# The Technical Impact of the Unbundling Process and Regulatory Action

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## ABSTRACT

The process, referred to as unbundling, of allowing alternative operators to use the copper twisted wire pairs installed and owned by the local or national monopoly telephone operator is currently underway in many parts of the world. Not entirely without reason, most see this as a purely economical and legal matter, but it also has a surprisingly large impact on the engineering of broadband communication systems. This applies to the standardization and design phase as well as to the deployment phase. We survey the background of unbundling, and the goals and thinking of a regulator, and elaborate on the technical impact of unbundling. Examples are taken from VDSL standardization and the regulatory situation in various European countries.

## INTRODUCTION

Unbundling refers to the process by which multiple operators besides the former monopolist (incumbent) have access to either the copper pair, a portion of the digital bitstream, or a portion of the frequency spectrum in a telephone local loop. Regulators and operators have resolved many of the issues concerning voiceband access to the local loop. Focus is now turning to broadband access, with digital subscriber line (xDSL) services over the unbundled local loop as one of the main topics. With this, the unbundling process also becomes more of an engineering matter, although the legal and economical aspects are still the driving forces. It is this engineering aspect that we attempt to describe below.

Unbundling engineering takes two forms and time frames: design-time engineering encompasses the development of the standards and equipment with multiple parameters and options that can be used on a worldwide basis; and deployment rule engineering, which is the development of frequency planning and selection of the particular options of the multiple types of transmission systems contained in the same multipair bundle or binder. Before we discuss these engineering aspects, we give a background of the events behind unbundling.

## LIBERALIZATION OF THE TELECOM MARKET: WHY AND HOW

The motivation for liberalizing the telecom market is economical. Increased competition is expected to lead to faster development of services, more attractive tariffs, and better usage of the existing investments in infrastructure, in this case the copper plant. This led to legal action, the creation of national and regional Telecommunications Acts, which prescribe the liberalization. This happened in both the United States and the European Union [1, 2].

Various Telecommunications Acts essentially state that anybody is allowed to operate telecom networks, although it is often mandatory to obtain a license from the regulatory authority for providing voice telephony or leased line services. Receiving a license is in general a formality. The Telecommunications Acts also state that operators with significant market power (in Europe a market share above 25 percent) have to accept interconnection between their network and those of competitors. The price for interconnection is often set by the regulator.

In Europe, unbundling is not mandatory according to the law. However, many countries such as Germany, Denmark, Austria and Sweden oblige the national incumbent to offer unbundling. Other European countries are on their way. In general, the European Commission favors unbundling. In the United States unbundling is mandatory.

The regulator's role in this is to promote (or enforce) competition. Technical, legal, and economical problems are to be solved simultaneously, and decisions are to be made on all topics where the players in the telecom market cannot agree.

## THE ROLE OF THE REGULATOR IN WIRELINE COMMUNICATION

In principle, the regulator has two tasks. One is legal regulation and enforcement, which covers the legal issues involved, and the other is political regulation, which deals with future national and international development in telecommunications. The frame for the legal part of regulation is defined by a national Telecommunications Act. It is influenced by international and regional standardization bodies such as the International Telecommunication Union (ITU), American National Standards Institute (ANSI), and European Telecommunications Standards Institute (ETSI).

A regulator's most obvious legal duty is to issue licenses for operating telecommunication networks. Anybody who fulfills defined economical and technical criteria (these criteria are nation-specific) may operate a fixed telecommunication network[1] and offer telecommunication services to the public. Once the new network operator has entered the market, it is the regulator's duty to check for the obedience of laws and some principal service quality parameters in the network. For voice-band access, these include call setup time and the rate of successful call attempts. For broadband access, these may include installation time, fault repair time, transmit power (especially in conjunction with power backoff), out-of-band emission level, and acceptable bit error rate.

Additionally, the regulator has to decide how unbundling is to be done. A regulator must enforce an environment where new entrants have a chance to effectively compete. Since all incumbents have large voice-band access market shares and an advantage in their easy access to the physical network, the regulations are often initially "asymmetric." Most decisions tend to be to the disadvantage of the incumbent operator, which would otherwise be able to use its dominating market position to essentially recreate a monopoly situation. This is likely to change as soon as other operators have stable market shares and a long-term presence on the market. After this is achieved, it is the regulator's task to prevent an oligopoly situation inhibiting competition. Finally, the regulator has to act as referee when operators (in most cases the incumbent and one or more new operators) cannot agree on vital technical and economical questions.

Political regulation is outlined only in general terms in the law. It is a task delegated from a government to its regulator. However, the regulator's degree of responsibility for this and its ability to successfully operate in that regime strongly depend on the role the regulator holds among other national bodies involved in telecom politics. Typical political regulation questions that have to be solved in the future include:

- The convergence process in telecommunications (e.g., fixed-mobile convergence)
- The introduction of voice services on broadband media (i.e., the migration from circuit-switched to packet-switched public networks)
- The introduction of new broadband services in the local loop
- Element ownership: Should broadband modems be owned by the end user or the service provider?
- Issues concerning protection of consumers' interests

At the same time regulators must cope with these questions, it is important that regulatory decisions are made reasonably fast not to delay the introduction of new services and technology. It is our impressions that regulators tend to steer away from indecisiveness at the cost of having to change their decisions more often, and it is our opinion that this is the correct strategy. The market situation changes so much that perfectly stable regulatory decisions are unattainable anyway.

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## UNBUNDLING IN PRACTICE

Although the principles of unbundled access are by now fairly clear, carrying out unbundling in practice is not always straightforward. There are some principal methods of addressing unbundling including direct access, bitstream access, and frequency access (Fig. 1).

The typical or generic use of unbundling often refers to what we term the *direct access* form of unbundling. Direct access means that alternative operators have direct access to the twisted copper pairs and may use them in any way agreed to by the regulatory authority. Typically there are limits on the power spectral density (PSD) emitted by the transmission systems [3]. It is mostly the direct access case we address.

The *bitstream access* form of unbundling is sometimes referred to as *service unbundling*. With bitstream access, the incumbent takes on two different roles. One is to maintain and develop the copper plant, including deploying all of the physical-layer transmission systems on it; the other is to offer services delivered on top of the physical layer. Alternative operators only take on the second role, competing with services to end customers on either a circuit- or switched-service basis. Bitstream access allows for a high degree of network optimization since the incumbent has full control over what physically happens in the copper plant. However, the lack of competition on the physical layer may lead to a less aggressive schedule for deployment of new systems and technologies. Also, all operators are limited to the access characteristics that the incumbent chooses to implement, which could give a poorer service offering.

*Frequency access* can be considered a hybrid access where portions of the spectrum in a single twisted copper-pair are allocated to different operators. Both alternative operators and the incumbent would have physical access to the copper plant. For example, the plain old telephone service (POTS) or integrated services digital network (ISDN) spectrum could be separated,[2] and may be reserved for the incumbent. Frequency unbundling has elegance in that different services can be ordered from different providers in a reasonably independent fashion. A drawback is that it may impede a migration to an all-digital access where the POTS band would be reallocated for digital communication (possibly with telephony inband) to enhance reach. Future frequency unbundling practice might allow individual ADSL/VDSL upstream and downstream bands to be provided by different operators.

In addition to those technical access methods, regional bodies often legally define access methods based on precedence or the previous regulatory environment. For example, in the United Kingdom, the Office of Telecommunications

[1] *In contrast, the number of licenses for* mobile *communication networks is limited because of the finite nature of the available radio frequency spectrum. Typically, three to four nationwide licenses for mobile communication networks are issued in Europe.*

[2] *For example, the POTS spectrum is separated from the asymmetric DSL (ADSL) spectrum in Annex A of G.992.1, and the ISDN spectrum is separated from the ADSL spectrum in Annex B of G.992.1 and ETSI TS 101 388.*

In a liberalized market of direct access, new operators will rent copper lines from the incumbent. In this situation, what happens if a customer of a new operator interferes with an incumbent's customer?

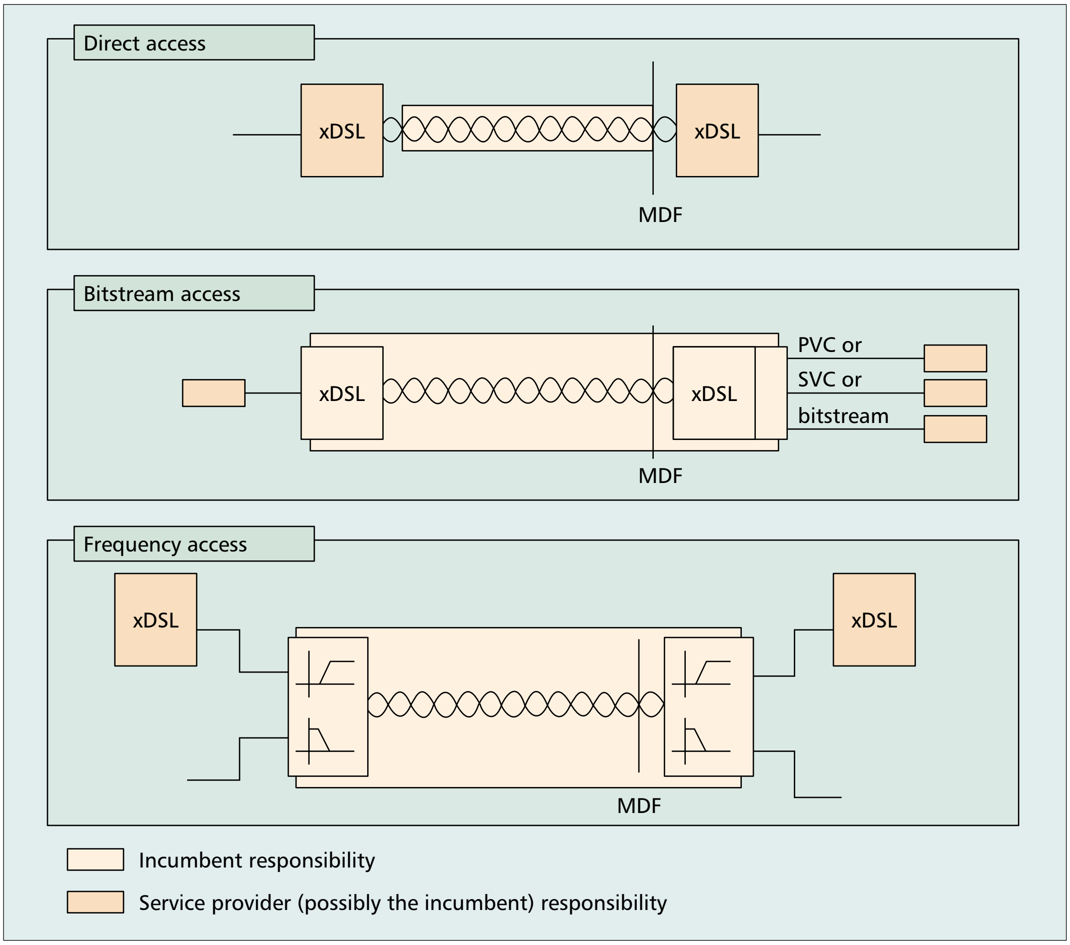


**Figure 1.** *Unbundling access methods. (MDF: main distribution frame; PVC, SVC: permanent and switched virtual circuit).*

(OFTEL) has defined five access methods for consideration [4].

In the earlier monopoly environment, where only one incumbent operator had access to the copper network and thus complete control over which systems were deployed, compatibility and security issues did not appear or were easily solved. In a multi-operator environment, there are many additional concerns, such as:

- Spectral compatibility between systems (due to crosstalk between copper pairs)
- Collocation of equipment at the central office or in outdoor containers
- Fairness in sharing capacity in a bundle (power backoff, bandwidth usage)
- The introduction and updating of technologies

Some of these problems could be solved by the operators directly (e.g., the question of collocation). New operators want to use the existing infrastructure of the incumbent for installing transmission equipment in the local exchanges. The incumbent, in turn, may have unused space to rent after the introduction of digital switches. On the other hand, the incumbent may not feel perfectly comfortable granting competitors access to their facilities. Preferably, the operators agree on collocation and rent instead of asking the regulator to define rules and cost. However, most problems arising from unbundling cannot be solved as easily as the collocation.

Let us investigate some of the more difficult problems in depth. For actual deployment, it is difficult to accurately predict how many copper pairs in a bundle can be used for xDSL systems maintaining a reasonable quality of service [5]. Additionally, each bundle and copper pair has individual transmission characteristics. The actual percentage of wires in a bundle suitable for xDSL transmission depends on the process of installation (e.g., the quality of splices is of vital importance). The location in the topology and the manufacturing process are also important. In a monopoly situation, the incumbent could easily cope with the situation by trial and error. The bundle could be filled with xDSL systems until customers complain about poor service quality. Furthermore, "bad" and "good" pairs could readily be swapped.

In a liberalized market of direct access, new operators will rent copper lines from the incumbent. In this situation, what happens if a customer of a new operator interferes with an incumbent's customer? Who investigates the facts? Who decides which equipment has to be powered down? These tasks have to be performed by the regulator in a nondiscriminating way. This in turn requires that the regulatory and legal framework be well defined.

Another difficult area is compatibility between different xDSL systems. Figures 2 and 4 illustrate potential spectral conflicts between broadband systems. For instance, say that ADSL systems would deteriorate the performance of high-rate DSL (HDSL) systems. Then consider two operators addressing different markets. The first operator offers high-quality symmetric services with guaranteed HDSL-based data rates to business customers. The second offers best-effort ADSL-based services to residential customers. The proximity of the pairs and typical transmission levels may lead to crosstalk interference between the systems and performance degradation. Again, rules have to be designed in such a way that all interests can be considered nondiscriminately.

Old transmission systems like alternate mark inversion (AMI) or high-density bipolar 3 (HDB3) modems are still connected to the local loop, typically for the implementation of T1 or ISDN primary rate lines. The HDB3 systems deteriorate the performance of all xDSL systems. Thus, the best thing would be to replace them with new equipment. Although this is technically reasonable, it might be impractical from an economical point of view. If an alternative operator wants to deploy xDSL equipment in a bundle with an HDB3 system, should the incumbent or alternative operator be financially responsible for upgrading the legacy equipment?

While the basic principles of how to use the local loop are accepted by telecom operators (which are relatively few), there is a much broader group of companies entering the arena. Internet service providers also claim direct access to the unbundled local loop.[3] If this is implemented, a large number of companies will deploy transmission equipment in the copper network. Acquiring expertise on the technical problems associated with direct access to the local loop may be too much for a small company focusing on its core business. Reaching a common understanding of fairness and the need for coordination of equipment among a large group of players can be difficult. Direct access unbundling may then emphasize the problems of doing unbundling in practice. A strict regulation regime (which in general is undesirable) could possibly be needed to guarantee the integrity of the network.

Let us then look briefly at what can be done, or has already been done, in practice. In order not to be overwhelmed by the situation, the regulator has to act pragmatically. To enforce competition and promote new technologies, the regulatory guidelines should be as loose as possible. The environment must enable rapid innovation of technology and services. The law states that everything is allowed as long as the principle integrity of the incumbent's network can be guaranteed. In Europe, network integrity is based on the Open Network Provision (ONP) guidelines [2] issued by the European Commission.

For the first phase of xDSL deployment, when not many xDSL systems are in the field, a set of basic rules for usage should be set up. These rules should state that new operators are allowed to do everything the incumbent does. New technologies beyond the incumbent's deployment plans should not be forbidden, but prior to implementation, the incumbent has to be informed about details. In general, all action has to be performed with caution in order not to disturb the integrity of the network. Early on, the regulator should initiate negotiations between different operators, at least on a technical level. It could be useful in order to speed up the progress, solving most potential problems before they arise.

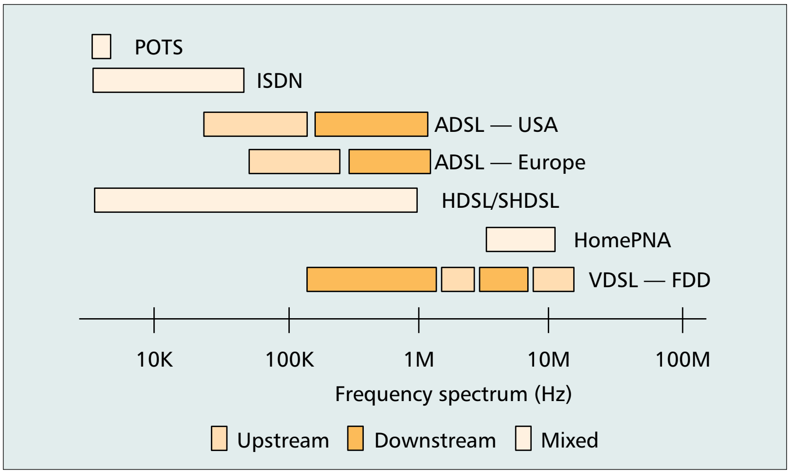


**Figure 2.** *Existing and tentative spectrum usage of various xDSL systems.*

It is important to note that the role of the regulator is to be a moderator, and if necessary to make final decisions, but not to be the supreme technical expert. In fact, it is impossible for the regulator to have superior expertise due to the lack of operational experience. Nonetheless, the regulator has to observe research, the development of technology, and the ongoing standardization processes.

## The Technical Impact of Unbundling

So far, we have discussed mostly legal, economical, and regulatory aspects of unbundling. It is now time to detail some of its technical impact.

The strongest influence of unbundling on the engineering of equipment is on the issue of compatibility, or coordination of the power spectral emissions. Broadband equipment operating in the same bundle will induce crosstalk into each other's signals. Figure 3 illustrates the relative power level of the signals involved. In essence, the copper network becomes a shared medium because of the crosstalk. Modems (typically belonging to more than one operator) present in the same bundle will limit each other's available capacity and performance due to the crosstalk [3]. Because of this, some level of agreement or coordination is necessary between the systems. The crosstalk leads to many fairness issues that need to be solved. Some of these also have an impact on modem engineering. We sketch a few.

- Power backoff and reach: Say that the first VDSL system installed in a bundle uses a short loop. Over this loop, high capacity can be sold and delivered to the customer. However, if the transmit power in the lower part of the spectrum is high, little capacity remains on longer loops in the same bundle. The longer loops can only use the lowermost spectrum, and the upstream capacity can be severely limited by the strong far-

*[3] In Austria, for example, the law states that anybody who uses the network is entitled to unbundled access. No operator license is needed unless public telephony is offered. For instance, Internet service providers could possibly have direct access to the copper network without a license.*

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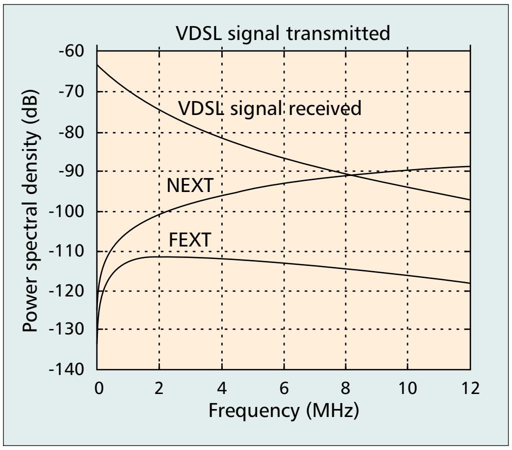


**Figure 3.** *Crosstalk levels. Typical levels of NEXT and FEXT compared to the received and transmitted signal power for a 500 m cable with nine VDSL disturbers.*

end crosstalk (FEXT) introduced by systems operating on shorter loops. (FEXT and near-end crosstalk, NEXT, are explained in [3].) Thus, a high-rate system installed by one operator on a short loop can severely reduce the reach of lower-rate services intended for longer loops. One operator aiming at the low-penetration short-loop market segment (typically small businesses) can then virtually eliminate the market for a competing operator going for high-penetration low-rate services intended for residential users. This would be a typical situation where the regulator would intervene. Two conclusions can be drawn. First, even if a system can deliver, say, 50 Mb/s, and the line can carry 26 Mb/s, maybe only 16 Mb/s should be sold in order to leave capacity on longer lines. Second, deployed systems should be flexible. If the high-rate short-loop system is not able to adapt to a new situation (through power backoff or similar measures), it may have to be removed. The regulator may even forbid the use of such systems. Thus, fairness aspects and system flexibility are important system design issues for robustness against regulatory action. Installed systems should be able to operate both in the early days of broadband deployment, and in the later stages.

- Asymmetry ratio and customer segment: All systems operating in the same bundle need to have the same frequency plan in order to avoid NEXT (Fig. 4). The frequency plan determines which bit rates can be delivered at various loop lengths. An important part is the ratio between the up- and downstream bit rates, the asymmetry ratio. An Internet service and content provider (which may be either a company or an individual with an ambitious family Web site) would probably like to have a larger upstream capacity than downstream, allowing fast customer or public access to the Web site. On the contrary, most residential users today would probably prefer ADSL-style services with a large downstream capacity and smaller upstream, for instance, for Internet surfing or video on demand. A third important customer segment is small businesses, which are likely to prefer symmetric services with up-- and downstream capacities equal or near equal. Once it has been decided how to use the spectrum in a bundle, this determines the market segment best served by that bundle. This may favor one operator or another since operators typically target different market segments. Thus, decisions on spectrum plans (and implicitly symmetry ratios) that once were fair and competition-neutral may later prove to be competition-inhibiting when the market or business plans change, or when new operators appear. Then the spectrum plan may be updated by the regulator. If installed equipment cannot adapt to new spectrum plans, it may prematurely be rendered obsolete.
- Frequency- vs. time-division duplex: For the VDSL standard, both time-division duplex (TDD) and frequency-division duplex (FDD) were considered. TDD shares the capacity between upstream and downstream by assigning certain percentages of time for transmission in the upstream and downstream directions, respectively. It has the advantage that this relation stays the same independent of the length of the loop. FDD divides the capacity by assigning different portions of the spectrum for either downstream or upstream transmission. With frequency division, the ratio between upstream and downstream capacity can be varied along the bundle. It is possible, for instance, to have a more symmetric ratio on short loops and more asymmetric on long, but it is difficult to control the ratio accurately. However, the main difference between FDD and TDD is the type of synchronization necessary between the modems. Given the precision necessary in time and frequency, it is easier from an engineering point of view to synchronize modems in frequency than in time. Frequency synchronization can be established by prior regulation or policy without the need for modems to intercommunicate in the field. Although time synchronization is certainly possible, also without direct communication between modems, it may require a more complicated legal framework to ensure responsibility for master clock generation and distribution between multiple operators. When this was recognized by operators, a preference for FDD for very high-rate DSL (VDSL) was expressed [6], and TDD was dropped from the standardization process.

## xDSL Development Scenarios

A difficult but important task is to predict the development of the xDSL market and technology. It is important for regulators to be aware of possible development scenarios to guide the selection of deployment rule engineering criteria in its regulations. (It is, of course, also important for the design-time engineering of systems.) The whole purpose of deregulation is to develop the telecom market, making it crucial to have a firm idea of the effects of alternative regulatory decisions. The development of broadband communication over the copper network will surely differ from country to country. We sketch some possible scenarios:

- Alternative physical media prevail: Broadband services are offered to the public today using physical media other than the copper network, notably through cable TV networks, via optical fiber, wireless local loop systems, and satellite. Broadband cable TV services have high penetration in some countries and areas, and a rapidly increasing number of customers. The customer base for broadband services via optical fiber is still rather small, but it is increasing steadily as many new buildings have optical fiber drawn to them, or at least are prepared for this. Fiber to the home was advocated by many as the immediate solution for delivering broadband services to the public. However, the cost of laying down the fiber is prohibitive unless the digging is done anyway, as in the construction of new residences. It is possible that cable TV, together with the ever more widespread fiber-to-the-home solution, can keep up with the increasing market demand in some countries and areas. If so, there may not be enough market share left for broadband services over copper lines to entice operators into making the necessary investments. In this case, not many regulatory solutions are needed. However, this is not a very likely scenario. For example, xDSL development in the United States indicates quite the opposite.
- xDSL becomes a niche market: There is a possibility that either a market segment has been taken by, say, cable TV, or that xDSL deployment becomes too slow or too expensive for some customer segments. For instance, it is plausible that the price-sensitive home-user market goes to cable TV, while the lucrative small business market is taken by VDSL. Businesses rarely have a cable TV connection, and have higher demands on quality of service than most residential users. xDSL can give stronger quality-of-service guarantees because the twisted copper pair only suffers from crosstalk, while the cable TV network is truly a shared medium. In this scenario, the role of the regulator will be large early on in the process, but quickly decrease. No real capacity problems are likely to appear and cause regulatory problems. The percentage of twisted copper pairs that carry broadband services will be relatively small, and crosstalk will not become such a capacity-limiting factor.
- xDSL becomes the dominating Internet-to-the-home solution: The demand for broadband services to homes and businesses is growing very rapidly now. At the same time, xDSL solutions are becoming available at a reasonable price. If demand is high enough, cost low enough, and operators (and regulators) go for an aggressive deployment and marketing, xDSL may become the standard for delivering broadband services to the public. xDSL may still slowly give way to fiber-optic-based services, but on a timescale of decades. In the massive deployment scenario, the regulator faces many difficult problems. There will be a set of problems associated with the early stages of deployment; some are discussed above. A different set of problems will appear later when a large number of systems are deployed in a single bundle. There will be several scaling problems when physical space for installing equipment starts to run out, crosstalk levels threaten previously guaranteed quality-of-service and capacity levels, and so on. This is little studied and understood today, and there may be a risk that regulatory decisions in the early stages of deployment badly fit the later capacity-limited stages.

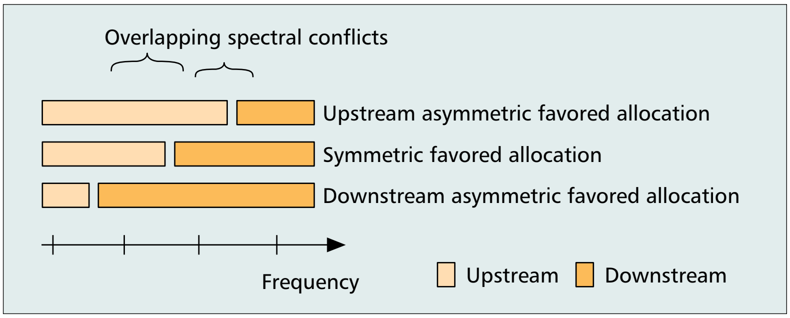


**Figure 4.** *Spectral allocation conflict. The amount of spectrum allocated for the direction of data flow is roughly proportional to the amount of data capable of being transmitted. Different desired asymmetry ratios for data transmission cause conflicts in spectral allocation.*

It is important to note that the regulator's (arbitration) actions will be proactive as well as reactive to the immediate situation. That is, the decisions of the regulators in the early phases of deployment will affect the momentum of further deployment. In this regard, it may be interesting to compare the success of voiceband modems — ITU — Telecommunications Standardization Sector (ITU-T) V-series — with the deployment of, say, ISDN. Over 500 million V-series units have been deployed in the past 10 years, compared to less than 10 million ISDN lines. The price of each unit is important, making mass-market acceptance essential. Regulators should thus promote standardized products if such are available that meet national needs. The installation process is even more crucial since this may not only be cumbersome, but also cost more than the modem itself. New line cards are needed on the network side of the bundle, and service personnel have to visit the access node to install them. Regulators need to be careful not to induce unnecessary cost or delay in the installation and maintenance procedures.

## Concluding Remarks

We look at regulators and regulatory action focusing on the impact on xDSL development and deployment. Our approach is not global, nor has the ambition to cover everything. Instead, we

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attempt to give examples of the impact the unbundling process can have on the design and deployment of xDSL equipment, and to give some idea of how a regulator thinks and works.

Present and future regulatory action, and the process of unbundling mainly put two kinds of requirements on xDSL technology. One concerns compatibility and coordination; the second addresses "future safety," robustness against future regulatory decisions made to promote competition and fairness in a market situation different from today's.

Regulatory activity is now high, with unbundling progressing in many countries. The coming years will be crucial for the future of broadband services over the public telephony network. Unsuitable regulatory action, or the lack of regulatory action, can endanger the xDSL business case. It is indeed important for regulators to create an environment that promotes fast progress to mass deployment. Regulators should facilitate simple deployment processes to handle hundreds of new orders per day and avoid regulatory decisions that necessitate case-by-case and trial-and-error engineering.

Regulators should also have a proactive stance and try to predict the regulatory problems that will appear a few years from now. The regulatory situation will look different when the xDSL market has reached mass deployment and capacity is limited by crosstalk.

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## Biographies


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