# Unbundling the Access Network: Technical Issues and Architectures to Boost Open Competition for Telecommunications Services

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*Abstract:* - Unbundling consists in the possibility for a new operator of having special access to the incumbent's network infrastructure, in order to provide value-added services without the necessity to duplicate the infrastructure itself. Access network unbundling has received most attention in Europe. Most European operators are interested mainly in the physical access to copper loop, which gives the opportunity of offering broadband services pervasively by exploiting the capabilities of Digital Subscriber Loop (xDSL) technology. Technical issues to be faced in offering these services are severe and include loop qualification, interference evaluation and shortage of available loops.

*Keywords:* - access network, asynchronous transfer mode, digital communication, local loop, market regulation, unbundling.

## 1 Introduction

In recent years, most European countries moved towards the liberalization of the telecommunications sector, according to the Directives of the European Parliament and Council [1]—[6]. Suppressing the restrictions to offer telecommunications services and to build new infrastructures, together with provisioning licenses to incoming operators, made competition for telecommunications services possible. Nevertheless, these measures are not sufficient to boost open market development and unrestricted competition, aiming at a balanced economic development. To this purpose, in principle, all operators should receive equal treatment. Thus, Regulation Authorities must pursue two goals:

- to promote open competition in all telecommunications sectors, in order to have fair pricing for customers and to stimulate technical innovation;
- to achieve as much efficiency as possible in infrastructure utilization by avoiding duplications, while preventing former monopolist operators from the arbitrary control of infrastructures that are necessary for service provisioning (*essential facilities*).

This regulatory task is complex [7][8]. Particularly in the access network, improving efficiency in resource utilization and management favours exclusive control of infrastructures and thus may impede open competition.

Dealing with interconnection, one of the thorniest issues is *unbundling*. Unbundling is the process by which the former monopolist, or *Incumbent Operator* (IO), grants incoming *Other Licensed Operators* (OLOs) the access to some elements of the network infrastructure, e.g. copper pairs, digital bistreams, frequency bands in a telephone local loop [8] at a regulated price level.

Unbundling the access network (local loop) has received most attention in Europe [8]. It may mean access to the physical medium, or to logical channels (such as ATM Permanent Virtual Connections, PVCs) or to other elements of the access network. European operators are interested mainly in the physical access to copper loop, e.g. to offer broadband services by use of Digital Subscriber Loop (xDSL) systems.

This paper surveys several technical aspects of unbundling the access network. First, its basic features are outlined and various unbundled services are detailed. Then, the paper focuses on unbundling the twisted-pair local loop: transmission technologies, electromagnetic issues and pair availability are addressed.

## 2 The Concept of Unbundling

By *unbundling* some network element, an Operator (usually the former monopolist IO, with significant market power) grants to other incoming Operators (OLOs) the access to some elements of the network infrastructure, without releasing ownership. Then, OLOs use unbundled elements to provide services to their customers. Let us notice that this concept implies an added value provided by the OLO: the unbundled element, as it is, can not provide a service of the same level as that provided by the OLO.

Unbundling plays a central role in achieving open competition in all telecommunications sectors, by lowering economical barriers that hinder OLO ingress, and in improving the efficiency in infrastructure utilization, by avoiding duplications of essential facilities [7]. Obviously, the key step in pursuing these goals is the correct pricing of unbundled services. Regulation Authorities are usually in charge of this complex task.

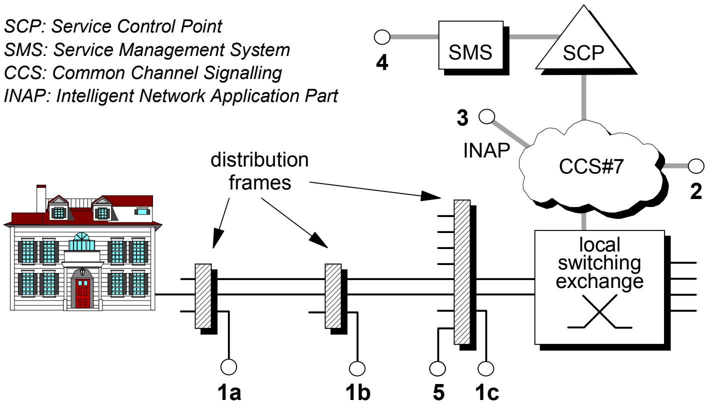


Fig. 1: Scheme of telephone network with possible interconnection points for unbundled services.

The unbundling principle is very general. Several portions of a network may be unbundled. For example, in the telephone network sketched in Fig. 1, we may identify:

- the access infrastructure (at points 1a, 1b and 1c, for example in the case of wireline local loop);
- the Common Channel Signaling infrastructure, or Signaling Transfer Point (STP) network (at point 2);
- the switched network, with exchanges providing Service Switching Point (SSP) functions (at point 3);
- the Intelligent Network (IN), with access from a Service Creation Environment (SCE) (at point 4);
- the transport network, with access offered to Personal Communication Service (PCS) providers (at point 5).

# 3 Unbundling the Access Network

In Europe, major attention has been devoted by Regulation Authorities to unbundling the access network [6]. This fact is mainly due to two reasons:

- the massive investments necessary for building alternative infrastructures;
- the availability of new xDSL technologies, which make possible to offer broadband services on copper-pair infrastructures originally deployed to provide Plain Ordinary Telephone Service (POTS).

## 3.1 Technical Aspects

Referring again to the scheme in Fig. 1, the possible interconnection points that may be considered for unbundling the access network are 1a, 1b and 1c. In the most common scheme, nevertheless, the IO leases the section of twisted-pair from the customer premises to the main distribution frame in the local office building (at point 1c). From the distribution frame, a cable connects to the OLO equipment, usually co-located in the same office building, which is connected to the OLO network by a dedicated line.

Although copper-pair networks are undoubtedly the most important in access unbundling, yet other physical elements can be considered: for example, optical-fibre or coaxial-cable networks. Moreover, also *logical* unbundling has been proposed. In this case, the OLO leases a digital communication channel between its network and the customer.

Unbundling the twisted-pair local loop poses important technological and procedural issues. Having on the same bundle and connecting on the same frame many twisted pairs yield problems of electromagnetic compatibility. Moreover, the transmission quality of the pair itself can not be guaranteed *a priori*, but depends on several unpredictable circumstances, such as the number of frames on the path, the wire diameter and interference issues.

## 3.2 Unbundled Services

In unbundling the access network, several types of service can be considered.

### 3.2.1 Physical Medium

In this case, the OLO rents some section of continuous physical transmission medium between two access points. The most notable example is unbundling a section of twisted pair in a copper local loop, according to the architecture shown in Fig. 2. All sections between access points T, $U_1$, $U_2$ and V are possible in principle, but only T-V and T-$U_1$ have been mostly considered.

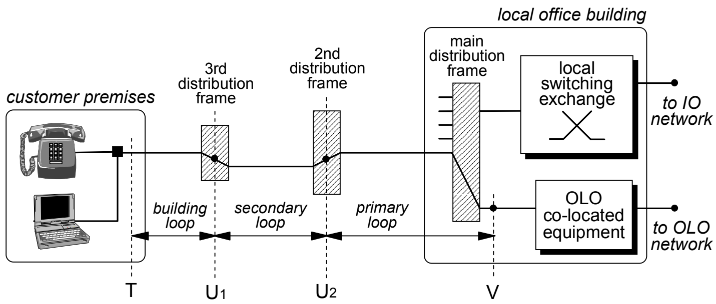


Fig. 2: Unbundling sections of twisted pair in the copper loop.

### 3.2.2 Analog Channel

This is a logical access service independent from physical medium aspects. In this case, the OLO rents a channel between two access points for transmission of analog signals. The channel may be specified in terms of technical parameters such as bandwidth and signal-to-noise ratio. It is independent on the type of modem that the OLO will use for voice or data transmission.

An example of analog channel that can be considered for unbundling is the xDSL broadband channel from customer premises to the local office building, accessed by the OLO at the POTS splitter on xDSL systems. The base band channel carrying voice services is still handled by the IO. This possibility is often called a *shared access* service.

### 3.2.3 Digital Channel

In this second case of logical access, the OLO rents a semi-permanent digital channel between the customer termination and a second access point, for the transmission of constant-bit-rate digital streams. The digital channel may be specified by the bit rate, the physical interface, frame structure, functional characteristics (such as the way in which user signalling is transported) and various quality parameters (e.g., bit error rate, slip rate, jitter limits, etc.).

Digital access interfaces of choice to this purpose are the V5.1/V5.2 interfaces, according to ITU-T Rec. G.964 and ETSI ETR 242, which allow to connect telephone subscribers with associated signalling (POTS and basic/primary ISDN access).

### 3.2.4 Virtual Channel

In this case, the OLO may rent an ATM PVC between the customer and its network. More specifically, the IO offers a broadband access to an ATM UNI (as specified by ITU-T Rec. I.432) through xDSL systems previously deployed, while keeping the system property and maintenance.

## 3.3 Accessory Services

Accessory services are services that must be provided by the IO together with the unbundled services. Without the provision of these accessory services, unbundled services may be neither practically useful nor convenient.

### 3.3.1 Co-location

To use some unbundled service, it is often necessary that the OLO be allowed to place its equipment in the IO building. Co-location management is a thorny matter, because, in spite of how detailed are the rules agreed, there are innumerable potential causes of contrast:

- the *price* of the co-location service may be the main cost that the OLO has to bear and thus should be controlled by the Authority, based on estimating *actual* costs for IO;
- often, the IO office building may have *not enough room* to host OLO equipment; this is often the case when unbundled pairs are terminated in low-level switching nodes, mostly located in little sites or even in containers;
- co-located equipment needs *additional power supply* and sometimes air conditioning;
- *regulating the access* of OLO personnel to co-location rooms is troublesome.

### 3.3.2 Access Extension

Pursuing the economical goals of unbundling implies also the need of relieving the infrastructure costs that OLOs must carry to reach interconnection points. With access extension, OLOs that have access to some unbundled service at a peripheral network location can interconnect with the IO network at a more central office, taking advantage of a link between the two sites, leased from the IO at a special tariff fixed by the Authority, provided that it is used only to extend unbundled access links and not for other purposes. The access-extension service may be offered by renting physical media (optical fibres), digital channels or even virtual channels.

# 4 Technical Issues in Unbundling the Twisted-Pair Local Loop

Unbundling the twisted-pair local loop poses important technological and procedural issues. Transmission technologies for offering broadband services on copper pairs, originally deployed for POTS, have been developed only recently. Moreover, the electrical characteristics of pairs and the possible interference do affect the maximum bit rate achievable.

## 4.1 Transmission Technologies

The term *xDSL* denotes a family of techniques for the transmission of digital streams on copper twisted pairs (cf. ITU-T Rec. G.995.1).

- *High-speed DSL (HDSL)*, specified by ITU-T Recs. G.991.1/2, allows the transmission of 2.048-Mbit/s symmetrical signals on two (or three) pairs, over distances ranging from 3.5 to 7 km, depending on a number of factors such as the cable diameter and the line disturbances. Line coding is normally 4-PAM, but also Carrierless Amplitude-Phase (CAP) modulation is used. HDSL systems are commonly used to bring leased lines or Primary Rate Access (PRA) ISDN signals to subscribers.
- *Symmetric DSL (SDSL)* is an evolution of HDSL, because it allows the transmission of 2.048-Mbit/s symmetrical signals on a single pair, over distances up to 4 km. Line coding is normally 4- or 8-PAM, although some CAP solutions exist. It is intended for data transmission, although using CAP modulation the base band can be left available for POTS.
- *Asymmetric DSL (ADSL)* has been standardized by ITU-T in Rec. G.992.1 on 1999. It allows the transmission of asymmetrical signals on a single pair. The attainable bit rate, in ideal electrical conditions, may be 8 Mbit/s downstream and 1 Mbit/s upstream, over distances up to 5 km. All ADSL products are rate adaptive, that is they adapt the transmission bit rate according to the line noise, length, etc. The standard modulation technique is Discrete Multi Tone (DMT), which leaves the base band available for a POTS or ISDN channel. This technique has been studied for asymmetrical services, such as broadband access to Internet. If POTS services are offered on the same pair, filters called *POTS splitters* can separate the POTS signal from the data signal on both the customer and the office end, as shown in Fig. 3.
- *ADSL Lite* (or *splitterless ADSL*), specified by ITU-T Rec. G.992.2, allows to avoid the deployment of POTS splitters at customer premises (see Fig. 3), but with lower transmission capacity: 1.5 Mbit/s downstream and 512 kbit/s upstream.

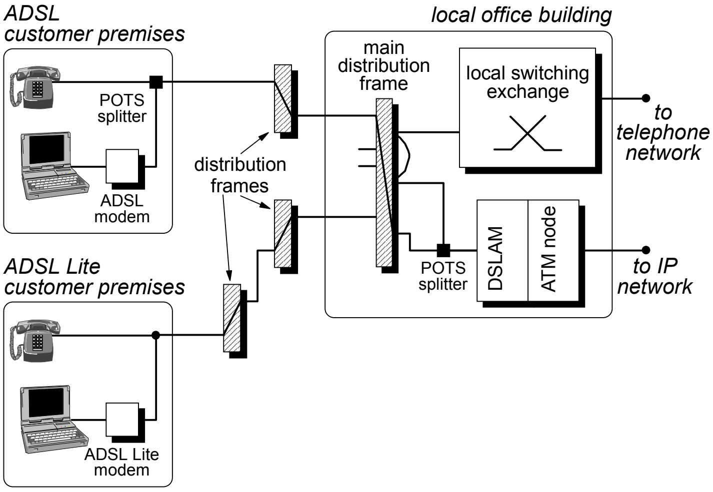

Fig. 3: ADSL and ADSL Lite systems in the copper twisted-pair local loop.

- *Very high-speed DSL (VDSL)* has been recently developed and allows the transmission at much higher rates, although over shorter distances: 50 Mbit/s downstream and 26 Mbit/s upstream, up to 500 m. Electromagnetic-compatibility issues do affect the rate achievable.

### 4.2 Electromagnetic Issues

Two main factors affect the maximum bit rate achievable by an xDSL system: the electrical characteristics of the copper pair and the interference.

#### 4.2.1 Electrical Characteristics of the Copper Pair

The first factor to take into account is the *line resistance*, which depends on wire diameter and length. Therefore, the first information needed, before planning xDSL deployment in a certain area, is the average pair length. On the other hand, wire diameter is highly variable and may change along different sections of the local loop. As shown in Figs. 2 and 3, there may be several intermediate distribution frames between the customer site and the local office. Hence, it is evident that it is not possible to estimate the actual bit rate of an xDSL system before some preliminary tests on the field.

#### 4.2.2 Interference Issues

The most important interference sources for xDSL systems are systems of same kind on pairs that are on the same bundle. Therefore, a rule-of-thumb for limiting interference may be to specify the maximum percentage of xDSL systems that can be accommodated on the same bundle. Such percentage can be assessed only by on-field experimentation, carried out in each area.

### 4.3 Shortage of Available Twisted-Pairs

Even if the percentage of pairs on single bundles that can be assigned to xDSL systems may be high, potential pair availability issues are foreseen even in the short term, especially in the primary loop.

## 5 Conclusions

In this paper, local loop unbundling was surveyed under several technical aspects. Various unbundled services were detailed, focusing on the twisted-pair local loop: transmission technologies, electromagnetic issues and pair availability were addressed.

In Europe, most incoming operators are interested mainly in the physical access to copper loop, which gives the opportunity of offering pervasively broadband services, besides POTS, by exploiting the capabilities of xDSL technology. The experience of the latest years is demonstrating that unbundling the access infrastructure is, as expected, a key factor in boosting open-market competition and the development and diffusion of advanced broadband services.

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