Performances and Capabilities of Access Networks Based on DSL Technologies (xDSL, ISDN)

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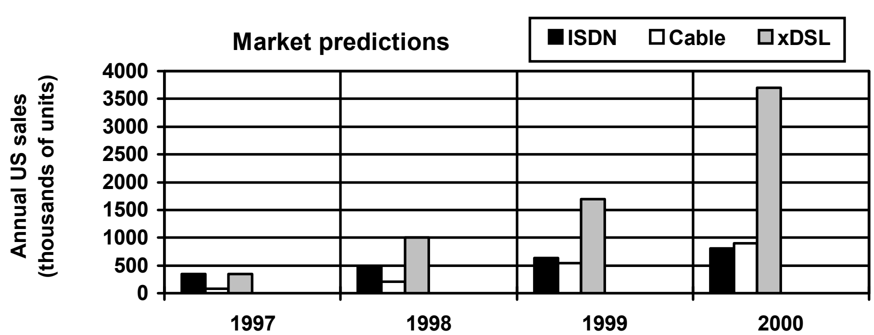
ABSTRACT

This paper presents the results of a comparative evaluation of the performances and capabilities of access networks based on digital subscriber loop technologies: xDSL (ADSL mainly), ISDN. The unifying technology for breaking down the barriers between LAN and WAN is highly agreed to be ATM. There is a discussion about their technological and commercial impact, giving the hottest issues by the time this article was submitted. According to the demonstrator system developed within COPERNICUS #1529 project ("Multimedia services over High-speed networks"), an ATM-over-ADSL solution has been tested, with BRI-ISDN lines as optional low-speed access technique. The conclusions are very useful for network and telecommunications managers to take the right decisions in deploying the new services over broadband networks.

1 INTRODUCTION

Nowadays, we wonder if the copper is able to be transformed into a broadband interactive medium, delivering up to 10 Mbps of data in both directions to the home and office. Consequently, the questions are related then to the requested investments in time and money for deploying high speed services. The specialists agreed that in order to adapt narrowband telephone lines for data transmission, some new technologies have to be involved: QAM *(Quadrature Amplitude Modulation)*, CAP *(Carrierless Amplitude and Phase Modulation),* DMT *(Discrete Multitone).* Obviously, special interactive bit coding, error correction and interference suppression techniques, together with digital signal processors in the 200 millions of instructions per second range are needed, too.

Among other local loop technologies, [Ste97a] discusses the future of cable modems and ADSL. Dataquest presents the market predictions for USA, as in Figure 1, stating that there may be nearly 10 million subscribers served by DSL technologies (2.6 million ISDN lines, 6.8 million xDSL units) by the end of 2000, compared to less than two million cable modems.



Source: Dataquest, 1997

Figure 1 Market predictions for annual US sales of ISDN, cable and xDSL

2 xDSL FAMILY

Having such promising predictions for deployment, ADSL could be a successful technology. But Alan Stewart, in [Ste97b], shows that for the moment the saga of ADSL seems to have a similar evolution like ISDN few years ago: industry response was almost favourable but there are no substantial orders for this new technology. Because of important investments in developing digital signal processing technology, access and network management systems (about USD 150 million) and because of large amount invested in broadband copper access networks and services (more than USD 500 million), the involved industries (suppliers, telecom operators) are not profitable for the moment (hopefully it will be in the near future).

There is also a technical issue concerning the fact that the commercial ADSL products are based more on CAP (non-standardized completely) and less on DMT (already standardized by T1E1.4). It is interesting that DMT was initially designed for Video-on-demand, whilst the new CAP-RADSL *(Rate-Adaptive DSL)* is mainly for Internet, Intranet and other remote data applications. The standard bodies must solve the CAP/DMT debate. CAP uses two carriers separated by bandpass filters, with impulse responses differentiated in phase. This method is considered to have inferior performances compared to DMT, which is a much more complex technique. The last one is based on the use of a large number of narrow carrier frequencies, each of them being required to accommodate only a relatively modest data rate [Wil97a]. Depending on the characteristics of the line, the subcarriers could be dynamically interchanged. The main disadvantage of DMT is related to its difficult implementation.

During the last period of time, the initial suitability of xDSL technologies has been extended. It was considered that HDSL has to be used at a distance less than 4 km., for unrepeatered T1 links over 2 copper pairs or E1 links over 3 copper pairs. The new standards include now E1 links over 2 copper pairs or over one pair [Wil97a]. Concerning ADSL, it was originally designed to provide Video-on-demand and other interactive services to customers. In 1997 the Internet and remote access proved to have a larger impact on ADSL market. Krish Prabhu, CEO of Alcatel Network Systems said that *"…VoD in system implementation is far more complex… Comparatively speaking, just giving you remote access to an enterprise network or the Web is far easier".* These reasons determined Alcatel to announce the shipping of 6 Mbps to 600 kbps ADSL product, as well as the forthcoming 8 Mbps to 800 kbps (both designed for Internet access) before its VoD-optimized ADSL product.

The pressure to offer Fast Internet access determined new members of xDSL family to appear. One of them is SDSL *(Symmetrical DSL),* able to run up to around 1 Mbps in either direction on a single pair. Dubbed FastInternet, produced by Orckit (Israel) is an example of a commercial 784 kbps SDSL system. Another new member of the family is RADSL *(Rate-Adaptive DSL)*, where the speed is automatically adapted to the quality of the line. According to [Wil97a], an example of RADSL modem is two-wire 19 AWG ASMi-50 (RAD Data Communications) at 768 kbps at 12.5 km (or 256 kbps at 18.5 km). The newest xDSL technology is VDSL *(Very high-bit DSL),* which automatically adapted 1024 channels to an optimum throughput of about 50 Mbps at a distance of less than 500 m.

DSL Product Category	***Copper Pairs***	***Range [m]***	***Maximum Downstream [Mbps]***	***Maximum Upstream [Mbps]***
ADSL/RADSL	1	5500	2/1.5	0.064
ADSL/RADSL	1	3600	6/8	0.640
ADSL/RADSL	1	300	25	0.001
SDSL	1	3000	0.384	0.384
HDSL	2	3000	2/1.5	2/1.5
(VDSL)	1	300	52	1.6/2.3

Sources: The Yankee Group Europe and Alcatel, 1997

Table 1. Comparison of xDSL technologies

3 MULTIMEDIA SERVICES

Concerning the speed, the vendors agreed that multimedia services over high-speed ADSL networks could be offered in conjunction with ATM technology. This means either ADSL with ATM backbone, either ADSL with ATM access. The standard bodies (ADSL Forum, ATM Forum, ANSI) agreed to sponsor interoperability between their respective technologies.

Talking about the first interactive multimedia service envisaged at the beginning, Video-on-demand, it was proved that a transport platform built only for it is very inefficient. That's why several trials, such as TITAN [Nal97], wanted to give the solution for a broad appeal of diversity of multimedia services on the mass market, but also for a good return of the significant investments. The results, indicated as percentages of the TITAN experts' indications, showed that the most popular is VoD (over 25 %), followed by home office - simple (over 20 %) and videotelephony (over 15 %). Several other services (around 5 %) are remote education, multimedia telegames, home office - advanced, home ordering systems, interactive TV, electronic newspapers, advertising and marketing.

Common Use	***Satellite System***	***PSTN Modem***	***BRI-ISDN***	***GSM***	***UMTS***	***xDSL***	***Cable Modem***	***MUX/Switch PDH/SDH***
File transfer	X	X	X	X	X	X	X	X
Web browsing	X	X	X	X	X	X	X	X
Hosting	X	-	-	-	-	X	X	X
Video on demand	-	-	-	-	-	X	X	-
Video conferencing	X	-	X	-	X	X	X	X
Workgroup	X	-	-	-	X	X	X	X
Interactive shopping	X	-	-	-	X	X	X	X

Sources: The Yankee Group Europe and Alcatel, 1997

Table 2. Common use for premises technologies

User Adoption	***Satellite System***	***PSTN Modem***	***BRI-ISDN***	***GSM***	***UMTS***	***xDSL***	***Cable Modem***	***MUX/Switch PDH/SDH***
Residential (Consumer)	-	Now	Near future	-	Distant future	Distant future	Now	-
Teleworker (SoHo)	Distant future	Now	Now	Near future	Distant future	Near future	Now	-
Brach Office (SME)	Near future	Now	Now	Near future	Distant future	Now	Now	Now
Major corporate site or campus	Near future	-	-	Near future	Distant future	Now	-	Now

Sources: The Yankee Group Europe and Alcatel, 1997

Table 3. User adoption for premises technologies

Analysys Publications, Cambridge (UK), produced a report about the two scenarios for future broadband services [Bri97]. The first one is based on the Internet model, with network and service provision separated, but with multiple players competing in each area. It is considered that this scenario would be profitable for smaller telcos, independent network service providers, but would depend on widespread of ATM and on the aggressive tariffing strategies. The second scenario involves a small number of vertical-integrated supercarriers, focused on providing end-to-end managed solutions. The national carriers will be partners of these organisations and will act as local agents for their global counterparts.

The first European carriers planning to launch in the near future broadband services over ADSL are British Telecom (UK), Telia (Sweden), Telecom Finland and Tele Denmark. The slowdown could have several reasons. One of them is the expected interactive service revenue which is not favourable to ADSL compared to cable modems, according to [Tho97]: USD 270 million vs. USD 6749 million. Another explanation could be the high growth of ISDN Basic Rate services within countries like Germany and France. An Israelian company (Orckit Communications) is trying to combine two technologies (apparently competitors !) over the same copper pair: ADSL-over-ISDN. In fact the classical POTS splitter will be replaced by a passive ISDN splitter, enabling parallel and transparent transmission of both ISDN and ADSL over the telephone line.

There are also some “strange” combination of technologies such as ISDN-over-POTS, promoted by American companies (ECI, Wescom, GoDigital) for delivering several POTS lines over one copper pair, or one POTS and one ISDN line, or one POTS and two ISDN lines. The idea is to replace the CAP and DMT schemes used by ADSL with a scaled-down version of the 2B1Q encoding mechanism [Law97].

Nevertheless, the ATM technology seems to be the key for breaking down the barriers between LAN and WAN services. The existing technologies have their disadvantages, such as frame relay which is good for bursty data traffic but it is not suitable for voice and video. The leased lines are extremely costly , especially if they must be used for broadband applications. The conclusion is that ATM represents the unifying technology designed to support multiple services including data, voice, video and multimedia through the existing physical layer technologies (leased lines, frame relay, SDH).

In order to encourage the deployment of ADSL, Advanced Telecommunications Modules Ltd. (UK) announced an integrated hardware and software solution for building xDSL systems [Pou97]. Based on proprietary ASICs, Atom Accelerator suite is the hardware proposal, including:

- Hydrogen chip, designed for xDSL modems and distributed loop carrier
- Helium chip, designed for DSLAMs *(Digital Subscriber Line Access Multiplexer)* in the local switching centres
- Oxygen chip, designed for switching systems in distributed loop carriers and central offices

The ATML's software proposal includes ATMOS, which is a microkernel-based real-time operating system, accompanied by device drivers for Ethernet & ATM and support for IP routing, Ethernet bridging, ATM Forum LAN emulation.

4 EXPERIMENTS WITHIN COPERNICUS #1529 PROJECT

4.1. Tele-education demonstrator network

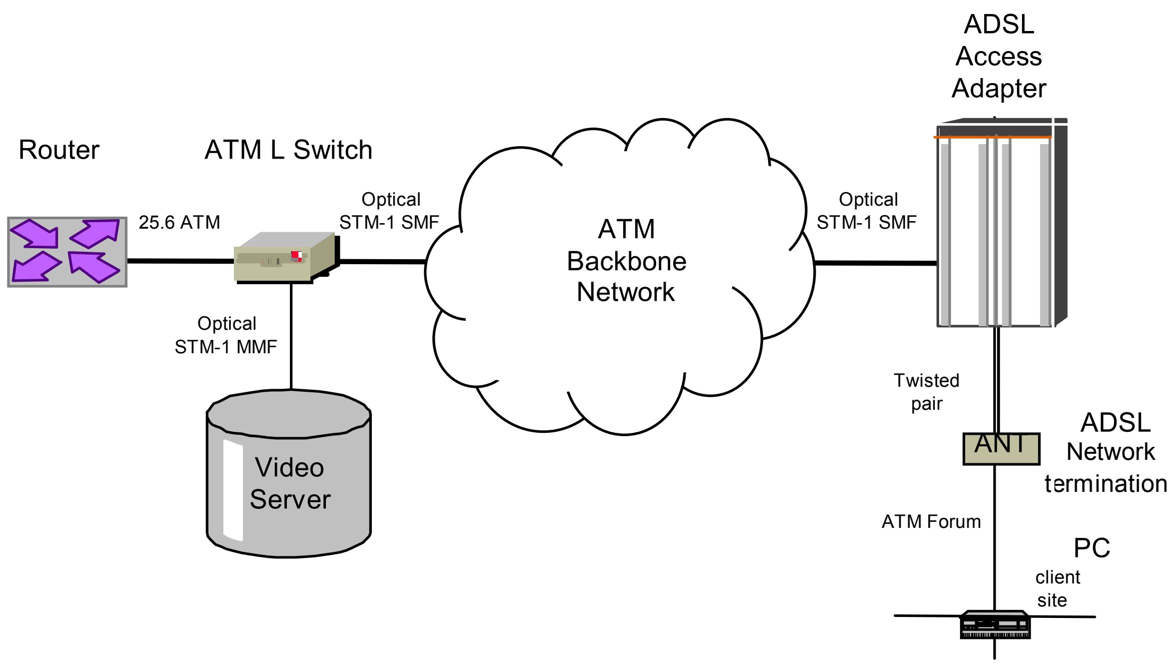


Figure 2. Tele-education Demo Network

The Tele-education demonstrator built within COPERNICUS #1529 involved ATM equipment produced by Advanced Telecommunications Modules Ltd. (UK) and ADSL equipment produced by Alcatel Bell (Belgium), as follows:

- **ATM VIRATAswitch** (VM1000-EU), including 12 integrated ATM25 25.6 Mbps ports (A1-A4, B1-B4, C1-C4) and one serial port (RS232) for configuration and status information
- 6 PC-based terminals with **ATM VIRATAlink PCI NIC 25 Mbps** (VL2010) connected to ports A1, A2, A3, A4, B1, B2
- **VIRATA 2x155 MMF SC/SMF FC** (VM3215) adaptor (plugged into D slot of VIRATAswitch 1000). It includes ports D1, D2.
- 2 x **A1000 ADSL Network Termination** (ANT R2.0) with three connectors: ATM25, in-house telephone (RJ11) and phone jack (RJ11)
- 2 x **A1000 ADSL Network Termination** (ANT R2.1) with four connectors: ATM25, Ethernet10, in-house telephone (RJ11) and phone jack (RJ11)
- **ADSL Access Adapter** (AA R2.0)

The structure of the ATM cell was conformed to ITU recommendation I.363. and the VCI numbers for VPI 0 were assigned according to *Table 4*.

VCI	***Used by***
1	MAST signalling (a proprietary lightweight signalling protocol for ATML's VIRATAswitches and links)
5	ATM Forum signalling
15	ATML's proprietary LAN emulation for broadcasts
16	ILMI (Interim Local Management Interface)
32…511	ATM Forum signalling to set up the SVCs
512…1023	MAST connections for VIRATAlink NICs
2048…8191	MAST signalling to set up the SVCs

Table 4. VCI numbers used for VPI 0

The Installation and Administration Guide of VIRATAswitch states that the switch responds to the following ATM Forum OAM *(Operation and Management)* loopback cells:

Characteristics	***Type of OAM cell***
VCI=3	Segment F4 flow
Payload Type=4	Segment F5 flow

Table 5. Type of OAM cells

The VIRATAswitch - VIRATAlink 25.6 Mbps connection uses UTP-5 patch cable with RJ-45 plugs (maximum distance is 100 m). The terminal connected via serial port (RS 232) provides configuration and status information facilities.In order to simulate the functions of a modem, pin 4 is wired to pin 1 and pin 6 (such as DTR is wired to DCD and DTR). Pins 7 and 8 (RTS and CTS) are wired to internal circuits but at present do not operate and cannot be used for flow control.

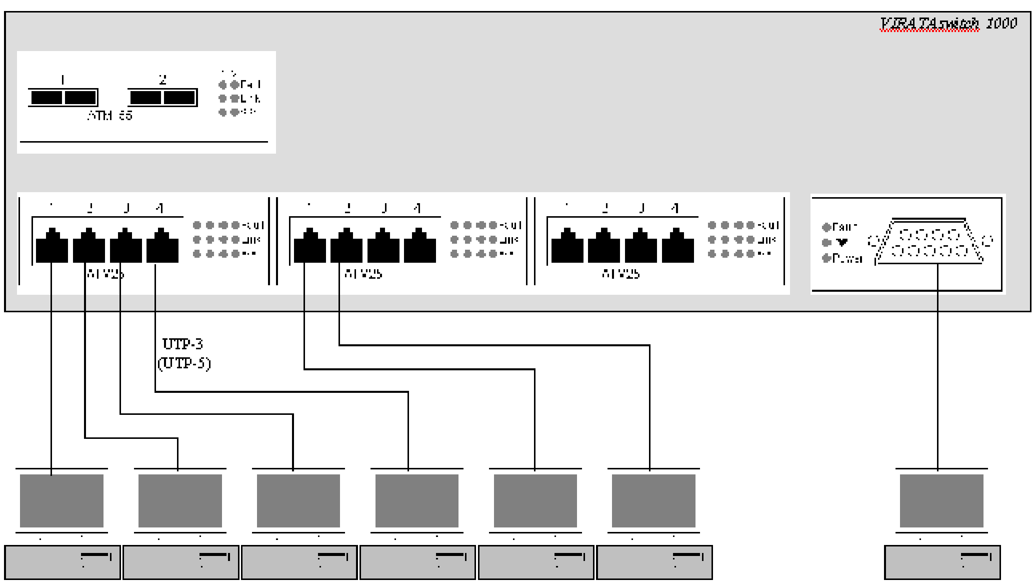


Figure 3. Configuration test for ATM equipment

4.2. Experiments

Evaluation of the impact of the network characteristics on the assessment of the overall Distance Learning application from the user point of view is discussed. First of all, the users should generally know that the DL application needs a hardware platform consisting on several PCs or workstations, TV sets, modems/ ISDN/ ADSL/ ATM accesses. The software environment, either the operating system, either the application could automatically offer statistics concerning the traffic: minimum/ maximum/ average bit rate, round-trip time and other QoS parameters.

After the installation of the network is completed, the target audience should be selected following criteria such as people from industry, telecommunications service providers, postgraduate personnel interested in tele-education. Obviously, the audience could be selected also according to the distance learning programmes carried out mainly by specialized university centers such as DL Center at Technical University of Cluj-Napoca, Romania [Vla97b].

From the technical point of view, the constraint of the limited number of end-terminals could be partially eliminated by taking into account both on-line and off-line displaying. The scenario for enabling off-line courses should be the following:

- additional hardware has to be installed, such as BRI-ISDN links between the tele-education system and the remote terminals or remote 10/100 Mbps LANs.
- the on-line courses have to be recorded, including the interactive dialog among end-users through the high-speed network
- the on-line courses have to be available for future off-line displaying by request coming from low-speed network end-users
- the genuine ADSL clients could act as a “proxy server” for non-ADSL clients

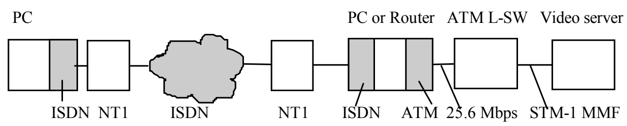


Figure 4. Remote access through video server’s site

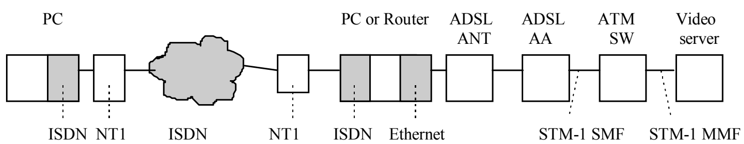


Figure 5. Remote access through an ADSL client

The experiments envisaged the physical, data link, network and transport layers only, the applications being described in [Vla97b]. The VIRATAswitch 1000 worked as ATM switch with the following clients: ODI DOS/Windows 16 bit, Windows 95 NDIS, Novell Netware 4.1 ODI. The signalling involved was VIRATA LAN emulation and Classical IP over ATM (PVC IP/ATM). The configuration test for ATM equipment, presented in *Figure 3*, involved three workstations (with ATM25 interface) connected to A1, A2 and A3 ports, having the parameters according to *Table 6.*

Workstation	***ATM25 port***	***IP address***	***Netmask***	***PVCs***
WS1 (Pentium)	A1	192.168.25.189	255.255.255.240	A1 33 -> A2 32 A1 35 -> A3 32
WS2 (Pentium)	A2	192.168.25.188	255.255.255.240	A2 32 -> A1 33 A2 35 -> A3 33
WS3 (Pentium) + Internet Router	A3	192.168.25.185 193.226.6.173	255.255.255.240 255.255.255.240	A3 32 -> A1 35 A3 33 -> A2 35

Table 6. Parameters for the configuration test of ATM equipment

The VIRATAswitch1000 was initialized as follows:

```
> ip enable atm 192.168.25.186
> ip subnet add atm.home . 192.168.25.176 ff:ff:ff:f0
> pvccreate a1 33 a2 32
> pvccreate a1 35 a3 32
> pvccreate a2 35 a3 33
> list pvc
```

Figure 6. VIRATAswitch configuration for testing the ATM equipment

WS3 acted as Internet gateway for the workstations connected to ATM-based local network (IP address = 192.168.25.176). Once the TCP/IP protocol was validated, the configuration test included also the ADSL equipment, according to *Figure 2*. Obviously the ATM backbone network was not available for experiments, the single-mode optical fiber between ATM switch and ADSL adapter had a limited length (less than 30 m). Due to the fact that the power transmitted by ADSL Adapter's SDH-NT is too high for VIRATAswitch receiver, a 10 dB attenuator had to be inserted.

CONCLUSIONS:

This paper intended to present a market survey of the existing and near future access technologies in order to give arguments for taking the right decision in offering or getting multimedia services over high-speed networks. There is no unique answer to the questions: ISDN ? Cable modems ? xDSL? It definitely depends on location, bandwidth, access issues, traffic flow, security, power, performance and obviously the price. It was highly agreed that the ATM represents the unifying technology for breaking down the barriers between LAN and WAN. It is also clear that a hybrid solutions could have a certain impact too, such as ISDN-over-POTS, ADSL-over-ISDN, ATM access-over-ADSL etc. COPERNICUS #1529 project experimented the classical solution, such as ATM-over-ADSL, including also ISDN as an optional low-speed access to multimedia services.

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ACRONYMS:

ADSL	Asymmetric DSL
ATM	Asynchronous Transfer Mode
BRI	Basic Rate Access
CO	Central Office
DLC	Distributed Loop Carrier
DSL	Digital Subscriber Line
DSLAM	DSL Access Multiplexer
HDSL	High-bit-rate DSL
ISDN	Integrated Services Digital Network
LAN	Local Area Network
SDH	Synchronous Digital Hierarchy
SOHO	Small Office/ Home Office
SONET	Synchronous Optical Network
RADSL	Rate-Adaptive DSL
SDSL	Symmetric DSL
VDSL	Very high-bit-rate DSL
MUX	Multiplexer
RAN	Remote Access Node
UMTS	Universal Mobile Telecommunications System
WAN	Wide Area Network
WLL	Wireless Local Loop