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Broadband Fiber Optical Access

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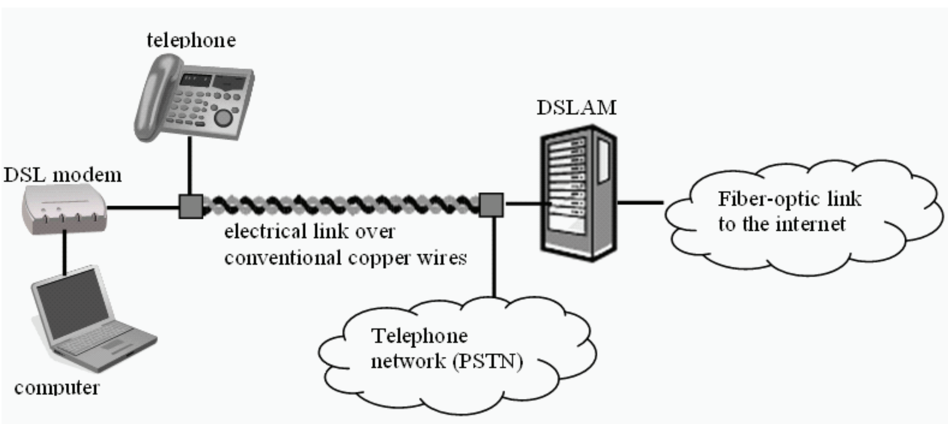
INTRODUCTION

We are currently witnessing an unprecedented growth in bandwidth demand, mainly driven by the development of advanced broadband multimedia applications, including video-on-demand (VoD), interactive high-definition digital television (HDTV) and related digital content, multiparty video-conferencing, and so forth. These Internet-based services require an underlying network infrastructure that is capable of supporting high-speed data transmission rates; hence, standards bodies and telecom providers are currently focusing on developing and defining new network infrastructures that will constitute future-proof solutions in terms of the anticipated growth in bandwidth demand, but at the same time be economically viable.

Most users currently enjoy relatively high speed communication services through digital subscriber line (DSL) access technologies, but these are widely seen as short-term solutions, since the aging copper-based infrastructure is rapidly approaching its fundamental speed limits. In contrast, fiber optics-based technologies offer tremendously higher bandwidth, a fact that has long been recognized by all telecom providers, which have upgraded their core (backbone) networks to optical technologies. As Figure 1 shows, the current network landscape thus broadly comprises of an ultrafast fiber optic backbone to which users connect through conventional, telephone grade copper wires. It is evident that these copper-based access networks create a bottleneck in terms of bandwidth and service provision.

In Figure 1, a splitter is used to separate the voice and data signals, both at the user end and at the network operator's premises. All data leaving from the user travel first through an electrical link over telephone-grade wires to the operator local exchange. They are then routed to an Internet service provider (ISP) and eventually to the Internet through fiber-optic links.

Figure 1. A conventional access architecture for Internet over DSL



In contrast to the access scheme depicted in Figure 1, fiber-to-the-home (FTTH) architectures are novel optical access architectures in which communication occurs via optical fibers extending all the way from the telecom operator premises to the customer's home or office, thus replacing the need for data transfer over telephone wires. Optical access networks can offer a solution to the access network bottleneck problem, and promises extremely high bandwidth to the end user, as well as future-proofing the operator's investment (Green 2006; Prat, Balaquer, Gene, Diaz, & Fiquerola, 2002). While the cost of FTTH deployment has been prohibitively high in the past, this has been falling steadily, and FTTH is now likely to be the dominant broadband access technology within the next decade (Green, 2006).

EXISTING BROADBAND SOLUTIONS AND STANDARDS

Today, the most widely deployed broadband access solutions are DSL and community antenna television (CATV) cable modem networks. As noted already, DSL makes it possible to reuse the existing telephone wires so that they can deliver high bandwidth to the user, while cable modem networks rely on infrastructure usually already laid from cable TV providers.

DSL requires a special modem at the user premises, and a DSL access multiplexer (DSLAM) at the operator's central office. It works by selectively utilizing the unused spectrum of telephone wires for data transmission. Since voice telephony is restricted to ~ 4 KHz, DSL operates at frequencies above that, and in particular up to ~ 1 MHz, with different regions of this range allocated to upstream or downstream traffic. Currently, there are many DSL connection variants, and we can identify four basic types, varying in technological implementation and bandwidth levels.

The basic DSL (IDSL) dates back to the 80s, and was implemented as part of the integrated services digital network (ISDN) specification (ITU-T, 1993). It offered symmetric capacity of 160 Kbps. The first DSL technology to gain wider market acceptance was the high-speed DSL (HDSL) (ITU-T, 1998b), which offers symmetric rates of 1.544 Mbps, and is still used today. Currently, the most successful DSL variant is by far the asymmetric DSL (ADSL) (ITU-T, 2002a), which allocates more bandwidth to the downstream direction than to the upstream one. ADSL2 (ITU-T, 2002a) was specified in 2002, and is a major improvement over traditional ADSL. In 2003, yet another ADSL version was specified, the ADSL2+ (ITU-T, 2005b), which is the most current ADSL variant. It is based on the ADSL2 standard but can offer double maximum downstream rate. Finally, the very high-speed DSL (VDSL) (ITU-T, 2004) can have symmetric or asymmetric rates, and can achieve much higher speeds than all ADSL variants but only for small distances. VDSL will never be widely deployed, as its second generation, VDSL2 (ITU-T, 2006), was specified recently, and is designed to offer similar speeds but with a reduced distance penalty. The major DSL standards are summarized in Table 1.

It should be noted that although the newest DSL

Table 1. Major DSL standards (maximum bandwidth rates are quoted)

Standard	Common Name	Upstream Rate	***Downstream Rate***
ITU-T G.961	IDSL-ISDN	160 Kbps	160 Kbps
ITU-T G.991.1	HDSL	1.544 Mbps	1.544 Mbps
ITU-T G.992.1	ADSL	1 Mbps	8 Mbps
ITU-T G.992.4	ADSL2	1 Mbps	8 Mbps
ITU-T G.992.4 Annex J	ADSL2	3.5 Mbps	12 Mbps
ITU-T G.992.5	ADSL2+	1 Mbps	24 Mbps
ITU-T G.992.5 Annex M	ADSL2+	3.5 Mbps	24 Mbps
ITU-T G.993.1	VDSL	26 Mbps 12 Mbps	26 Mbps 52 Mbps
ITU-T G.993.2	VDSL2	100 Mbps	100 Mbps

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