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ADSL Roll-Out in Belgacom

A Technical and Operational Perspective on the Physical Layer

This paper describes technical and operational aspects of the roll-out of an asymmetric digital subscriber line (ADSL) network in Belgacom. Firstly, the typical archetecture of the ADSL end-to-end network is reviewed, followed by the typical backbone interfaces and their impact on the processes. Next, the use of microfilters at the customers premises, to ease and speed up the provisioning and avoid the need for an engineering visit, is discussed. Finally , a typical European issue is considered: the use of ADSL over ISDN by means of the shifted ADSL spectrum, taking into account the impact on the spectral management in copper cables.

Introduction

Belgacom started a trial of asymmetric digital subscriber line (ADSL) technology in January 1998 in some main Belgian cities including Brussels, Mechelen and Antwerp. 1000 pilot-users were connected via ADSLs to the asynchronous transfer mode (ATM) backbone. A fast-Internet package, called *Turboline* was offered using a downstream bandwidth of 500 kbit/s and an upstream bandwidth of 100 kbit/s.

During this trial, the technology proved to be stable and reliable for broadband services. The procedures have also proved to be suitable for a commercial roll-out. A survey of the pilot users showed 80% of them recommended the service.

The commercial phase started in April 1999, offering two principal products:

- *Turboline-service profile:* This is a residential customer-oriented package that targets heavy Internet surfers with its particularly fast Internet package. (The fast-Internet market in Belgium has several players like Telenet with its Pandora service using cable-modem technology.) Turboline-service offers no guarantees on the delivered bandwidth. It is based on a 'best-effort' situation; however, the delivered packages have a peak-bandwidth of 1 Mbit/s downstream and 100 kbit/s upstream. The price of the package depends on the maximum volume of downloaded data offered by the service, or it can be on a flat-fee basis plus a charge for each extra downloaded Mbyte.
- *Turboline-PRO service profile:* This package targets business-customers, and also offers a fast Internet service but with a guaranteed bandwidth. At the customer premises, an ADSL modem with router functionality connects multiple users. Within the profile of 1 Mbit/s downstream and 512 kbit/s upstream, there is a guaranteed bandwidth of 256 kbit/s downstream and 64 kbit/s upstream. As in the Turboline package there are various volume-based prices on offer or a flat-fee option. In this commercial phase different Internet service providers can be used for the ADSL connection.

The Turboline-service itself contains the following main features:

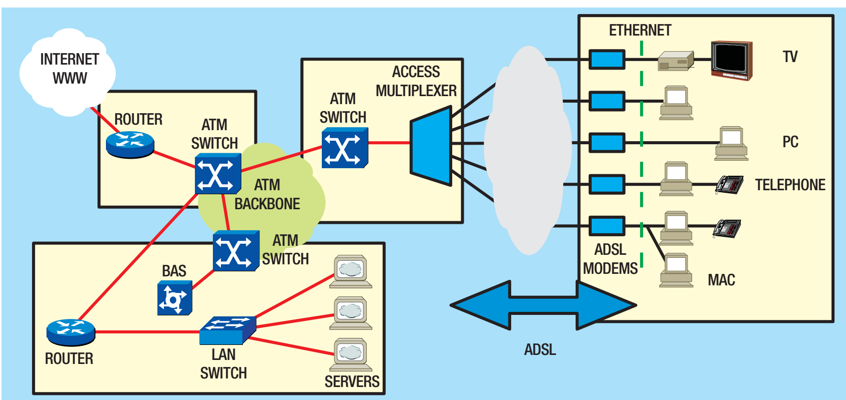
- home installation of ADSL modem and splitter, configuration of the fast Internet access as well as free customer support and repair;
- a basic service including: mail, newsgroups, web, chat, etc.; and
- an extended service including: downloading of software and data, audio- and video-on-demand, education, entertainment, videoclips, movietrailers, etc.

Network Topology

Figure 1 illustrates how the end-to-end network topology on ADSL is configured for the Turboline service.

The access side of the network consists of an ADSL modem installed in the customer premises together with a separate low-pass filter. On the local exchange side a digital subscriber line access multiplexer (DSLAM) is installed to concentrate all ATM cells coming

Figure 1—End-to-end network topology on ADSL



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from different clients and to map them on to a dedicated interface to the ATM backbone. This can be an STM-1 interface, an E3 interface or multiple E1 interfaces, depending on the expected load on the specific DSLAM.

The Belgacom ADSL network can be considered as a 'client' of the national ATM backbone. The ADSL using client is authenticated by a broadband access server (BAS). The client gets the IP address via this server to make the connection to, say, the Internet.

Additional servers are installed to offer local content; for example, on-line gaming, audio and video-on-demand, etc.

The DSLAM Interfaces to the Backbone and Their Impact on the Processes

Depending of the interface used, we can separate the typical architecture in to two parts:

Direct connection to the ATM backbone

In this case the interface of the DSLAM is directly connected to the ATM switch via an STM-1 or E3 interface (Figure 2). (Multiple E1 access is also possible.)

The physical link between the DSLAM and the ATM switch can be made using an optical connection for the STM-1 interface or an E3 leased line.

Subtended configuration of a DSLAM to a 'HUB' DSLAM

The second option is to connect a DSLAM to the network by 'subtending' this DSLAM with an interface to another DSLAM that is connected to the ATM backbone. The subtended DSLAM has no direct connection to the network (Figure 3). Typically this would be used with the multiple E1 interfaces.

In this case the connection between the two DSLAMS can be made by means of multiple (typically up to four) E1 leased lines. The HUB DSLAM connection to the ATM network usually uses an STM-1 (a synchronous transport module) or E3 leased line.

STM-1 interface

The STM-1 interface is an optical interface to the ATM backbone. When there is no direct connection to the SDH network by means of an add/drop multiplexer (ADM), the maximum acceptable optical attenuation imposes distance limitations.

So, when the decision is made to equip a DSLAM in a central office with this type of interface, the position of the central office to the ATM equipment has to be considered. When the distance is too long, an extra ATM concentrator can be placed in the neighbourhood (in the same central office) of the DSLAM. The STM-1 connection is placed between the DSLAM and the concentrator. Then, from the interface of the concentrator, we enter the ATM backbone. This interface need not be the same capacity as the STM-1.

The disadvantage is that an extra investment has to be made for the installation of the concentrator.

A big advantage of the STM-1 interface is the flexibility of the available bandwidth. Taking capacity (in terms of maximum installed clients per DSLAM) into account, there are almost no restrictions on selecting a certain bandwidth profile. Moreover, the 'simultaneous usage' and 'burstiness rate' of the IP traffic it possible to concentrate more clients into the available bandwidth.

The optical connections between the interfaces require skilled optical teams. This has also impacts on the repair process where, in case of optical faults, extra reminders have to be given to the responsible optical teams to check out connectivity.

When in-band monitoring of the DSLAM is carried out by centralised management, an optical fault can result in all communication with the DSLAM being lost. Troubleshooting requires an extra engineering visit(s) to the central office involved.

E3 (PDH 34 Mbit/s) Interface

The E3 interface is via a coaxial connection to the ATM backbone rather than an optical connection. There are typical options: in the first case, where the ATM backbone interface is situated in the same central office as the DSLAM, the connection is made using a coaxial internal connection in the building. Extra attention has to be paid to the quality of the cable used and the maximum distance between the two connection points, to prevent increased attenuation and possible loss of quality due to bit errors.

In the second case, where the ATM backbone access is not in the same central office, a 34 Mbit/s leased-line used between the two central offices.

The construction of a DSLAM connection is more complex than for a STM-1 interface because there has to be a synergy between the DSLAM installation team and the leased-line provisioning team to achieve an acceptable cycle time. End-to-end connectivity tests are mandatory to ensure the quality.

If the same client concentration is used on the DSLAM as for the STM-1 connection, extra attention has to be added to the used client profile to prevent an overload of the available

Figure 2—A direct connection to the ATM-backbone

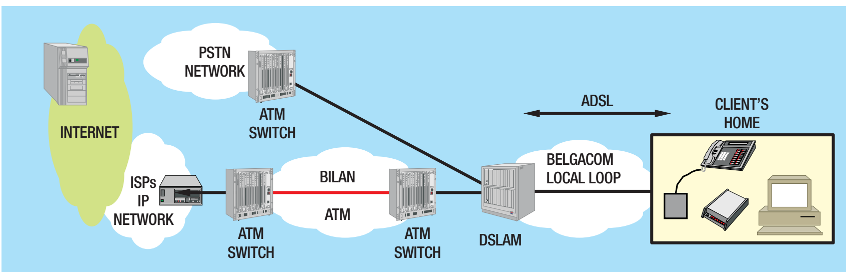
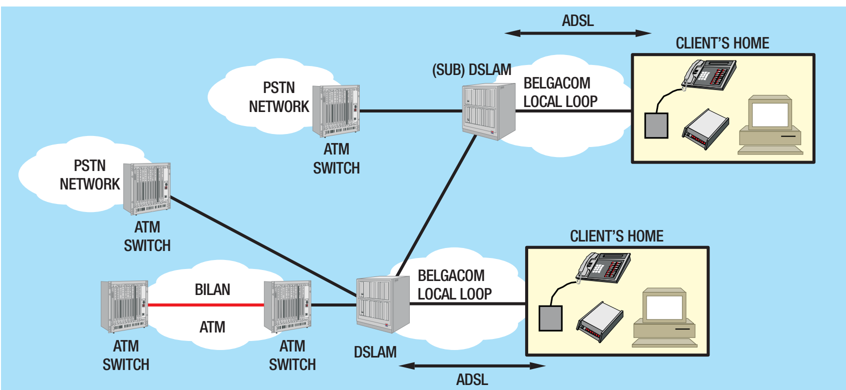


Figure 3—Connecting a DSLAM to the network by 'subtending'



bandwidth occurring. This can happen when, for example, ATM layer minimum bitrate guarantees are given to the clients.

With regard to the management of the DSLAM, especially for the repair process, it is important to recognise the difference between a fault at theDSLAM-interface level or at the leased-line level to prevent wasted time during troubleshooting. Hence, a good process flow is mandatory.

The N×E1 Interface (PDH Multiple 2Mbit/s)

This interface has two possible architectures. First we can have a direct (multiple) leased-line connection to the ATM backbone, similar to the E3 interface solution. Second, there is the 'subtended' architecture, as described above. In case of the subtended configuration, the leased-line connections are not made between the involved DSLAM and the ATM backbone interface, but between the so-called *subtended DSLAM* and the HUB DSLAM situated in an other central office.

An important difference with the above mentioned interfaces is the fact that multiple leased-line connections can be used between the two DSLAMS. This gives extra flexibility due to a degree of scalability of the available bandwidth.

On top of the E1 layer there can be an inverse multiplexer (IMA) running. This means that the DSLAM, in the case of multiple E1s, does not 'see' the separate E1 leased-line links but an overall bandwidth. Thus the ATM traffic is fitted on to the available bandwidth. The result is more economic use of the available bandwidth.

The use of the IMA facilities has also an impact on the repair process. In fact, the IMA group makes the interface connection dynamic. This means that the traffic is adjusted dynamically when the bandwidth changes; for example, when there is a leased line error.

When a different routing is used for the selected E1 leased lines for the DSLAM connection, a failure of one of the leased lines does mean that the DSLAM goes out of service, but the traffic is redistributed among the E1(s) still in service. Trouble shooting from a central management station is still possible via the in-band monitoring of the remaining E1(s).

Because a subtended DSLAM is connected to a HUB DSLAM, a fixed part of the interface bandwidth of the HUB DSLAM is used for the sub DSLAM. This is important when setting up the network architecture using the maximum possible subtended DSLAMS, connected to a hub, taking into account the interface bandwidth of the hub and the used client profiles.

ADSL Cabling at Customer Premises: Use of Distributed Splitters

Initial set-up

By installing ADSL on the client side, a low-pass filter is placed between the network entry and the customer premises equipment (CPE). This makes it possible to transmit simultaneously both the existing POTS services and the new ADSL services over the same copper pair. An additional in-built high-pass filter in the ADSL modem takes care of the fact that there is as little as possible interference between the two spectra.

The disadvantage of such an installation is that, in most cases, extra cabling has to be included in the house cabling, besides the normal configuration of the client PC. So the installation requires the visit of a telecommunications company installer. Thus, there is a search for alternative installation solutions to make the engineering visit more effective while saving time or even a situation where a visit is not necessay—there is a need for a self installation plug-and-play solution.

The use of distributed splitters

One solution can be the use of distributed splitters, the so called *microfilters*. Laboratory tests have been made and a trial carried out to check the technical and process impact on the installation. (Note: the use of G.Lite solutions or splitterless configurations are not considered.)

We only considered the possible use of microfilters on full-rate ADSL.

The microfilter can be delivered in different configurations depending on the needs of the telecommunications company and the network situation. Here we consider the 5-pole solution and the in-line RJ11 solution.

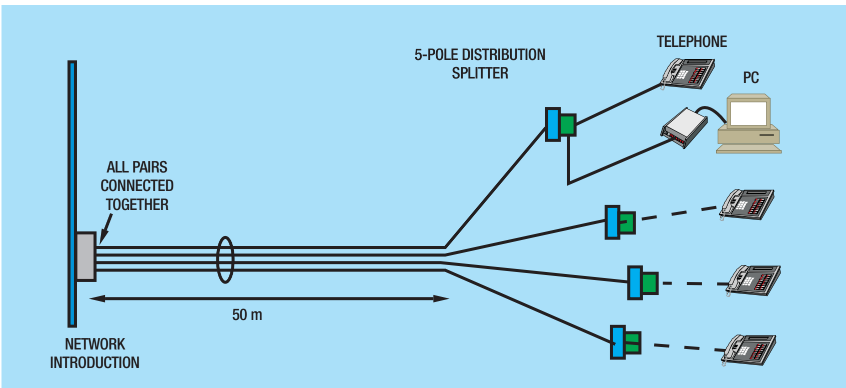
The 5-pole microfilter can be connected into the normal 5-pole wall socket between the wall socket and the connector of the CPE. The RJ11 connection of the microfilter is connected to the ADSL modem. The RJ11 in-line version has two RJ11-connection points (male and female) and is fitted in serial on the cable to the CPE. The house cabling determines which type of microfilter can be used. Both types have the same electrical functionality.

The installation set-up is different from the conventional splitter set-up: the microfilter is installed on *each* connection point in the home rather than at the network entry to the home. The number of microfilters used in an installation depends on the number of available wall connections in the house.

Also the in-house wiring becomes included in the system because the microfilters are connected to the wall sockets. This means that building's internal cabling has to be taken into account for the overall performance of the ADSL modem. Hence, bad or extensive cabling can influence the performance negatively. The laboratory set-up illustrates the impact on performance (Figure 4).

The internal wiring is simulated by a 50m cable of which five pairs are selected, each going to a different room in the house. One of the rooms is provided by the ADSL installation. In the other rooms, only POTS equipment is installed. To check out the impact of the house wiring, the test started by installing one microfilter with its POTS equipment.

Figure 4—A building's internal wiring



Then one items of POTS equipment was consecutively installed on each of the remaining wall sockets.

The results were that with the second microfilter, there was a performance loss of 9.3% compared with the initial maximum performance. With the third microfilter, there was an additional loss of 10.2%; the fourth microfilter caused 2.6% additional loss.

These results mean we can take into account the performance loss due to the impedance changes caused by the additional POTS equipment and microfilters on the line. Additionally, there is a bridged-tap effect when a wall socket is not used and no microfilter is installed in it.

Note that the performance loss is encountered on the downstream traffic, due to the higher frequencies used in this spectrum. The laboratory tests present the worst case situation since pairs wires are rarely together for a distance of 50m in the same sheath in a house.

Considering the technical impact, we can conclude that the internal wiring on the client side can influence the overall ADSL performance and reduce the maximum usable distance from the central office to the customer. The rate of that impact is unknown and depends on the quality and the cabling situation in the house.

A technical trial is necessary to check if there is internal wiring that does not cover the use of microfilters for full-rate ADSL. This trial would also indicate if it is feasible to create a self-install package with microfilters included in the package; for example, consider the number of helpdesk calls requiring installation assistance. In this trial it is also possible to determine the proportion of used 5-pole/in-line microfilters.

It is important for the self-install option to have a good user installation manual.

The use of microfilters on full-rate ADSL also impacts the provisioning process.

When an order is taken, it is strongly recommended that as much data as possible about the cabling at the customer premises is collected. Then a decision can be made as to the feasibility of installing microfilters without too much risk. One determining factor can be the number of wall sockets in the home. Special cases, such as alarm centrals or PBX installations, can result in the need to install a conventional splitter instead of a set of microfilters. In the case of corporate clients, who already have an in-house structured cabling for other high-speed services, it is essential to use conventional splitters.

Use of ADSL Over ISDN: Implementation in the Network and Technical Feasability

The European telecommunications market is promoting ISDN as a means of accessing the Internet. It is possible that this client segment will eventually consider an upgrade to ADSL for high-speed Internet access. It is unlikely that the client would downgrade from ISDN to POTS while installing ADSL.

So, for the European market, ADSL over ISDN is taken into consideration.

The fact that ISDN uses a larger frequency spectrum (2B1Q: 80 kHz / 4B3T: 120 kHz), has impact on the use of ADSL technology in the higher frequencies (Figure 5).

In the illustration mentioned above we can see that the used ADSL spectrum in the ISDN variant is shifted to the higher frequencies. This also means a reduction of the downstream bandwidth due to a reduction in the number of carriers.

Moreover, we have to take into consideration additional crosstalk, especially when a conventional ADSL over POTS line is collocated with ADSL over an ISDN line.

The most significant crosstalk comes from the part of the downstream spectrum of the ADSL over POTS on the upstream part of ADSL over ISDN. This makes the coexistence of both solutions in the same binder difficult.

Also the shifted spectrum makes both technologies incompatible. This requires additional hardware at both the central office side and at the customer premises.

A solution, offered by vendors is the universal splitter. This is an adapted filter that can be used to filter out POTS, ISDN 4B3T and ISDN 2B1Q. It makes eventual up or downgradeability possible without the need for an engineering visit or hardware changes.

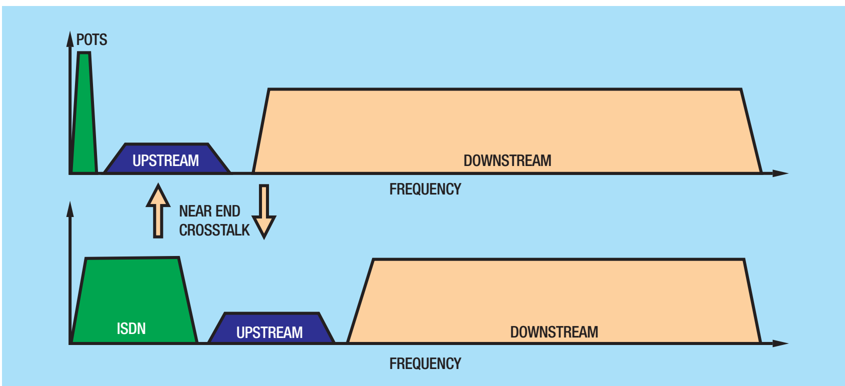
So two provisioning solutions are possible. The first is a universal solution where only ADSL over ISDN hardware with a universal splitter is used. This can be a solution for networks with a high penetration grade of ISDN. The universal splitter makes it possible to downgrade to ADSL over POTS without any hardware changes. The same hardware is used for clients who continue to use their POTS services without upgrading to ISDN. Then an eventual upgrade to ADSL over ISDN does not require any additional hardware at that time.

The fact that this solution only uses one type of equipment makes it more manageable. Also the additional near end crosstalk issue disappears.

A disadvantage is that even the POTS user has a decreased downstream performance due to the shifted spectrum, nor is there compatibility with G.Lite later.

The other solution can be the coexistence of ADSL over POTS with ADSL over ISDN in the same binder or cable. Therefore, pair-selection guidelines have to be adapted to make the additional NEXT acceptable. This can be a solution for networks where the ISDN penetration is rather low. A disadvantage is that new hardware is introduced at the central office and at the customer premises. Thus an ADSL-over-POTS client who wants to upgrade to ISDN, while keeping the ADSL service, has to change his/her hardware to make this possible. However, the ADSL-

Figure 5—The frequency spectra for the POTS and ISDN cases



over-POTS clients can benefit from the full downstream capacity.

Note that, eventually, the NEXT can be reduced by disabling the interfering carriers in the profile of the ADSL-over-POTS client. At that time, we have to remember that the ADSL-over-POTS client gets the same downstream reduction of an ADSL-over-ISDN client.

It is obvious that the presence of ISDN in the network can cause additional provisioning difficulties when we take into account the deployment of ADSL on the same copper pair. One important point in the future deployment of both technologies is the flexibility and manageability of the whole technology, in particular the spectrum management in the copper cable network.

Biography

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Koen received his degree in Electronics at the V.H.T.I Kortrijk in 1992. He joined Belgacom in 1994 in the transmission department where he was responsible for the operational part of optical-line systems and the zonal optic-cable network in Brussels. In 1998 he was involved in the selection of ADSL equipment during a pre-commercial trial. Since then he has been responsible for the physical layer and transmission part as well as the set-up of the construction and repair-process of the ADSL project.