Asymmetric Digital Subscriber Line

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INTRODUCTION

The plain, old telephone system (POTS) has formed the backbone of the communications world since its inception in the 1880s. Running on twisted pairs of copper wires bundled together, there has not really been any seminal developments in its mode of transmission, save for its transition from analogue to digital toward the end of the 1970s.

The voice portion of the line, including the dial tone and ringing sound, occupies a bandwidth that represents about 0.3% of the total bandwidth of the copper wires. This seems to be such a waste of resources, as prior to the advent of the Internet, telecommunication companies (telcos) have not really sought to explore better utilization of the bandwidth through technological improvements, for example, to promote better voice quality, to reduce wiring by routing two neighboring houses on the same line before splitting the last few meters, and so on. There could be two possible reasons for this state of affairs. One reason is that the advances in microelectronics and signal processing necessary for the efficient and cost-effective interlinking of computers to the telecommunications network have been rather slow (Reusens, van Bruyssel, Sevenhans, van Den Bergh, van Nimmen, & Spruyt, 2001). Another reason is that up to about the 1990s, telcos were basically state-run enterprises that had little incentive to roll out innovative services and applications. When deregulation and liberalization of the telecommunication sector was introduced around the 1990s, the entire landscape underwent a drastic transformation and saw telcos introducing a plethora of service enhancements, innovations, and other applications; there was also a parallel surge in technological developments aiding these.

As POTS is conspicuous by its ubiquity, it makes sense to leverage on it for upgrading purposes rather than deploy totally new networks that need considerable investment. In recent times, asymmetric digital subscriber line (ADSL) has emerged as a technology that is revolutionizing telecommunications and is a prime candidate for broadband access to the Internet. It allows for the transmission of enormous amounts of digital information at rapid rates on the POTS.

BACKGROUND

The genesis of ADSL can be traced to the efforts by telecommunication companies to enter the cable-television market (Reusens et al., 2001). They were looking for a way to send television signals over the phone line so that subscribers can also use this line for receiving video.

The foundations of ADSL were laid in 1989 by Joseph Leichleder, a scientist at Bellcore, who observed that there are more applications and services for which speedier transmission rates are needed from the telephone exchange to the subscriber's location than for the other way around (Leichleider, 1989). Telcos working on the video-on-demand market were quick to recognize the potential of ADSL for streaming video signals. However, the video-on-demand market did not take off for various reasons: Telcos were reluctant to invest in the necessary video architecture as well as to upgrade their networks, the quality of the MPEG (Moving Picture Experts Group) video stream was rather poor, and there was competition from video rental stores (Reusens et al., 2001). Also, the hybrid fiber coaxial (HFC) architecture for cable television, which was introduced around 1993, posed a serious challenge. At about this time, the Internet was becoming a phenomenon, and telcos were quick to realize the potential of ADSL for fast Internet access. Field trials began in 1996, and in 1998, ADSL started to be deployed in many countries.

The current motivation of telcos in warming toward ADSL has more to do with the fact that it offers rapid access to the Internet, as well as the scope to deliver other applications and services whilst offering competition to cable-television companies entering the Internet-access market. All this means multiple revenue streams for telcos.

Over the years, technological advancements relating to ADSL as well as the evolution of standards for its use have begun to fuel its widespread deployment for Internet access (Chen, 1999). Indeed, it is one of those few technologies that went from the conceptual stage to the deployment stage within a decade (Starr, Cioffi, & Silverman, 1999).

This article provides an overview of ADSL.

ADSL TECHNOLOGY

ADSL is based on the observation that while the frequency band for voice transmission over the phone line occupies about 3 KHz (200 Hz to 3,300 Hz), the actual bandwidth of the twisted pairs of copper wires constituting the phone line is more than 1 MHz (Hamill, Delaney, Furlong, Gantley, & Gardiner, 1999; Hawley, 1999). It is the unused bandwidth beyond the voice portion of the phone line that ADSL uses for transmitting information at high rates. A high frequency (above 4,000 KHz) is used because more information can then be transmitted at faster rates; a disadvantage is that the signals undergo attenuation with distance, which restricts the reach of ADSL.

There are three key technologies involved in ADSL.

Signal Modulation

Modulation is the process of transmitting information on a wire after encoding it electrically. When ADSL was first deployed on a commercial basis, carrierless amplitude-phase (CAP) modulation was used to modulate signals over the line. CAP works by dividing the line into three subchannels: one for voice, one for upstream access, and another for downstream access. It has since been largely superseded by another technique called discrete multitone (DMT), which is a signal-coding technique invented by John Cioffi of Stanford University (Cioffi, Silverman, & Starr, 1999; Ruiz, Cioffi, & Kasturia, 1992). He demonstrated its use by transmitting 8 Mb of information in one second across a phone line 1.6 km long. DMT scores over CAP in terms of the speed of data transfer, efficiency of bandwidth allocation, and power consumption, and these have been key considerations in its widespread adoption.

DMT divides the bandwidth of the phone line into 256 subchannels through a process called frequency-division multiplexing (FDM; Figure 1; Kwok, 1999). Each subchannel occupies a bandwidth of 4.3125 KHz. For transmitting data across each subchannel, the technique of quadrature amplitude modulation (QAM) is used. Two sinusoidal carriers of the same frequency that differ in phase by 90 degrees constitute the QAM signal. The number of bits allocated for each subchannel varies from 2 to 16: Higher bits are carried on subchannels in the lower frequencies, while lower bits are carried on channels in the higher frequencies.

The following theoretical rates apply.

- **Upstream access:**
  20 carriers x 8 bits x 4 KHz = 640 Kbps
- **Downstream access:**
  256 carriers x 8 bits x 4 KHz = 8.1 Mbps

In practice, the data rates achieved are much less owing to inadequate line quality, extended length of line, cross talk, and noise (Cook, Kirkby, Booth, Foster, Clarke, & Young, 1999). The speed for downstream access is generally about 10 times that for upstream access.

Two of the channels (16 and 64) can be used for transmitting pilot signals for specific applications or tests. It is the subdivision into 256 channels that allows one group to be used for downstream access and another for upstream access on an optimal basis. When the modem is activated during network access, the signal-to-noise ratio in the channel is automatically measured. Subchannels that experience unacceptable throughput of the signal owing to interference are turned off, and their traffic is redirected to other suitable subchannels, thus optimizing the overall transmission throughput. The total transmittance is thus maintained by QAM. This is a particular advantage when using POTS for ADSL delivery since a good portion of the network was laid several decades ago and is susceptible to interference owing to corrosion and other problems.

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