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ADSL TECHNOLOGY

ABSTRACT

The paper deals with the ADSL (Asymmetric Digital Subscriber Line) technology - the asymmetric digital telecommunication technology. It is characterised by high-speed transmission of data and simultaneous transmission of information regarding the throughput capacity of the telephone network. This results in better efficiency of transmission, and higher utilisation of the bandwidth. Due to its advantages, the use of ADSL technology is increasing daily, especially by enterprises in Europe and worldwide.

KEY WORDS

ADSL, telecommunications, data transfer

1. INTRODUCTION

The ever more demanding users who want maximal speed of data transmission i.e. bandwidth and maximal quality of services at minimal costs, require from the operator of telecommunication services worldwide, introduction of new technologies and maximal utilisation of the current technology.

In the increasingly competitive environment, telecommunications operators who are at the same time also the owners of copper infrastructure want to make maximum advantage of the already built-up network that they have been developing and into which they have been investing. Therefore, network managers are actively looking for technological solutions that would use the whole of the existing network and thus provide efficient means of competition with new operators entering the telecommunications market, such as e.g. cable TV providers some of whom, worldwide, already offer various alternatives and data services.

Among the great number of advanced technologies that are interesting, there are also the xDSL technologies that appeared in the nineties and allow the telecommunication service operators addition of "new added value" to the existing copper pairs, thus increasing the financial income.

The currently most popular is the ADSL (Asymmetric Digital Subscriber Line) technology. With the fast development of the Internet recently, new multimedia applications have also appeared on the world market, and for a relatively good quality they require relatively high bit rates.

The copper telephone subscriber infrastructure, which is still the most widespread individual means connecting the network operator with home or workplace, with the addition of new ADSL transmission technology opens up relatively safe and capable routes into the world of interactive multimedia and fast data transmission.

2. TELECOMMUNICATIONS AND ADSL

The acronym ADSL denotes the currently most popular version of the xDSL technology family. The letter x at the beginning of the abbreviation denotes that it is a family of similar but alternative forms of digital data transmission technology (voice, image, etc.).

Recently, the telecommunication operators have increased the telecommunication network capacity (primarily ATM) by installing optical fibres between switchboards, by setting digital switchboards and by expanding the data network. This, however, does not eliminate the bottleneck occurring in the link between the end switchboard and the subscriber.

Installation of optical fibres to every house is related to huge investments. Therefore, the transition is supposed to be gradual, and will develop in the following phases: optical fibres to the end switchboard, optical fibres into every street and eventually optical fibres to the house. Figure 1 shows the comparison of the transmission speeds in comparison with the transport means. Today's available telecommunication net-

works still include a great amount of copper pairs. Therefore, for the construction of fast accessible networks the most adequate is the ADSL technology, which uses the existing copper pairs for data transmission allowing data and the existing telephone signals to be delivered simultaneously over the telephone line.

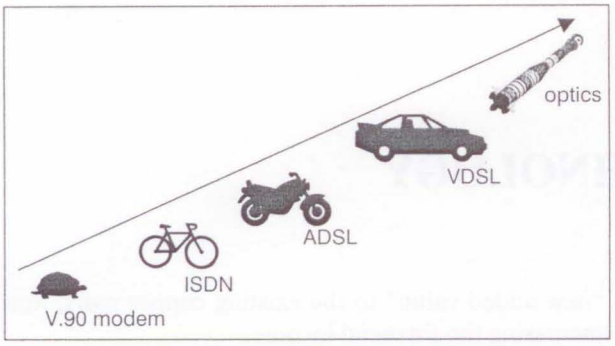

Figure 1 - Comparison of speed

Source: the INTERNET: http://www.adsl.com

On the POTS (Plain Old Telephone System) telephone lines with 4 kHz bandwidth, the technology of dial-up modems has reached its limit through V.90 technology. The ISDN-BA lines allow data transmission at speeds of 2 x 64 kbit/s. Simultaneously with the appearance of increasingly demanding data applications and services, the end users and service providers require also higher transmission speeds.

Table 1 –The range of ADSL modems

downstream	cable length	cable diameter
1.5 or 2 Mbit/s	5.5 km	0.5 mm
1.5 or 2 Mbit/s	4.6 km	0.4 mm
6.1 Mbit/s	3.7 km	0.5 mm
6.1 Mbit/s	2.7 km	0.4 mm
8 Mbit/s	2.2 km	0.5 mm
8 Mbit/s	1.7 km	0.4 mm

Source: G. Penko: Tehnologija ADSL, Škrjanček, Ljubljana, 1999, p. 20

Transmission speeds with ADSL modems are up to 150 times higher than with transmission via analogue modems and up to 50 times higher than speeds via ISDN. The ADSL technology is an upgrade (improvement of capacity and transmission quality) of a regular analogue or ISDN telephone cable, with telephony remaining unchanged and used in the same manner as before the mentioned upgrade. Thus, the services of analogue or ISDN telephony can be used and at the same time information from the Internet can be recorded at a speed of up to 8 Mbit/s or one may watch TV program, films and similar. Table 1 shows a correlation of the cable diameter, length of cables and the downstream. According to the forecasts offered by the analysts, millions of subscribers worldwide will have ADSL solutions installed in the following years. The ADSL technology was first introduced in 1995, but by the year 1999 there had been no major installations of such technologies.

The ADSL technology (Asymmetric Digital Subscriber Line) is asymmetric because the greater part of the band is intended for data transmission towards the user (downstream), and a smaller part of the bandwidth is intended for data transmission from the user towards the network. Most of the Internet graphically demanding and multimedia applications require increased bandwidth towards the user (downstream). The asymmetric characteristic of the technology is reflected in the distribution of the frequency band since the whole bandwidth intended for transmission is divided into two parts. The asymmetric character is similar to the asymmetric character of the V. 90 protocol which is greatly used on analogue lines with dial-up for accessing the Internet services providers (ISPs).

The demands and the reactions of users require small bandwidth. The ADSL technology uses the concept of discrete multi-tone modulation (DMT), which together with using advanced procedures of digital signal processing and data coding allows transmission of data with great bandwidth via the existing copper infrastructure.

The ADSL technology allows transmission of several Mbit/s at a distance of several kilometres with BER (Bit Error Rate) smaller than 10^{-7} (maximum 8 Mbit/s downstream and 1 Mbit/s upstream).

The ADSL modem on a copper pair creates three separate frequency bands: one band for data transmission towards the user, the second for data transmission in the direction from the user towards the network and the third one for the existing voice POTS or ISDN-BA channel. POTS or ISDN-BA channel is separated from the other two by a passive filter separator (splitter) and operates independently of the ADSL devices. The ADSL device on the telephone connection reacts to the disturbance. To separate the data channel on the line of interface, the ADSL of the first generation use the frequency multiplexer (FDM), and the systems of the second generation use echo cancellation. For the transmission of data via the existing telephone lines the ADSL technology uses discrete multi tone modulation (DMT). DMT divides the useful bandwidth on the copper pair into 256 channels (tones) with the bandwidth of 4.3125 kHz. By using these channels DMT can precisely determine what are the line characteristics in each of these channels, and the number of transmitted bits in each channel is determined on the basis of the signal / noise ratio. Each channel provides a maximum transmission speed of 32 kbit/s. Data transmission speed using the existing ADSL-upgraded telephone line depends on many fac-

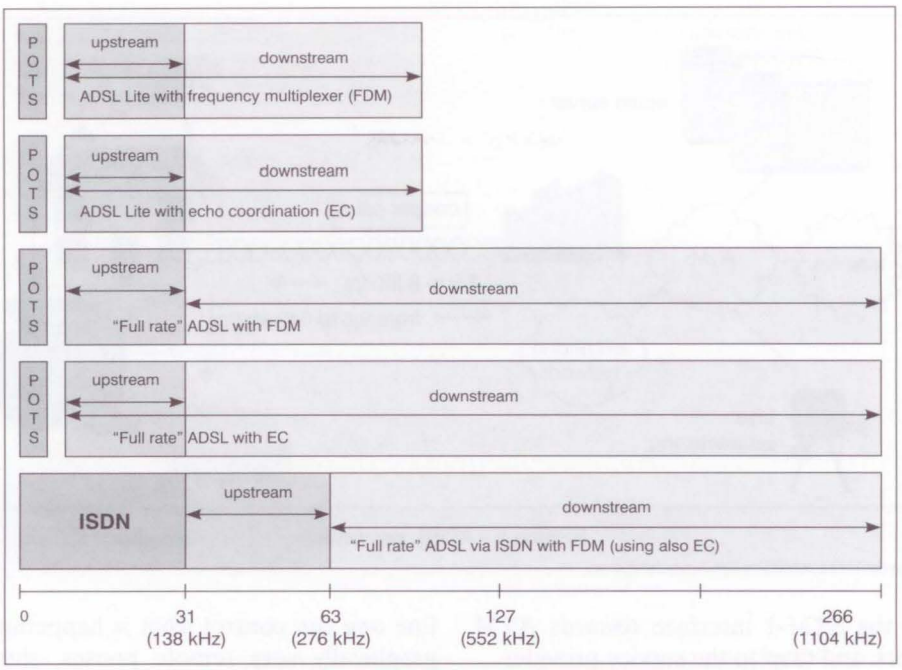

Figure 2 - The division of the frequency space ADSL/POTS (ISDN)

Source: G. Penko: Tehnologija ADSL, Škrjanček, Ljubljana, 1999, p. 20

tors, primarily on the length of the line, diameter of the copper wire, presence of split and interference. With ADSL interface the function of speed adaptation is defined. The speed of ADSL line is dynamically adapted with regard to the current conditions of the line.

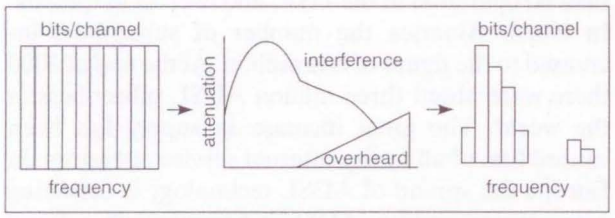

Figure 3 - DMT optimisation of data transfer

Source: G. Penko: Tehnologija ADSL, Škrjanček, Ljubljana, 1999, p. 21

The ADSL interfaces check all the time the condition on the line and depending on the results, optimise the transmission speed.

2.1. DMT line code

DMT is derived from frequency multiplexing. DMT line code has long symbols, each of which is focused in the narrow frequency band. The event in the time space will be straightened over the whole tone, which reduces its effect. The noise in the frequency space will directly affect only several tones.

The advantage of DMT lies in the fact that the frequency noise is more stable. With the distribution of symbols to tone DMT can thus be separated from wasting of energy in unpleasant frequency bands. Besides, DMT is very flexible in bit speeds.

Among DMT, CAP and QAM line codes the ANSI T1 committee has selected the DMT line code as the standard for ADSL. Nevertheless, assuming certain advantages, some producers have been producing systems with the CAP line code, which are at the moment prevailing on the market. In 1998, ITU – T selected DMT line code for ADSL systems, which meant the end of the development of systems with the CAP code.

3. THE ADSL NETWORK ARCHITECTURE

On the user's side, the ADSL connection means the end of the network (NT – Network Terminator, i.e. ADSL modem) which provides the user with the Ethernet (10 baseT) or ATM25 interfaces for the connection of the terminal devices. Advanced ADSL can be of desk design or in the form of connecting card for the computer. The splitter which separates the telephone signal from the data signal can be installed in the ADSL modem or can be an independent unit. On the side of the network, the ADSL equipment has the form of an optical network unit DSLAM (Digital Subscriber Line Access Multiplexer) which is installed at the end telephone centrala. The DSLAM unit contains the ADSL interfaces (modems) for each subscriber separately. Besides, a filter for the splitting of the voice telephone and the data transmission has been installed for every subscriber. The ADSL data traffic in the DSLAM unit is condensed and then

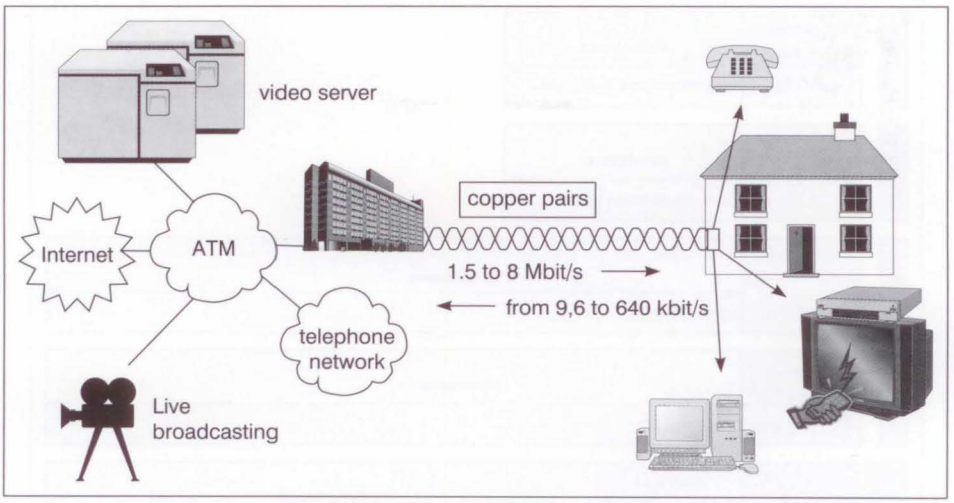

Figure 4 - ADSL network

Source: INTERNET: http://www.adsl.com

transmitted via the STM-1 interface towards ATM backbone network and then to the service provider.

4. STANDARDISATION

ADSL became internationally standardised only when the International Telecommunications Union - – Telecommunications (ITU - T) announced the recommendations. The significant recommendations are: G.992.1, G.992.2, G.994.1. ANSI (American National Standards Institute) work group T1E1.4 first approved ADSL in 1995. It supported data speeds of up to 6.1 Mb/s (ANSI Standard T 1.413). In the meantime ETSI (European Telecommunication Standard Institute) elaborated the Annex k T1.413 in order to meet the European requirements. The item (I – 1.413) was limited to only one insert on the subscriber's side.

The second edition (T1.413i2) was approved in the year 1998. The expanded standard which included the multiplex insert at the subscriber's end, the configuration protocol and the network manager and some other approvals.

The third edition complied with the international organisation ITU-T in order to issue the international standard for ADSL. ITU-T standards for ADSL are mainly built upon G.lite (G992.2) and G.dmt (G9.992.1) which were approved in June 1999.

5. SERVICE PROVISION AND IMPLEMENTATION IN PRACTICE

The approach via ADSL technology is intended for access to new data services that need great bandwidth and whose characteristic is the asymmetry of data transmission, e.g. high-speed access to the Internet, remote control (using asymmetric digital subscriber line one can control what is happening even at geographically very remote houses, shopping centres, etc.) teleworking (employees working at home over the Internet so that the employer has no expenses regarding renting the premises, the employees have access to all the databases of the company, etc.), telemedicine (counselling, opinions of other physicians, etc.), distance learning, shopping from home, video on demand (film is selected and paid on the "pay per view" principle), watching TV, etc.

Today, ADSL is commercially supplied by more than 60 operators in the USA, and over 25 in Canada. In North America the number of subscribers increased to the figure of one million. At the end of 2000 there were about three million ADSL subscribers in the world. The great increase in supply has been caused first of all by the Internet service operators. In Europe the spread of ADSL technology is occurring with greater caution. ADSL is commercially offered by Belgacom (Belgium), Helsinki telephone Co. (Finland), Telekom Italia (Italy), Deutsche Telekom (Germany) and in Norway, Spain, France and experimentally also in Slovenia.

In Asia ADSL is offered by major Asian enterprises which are located in Japan, Taiwan, Korea and Singapore.

5.1. Data protection

For its operation, ADSL uses two-pair line which allows point-to-point link between the subscribers and the main telephone exchange. The neighbouring subscribers do not share cables and therefore have no access to data of the other subscribers, which is very important in business and private transactions.

The literature used as the background for this article states that the data protection is at the highest level. However, it may be supposed that there will oc-

cur problems with hackers who will know how to use the fact that ADSL link is constantly on-line and will try to abuse this to their advantage and to the disadvantage of ADSL system subscribers.

6. CONCLUSION

During the development phase and the expansion of the ADSL system, it seemed that ADSL would be competitive with ISDN and that it would threaten its survival. All the functions of ISDN subscriber relation (two simple 64 kbit/s channels for voice, fax or data) remain unchanged in spite of the parallel use of the high-speed ADSL data link (the third independent channel).

All the three secondary available communication channels share a physical medium i.e. the already existing telephone copper pair.

ADSL provides all that had been previously provided by ISDN and moreover some additional services, at a 50 times greater speed. The ADSL speed is of 8 Mbit/s which is as much as 50 times faster compared to the regular line, and the world is already facing the development of mobile telephony of the third generation, 3G, which will allow transmissions at a speed of 384 kbit/s which is six times faster than ISDN but still slower than ADSL.

The DSL technology allows the subscriber to be constantly on line and thus the subscriber needs not wait for the line or check whether e-mail has arrived. Therefore, there is no need to dial in and wait for call set-up with funny noises coming from the modem. With ADSL the whole world is at hand. ADSL is thus used both in the business world and in private life, for education and for entertainment (multimedia).

The common two-pair network used by ADSL is one of the safest infrastructures in the world. It very rarely happens that the network breaks down, and if this happens, the fault can be recovered very fast.

The ADSL technology which significantly influences data transmission via telephone network is one of the technologies included in the xDSL family.

The essence of this technology is in the speed of data transmission and in adapting the transmission speeds regarding the throughput capacity of the telephone network.

The quality of the service is significant and provided in accordance with what the user needs, orders and of course, pays for. And this is one of the main trends in advanced telecommunications.

POVZETEK

TEHNOLOGIJA ADSL

V članku se govori o tehnologiji ADSL - asimetrični digitalni telekomunikacijski tehnologiji. Njena odlika je velika hitrost prenosa podatkov in prilagajanje toka prenosa informacij glede na prepustnost telefonskega omrežja. Zato je prenos učinkovitejši, pasovna širina pa bolj izkoriščena. Tehnologijo ADSL zaradi svojih prednosti vsak dan uporablja več in več posameznikov, posebno pa podjetja v Evropi in svetu.

LITERATURE

[1] **Penko, G.**: *Tehnologija ADSL*, Škrjanček, Ljubljana, 1999, Vol. 11, pp. 19-21

[2] **Šarić, S., Peraković, D., Brdar, G.**: *Asymmetric Digital Subscriber Line (ADSL)*, Promet-Traffic-Trafico, Zagreb, 1997, Vol. 9, No. 5-6, pp. 237-244

[3] **KOBLAR, M.**: *Tehnologija ADSL*, Škrjanček, Ljubljana, 1999, Vol. 12, p. 21, 24

[4] *Telekomunikacijska zvezda ADSL*, Delo, Ljubljana, 1999, 24. Dec. 1999, p. 47

[5] Internet: http://www.adsl.com

[6] Internet: http://www.slip.net/dedicatedsales/adsl_tutorial.html

[7] ITU-T: *preporuke serije G.99X*