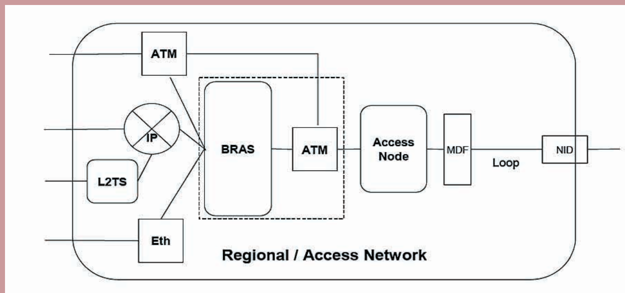

Figure 6: Access network incorporating BRAS [12]

DSL Bonding

DSL Bonding allows two or more DSL lines to be aggregated and provide a single interface whose bandwidth can be appropriately scaled to serve present and future needs, while still leveraging the simplicity and low cost of DSL installation [13].

The major driver for DSL Bonding is to the flexibility of providing a bandwidth that is actually required by the users (a range of bandwidths between those of T1 and T3) and not limited by the standardized bandwidths provided by ADSL or VDSL. This is comparable to the *Inverse Multiplexing over ATM* technique. Suitable DSL technologies for bonding in the residential and video applications include both ADSL and VDSL. This huge bandwidth finds applications in situations where service providers intend to broadcast TV over the Internet, thereby enablingthem to compete with cable TV operators. Figure 7 illustrates the concept of bonding.

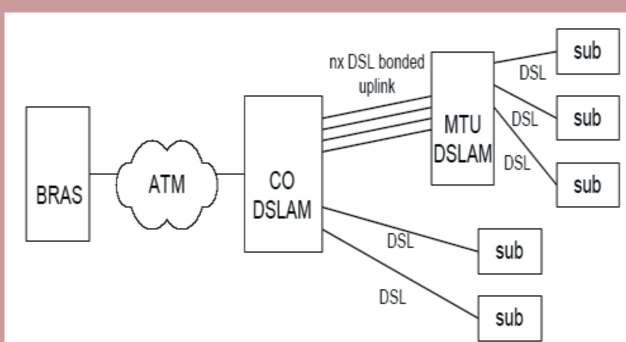

Figure 7: Bonding Concept [13]

DSL Bonding Techniques [13]

i. *Physical Layer Bonding*: The data rates of a number of DSL links are grouped to provide a single link of higher bandwidth. Although this type of bonding has the advantage of protocol transparency, it is limited only to SHDSL as well as the number of lines that can be grouped. SHDSL currently limits bonding to a maximum of 2-pairs.

ii. *ATM Layer Bonding* (IMA): Inverse Multiplexing for ATM (IMA) is fully specified in the ATM Forum standard AFPHY-0086.001 and is applicable to any ATM UNI/NNI including the DSL loop in cases where ATM framing is used over DSL. IMA introduces a common multiplexing sublayer between the ATM layer and the individual ATM. Transmission convergence sublayers of physical links being grouped. An IMA sublayer implementation typically consists of grouping [1,32] SHDSL transceivers.

iii. *Multilink PPP* (ML-PPP): as defined in RFC 1990, it can be used to group multiple PPP links into a single virtual bundle. In the transmit direction, ML-PPP takes a PPP packet, optionally fragments it and forming a new ML-PPP header. Each resulting fragment (or whole packet) is transmitted across a separate physical link. At the receiver, the per-fragment headers are used to reconstruct the complete packets.

Further, ITU / ATIS (T1E1) ratified the G.BOND G.998 standard to allow all DSL technologies to multiplex various data streams. The G.998.1 describes a method for bonding of multiple digital subscriber lines (DSL) to transport ATM streams. G.998.1 describes a method for bonding of multiple digital subscriber lines (DSL) for Ethernet transport. G.998.3 describes a method for bonding of multiple digital subscriber lines (DSL) using *Time-Division Inverse Multiplexing* (TDIM)[15].

5.0 Conclusions

Recent surveys suggest that DSL (Digital Subscriber Line) and IP (Internet Protocol) will be the preferred transport technologies for video in tomorrow's networks. We should see a converged IP-based networks for voice, video and data appear within three years [14]. However, the single biggest hurdle in this direction is government regulation - and not the technology. The number of DSL subscribers has crossed the 100 million mark in 2004. With the bundling of services such as broadcast television, VoIP over DSL, as well as the techniques that have been discussed here, DSL will be viewed as serious competition to the Cable Modem network.

6.0 Acknowledgment

I would like to thank Mr. Frank Chan of Bell Canada for providing valuable insight into the DSL technology.

7.0 References

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About the author

Naresh Kurada obtained his B.Eng. in Instrumentation Engineering from Bangalore University, India in 1996 and started working as an Instrument Engineer in Kuwait. He left for Canada in 1998 and expanded his career into Data Communications. In 2004 he obtained his MSEE with an emphasis in Telecommunications from the University of Texas at Arlington and is currently pursuing his MBA at the Schulich School of Business - York University while working in Data Communications for the Bank of Montreal. Naresh serves in the IEEE Toronto Section as Vice Chair of the PCS Chapter and Newsletter Editor.