Bitstream Access

ERG Common Position – Adopted on 2nd April 2004
and amended on 25th May 2005

ERG Common positions shall not be binding on its members, but members shall take the utmost account of such positions or opinions. Where national circumstances prevent individual members from applying one of those positions or opinions, their reasoning for not following that position or opinion shall be published. Otherwise, parties to a collective position or opinion would be expected to take all appropriate steps to abide by that position or opinion, except in circumstances which could not be foreseen at the time when the position or opinion was agreed.

NOTE1: This document was checked with the final version of the ERG Common Position on remedies in the regulatory framework as adopted by ERG on 1 April 2004. In case the Remedies Document will be changed following a review, the ERG Common Position on Bitstream Access will also be looked at again. For now, no changes on the substance were made except including a reference to the offer of VoIP services to end users (p. 3), the table containing the BSA regulations in place in Europe (see below p. 9-11) was updated.

NOTE2: The ERG discussed since mid-2004 the questions related to cable BSA. After adoption for consultation at the 12th ERG Plenary on 10 Febr. 2005, the cable BSA document was publicly consulted from 18 February to 4 April 2005. 14 comments were received and evaluated, from which a few changes resulted. At the ERG13 Plenary meeting on 25 May 2005 it was decided to add the cable BSA document as part IV (pp. 14). to the existing ERG Common Position on BSA, which dealt with DSL BSA.

Introductory Notes

This document focuses exclusively on bitstream access and the regulatory approach. The Bitstream access document published on 14 July 2003 for consultation has been revised in the light of the comments received in the consultation and the subsequent discussion in the IRG and ERG at the meeting on 20/21 November 2003. It does not cover other forms of wholesale broadband access such as unbundled and shared access. It outlines the regulators' understanding of bitstream access and the regulatory approach. NRAs should try to adhere to its conclusions as much as possible when taking decisions, but nonetheless the ultimate responsibility remains with the individual NRA. At the end of the document, some conclusions are drawn.

The document responds to the mandate given to the Fixed Network WG by ERG at its 3rd meeting on March 28th 2003 in Brussels. The Conclusions of the meeting state the following with regard to Bitstream Access "As bitstream access is important for the rollout of broadband services and applications, ERG agreed to investigate whether a harmonised approach is needed and possible. The issue will therefore be added to the ERG Work Programme 2003 and be discussed in the ERG September meeting (*25 September 2003*)"[1]. The paper is structured as follows:

[1] Cf. ERG(03)15 "Conclusions" (http://www.erg.eu.int/activities/meetings/index_en.htm).

I. Definition of bitstream access and delineation to resale
II. Regulatory issues
III. Conclusion.

It is based on the first part of the IRG-document Plen(02)51rev2 (Local and broadband access, as updated on 22 March 2003 for the IRG High level Broadband Workshop) and incorporates the various documents, in which the Commission addresses the subject, namely:

- ONPCOM01-18 (June 22nd 2001; Rev1 on Sept. 26th 2001) High speed bitstream access;
- C(2003)497 Recommendation On Relevant Product and Service markets within the electronic communications sector susceptible to ex ante regulation in accordance with Directive 2002/21/EC (Febr. 11th 2003);
- COCOM03-04 (Febr. 11th 2003; Rev1 on April 4th 2003; Rev2 on June 15th 2003) Bitstream access: current regulatory situation in Member States;
- ERG(03)12 (March 18th 2003) Bitstream access[2].

Since the 2nd half of 2002, the focus shifted away from unbundled and shared access as mandated by Regulation 2887/2000 to bitstream access. The reason behind this shift of focus to other types of wholesale products for competitors (operators and service providers) seems to be that the main objective of the Regulation – namely to foster competition in order to promote fast internet access offers to consumers – is being reached only in an unexpectedly slow way. As a result, there is concern that the incumbent is profiting from a first mover advantage possibly pre-empting the xDSL retail services market (e.g. ADSL, SDSL, VDSL services). In order to speed up the process of promoting a competitive broadband market under the new European regulatory framework for electronic communication networks and services, ERG is taking a closer view on how to enforce the provision of bitstream access, which in many instances may be seen as the more appropriate wholesale product to open the retail DSL services market for competitors.

The analysis focuses on the 3rd stage of applying proportionate and appropriate remedies to solve a competition problem identified, i.e. it assumes that the market review has been carried out, which means that the relevant market is defined (stage 1) and an SMP operator is determined (stage 2).

[2] Besides the documents mentioned, the Commission collects data on the availability of bitstream access in the MS. Cf. the following documents:
- ONPCOM02-03 (Febr. 6th 2002) Local broadband access – developments regarding unbundling, bitstream access and leased lines;
- ONPCOM02-18 (March 26th 2002; Rev1 on June 5th 2002; Rev2 on July 10th 2002) Tables for collection of data on local broadband access;
- 8th Implementation Report (SEC(2002)1329, Dec. 3rd 2002)
- COCOM03-03 (Febr. 11th 2003; Rev1 on April 4th 2003; Rev2 on June 15th 2003) Tables for collection of data on local broadband access;
- COCOM03-40 + annex (Sept. 10th 2003) Broadband access in the EU;
- COCOM04-20 (March 3rd 2004) Broadband data.

The Fixed Network WG also collects data, which is not yet ready for publication.

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I. Definition of bitstream access and delineation to resale

In document ONPCOM01-18Rev1 high bitstream access is defined in the following way: "High speed bit stream access (provision of DSL services by the incumbent operator) refers to the situation where the incumbent installs a high speed access link to the customer premises (e.g. by installing its preferred ADSL equipment and configuration in its local access network) and then makes this access link available to third parties, to enable them to provide high speed services to customers. The incumbent may also provide transmission services to its competitors, to carry traffic to a 'higher' level in the network hierarchy where new entrants may already have a point of presence (e.g., transit switch location). The bit-stream service may be defined as the provision of transmission capacity (upward/downward channels may be asymmetric) between an end-user connected to a telephone connection and the point of interconnection available to the new entrant."

COCOM03-04Rev1 adds the following: "Bitstream depends in part on the PSTN and may include other networks such as the ATM network, and bitstream access is a wholesale product that consists of the provision of transmission capacity in such a way as to allow new entrants to offer their own, value-added services to their clients. Resale offers are not a substitute for bitstream access because they do not allow new entrants to differentiate their services from those of the incumbent." In order to be able to differentiate their services (including such services as VoIP) from those of the incumbent, new entrants must have access at a point where they can control[3] certain technical characteristics[4] of the service to the end-user and/or make full use of their own network (or alternative network offerings[5]) thus being in a position of altering the quality (e.g. the data rate or other features) supplied to the customer.

The main elements defining bitstream access are the following:

- high speed access link to the customer premises (end user part) provided by the incumbent;
- transmission capacity for broadband data in both direction enabling new entrants to offer their own, value-added services to end users;
- new entrants have the possibility to differentiate their services by altering (directly or indirectly) technical characteristics and/or the use of their own network;
- bitstream access is a wholesale product consisting of the DSL part (access link) and "backhaul" services of the (data) backbone network (ATM, IP backbone).

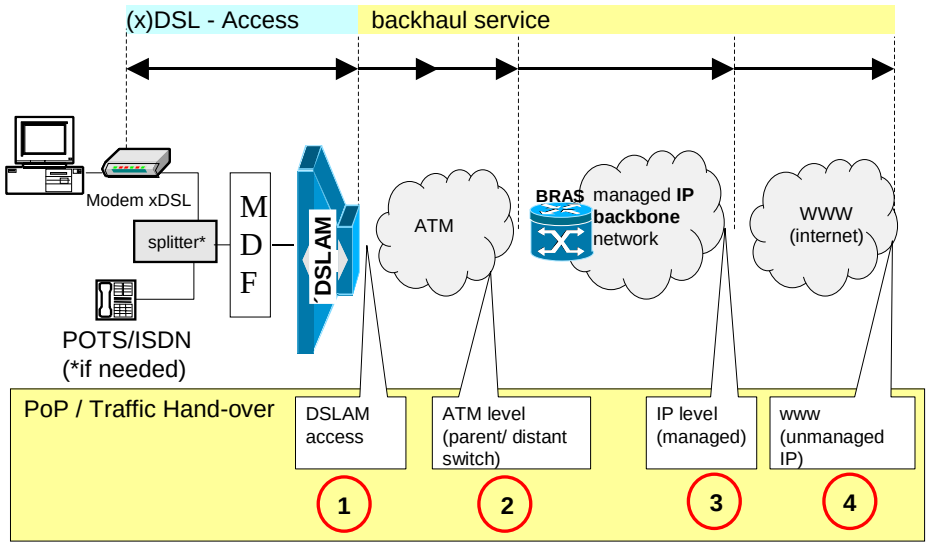
Bitstream access is thus defined as the corresponding wholesale product for DSL services (high speed services). However, this definition leaves open at which point the traffic is handed-over as there are various hand-over points for DSL traffic

[3] This includes indirect control, i.e. the incumbent alters the technical parameters as requested by the new entrant (see below for the details).
[4] See below for the details regarding technical parameters.
[5] the market for backbone facilities, where alternative operators offer backhaul services should not be left aside when considering bitstream access.

between the incumbent and the OLO/ISP (OLO = other licensed operator, ISP = internet service provider).

According to document ONPCOM02-03 high speed services offered to new entrants on the basis of unbundling, shared access and resale are explicitly mentioned as not being counted as bitstream access.

The point of access (point of handover of traffic) determines both the possibility to control the technical parameters with which the xDSL service[6] is provided to the end user and the possibility to use the own network instead of the incumbent's. The following main options can be distinguished[7]:



The main difference between shared access[8] and bitstream access is the provisioning of the DSLAM. In the case of shared access the DSLAM is always operated by the new entrant (even in the case of virtual collocation the incumbent only maintains the DSLAM), whereas in the case of bitstream access, the DSLAM is operated by the incumbent. As the incumbent operates the DSLAM, there is no possibility for the new entrant to technically alter the xDSL access link (towards the customer) as such.

The possibility to differentiate the service offered to the end user (and thus the extent to which value can be added by the new entrant) declines from Option 1 to 4, in other words: the further to the right the access point is, the less possibilities the new

[6] to be exact it is not the xDSL access link as such that is altered, but the service offered to the end user (the high speed internet access product). The incumbent does not control the end user equipment (RTTE Directive).
[7] The list is not exhaustive; also, the situation might change over time due to technological development.
[8] Or fully unbundled lines used to provide xDSL access.

entrant has to differentiate the service. It is important that the beneficiary's request defines the service.

Option 1: The incumbent provides the DSL access link and hands over the bitstream to the new entrant directly after the DSLAM.

A DSLAM can handle only a limited number of profiles (e.g. 64/512, 512/256, 256/256) respectively it makes no sense to offer e.g. 10/600. The new entrant can only request the incumbent to get the product (the access part) technically altered so that he can use one or more of the implemented profiles or ask the incumbent to implement a further profile according to the beneficiary's choice if technically possible[9].

But as with this option the new entrant is present physically at the DSLAM, he is supplying the backhaul product (ATM, IP backbone) himself and can make full use of his own network. This enables him to determine the Quality of Service through backbone networks (ATM and/or IP) and to offer a better quality of the **backhaul product** (lower overbooking factor) thus offering an end user DSL service with different technical characteristics.

This option requires a large upfront investment from the new entrant to be present at the **DSLAM level** (very cost intensive option).

Option 2: The incumbent provides the DSL access link plus a backhaul service and hands over the bitstream to the new entrant at an ATM-PoP or other technologies used[10] (at **ATM/corresponding technology level**). Different overbooking factors in the ATM backbone (reserved capacity for the PVC [tunnelling]) can be employed for different types of traffic (up-/downstream, ISP 1/ISP 2). The new entrant has the possibility to subdivide the virtual path further into virtual circuits[11]. The new entrant runs the BRAS (broadband remote access server) and has thus the possibility to alter parameters of the BRAS (depending on the BRAS type).

The new entrant is able to offer an end user product with different technical characteristics as he can alter the Quality of Service parameters (QoS) such as different overbooking factors provided by the incumbent.[12]

Option 3: The incumbent provides the DSL access link plus a backhaul service and hands over the bitstream to the new entrant at an IP-PoI (at **IP level**).

[9] It makes no sense to draw the distinction between "Bitstream Access" and reselling according to whether the incumbent offers all or only a limited number of the available profiles at the DSLAM to its own end customers. The important point is that the product is defined by the beneficiary and the burden of proof that the requested profile is technically impossible to implement lies with the incumbent operator.

[10] Principle of technological neutrality.

[11] By actually subdividing the virtual path into virtual circuits the new entrant defines the minimum throughput in hours of high traffic demand.

[12] However, in order to be able to define such parameters per customer, i.e. to be able to define the QoS of the Virtual Circuits (VC) over the Virtual Path (VP), the incumbent has to configure this on the DSLAM as the VCs have to be defined at both the end of the new entrant and the end of the incumbent. The configuration is performed by the incumbent as requested by the new entrant.

As the traffic is tunnelled in a managed IP network (it is a private IP network, not the public IP network of the www!), the quality of service can be guaranteed. A differentiation is possible to the degree that the new entrant can negotiate different overbooking factors with the incumbent (if offered) or the new entrant has other possibilities to influence the connection to the end user as he completes the downstream link[13]. In this option, the internet traffic of the new entrant goes over the incumbent's BRAS. As in this option the incumbent runs the BRAS, he has the possibility to monitor the end user and controls the virtual private channel (VPC).

Option 4: The incumbent provides the DSL access link plus a backhaul service and also provides the **connectivity** to the public IP network of the World Wide Web.

At this level, the product the incumbent sells to the new entrant is technically the same, which the incumbent sells to his own customers. The new entrant does not need to run his own infastructure, the only thing he has to do is to market (brand), distribute and bill the product. As the new entrant cannot offer a differentiated product (end user product with different technical characteristics), this product is to be classified as "**Simple Resale**" (and not bitstream access). The new entrant provides in general the portal.

With Option 4, the delineation between bitstream access on the one and simple resale[14] on the other side and how to draw the borderline between the two is addressed. This is rather difficult as bitstream is a technical term whereas resale is an economic term, but the following distinction can be made.

With bitstream access the new entrant has the possibility to differentiate the xDSL product bought from the incumbent, which means he is legally allowed (by contract) or technically capable of changing the technical parameters (features/profile) in such a way as to create his own end user service which differs from the incumbent's xDSL retail product. This generally goes together with the use of his own network in order to complete the service, in other words the new entrant manages the access service. "In contrast to bitstream access, simple resale occurs where the new entrant receives and sells on to end users – with no possibility of value added features to the DSL part of the service – a product that is commercially similar to the DSL product provided by the incumbent to its own retail customers, irrespective of the ISP service that may be packaged with it"[15]. In this case the incumbent is in control of the technical parameters of the service thus defining the features/profile of the end user product. It was suggested to take as a criterion for a resale product the provision of the IP address by the incumbent, as this directs the routing via the incumbent's network

[13] The level of control that the new entrant has over the entire access service (by having control of the tunnel) is limited in terms of QoS and lacks the flexibility to customize QoS parameters to the end user. It is less than in Option 2.

[14] "… **Resale** is defined in such a manner, that a product is not acquired by a final user for the purpose of the use, but that it is acquired by another supplier for the purpose of sale to customers or final users. These suppliers are called retailers or service providers. The retailer therefore does not produce the product. Its achievement is *in nuce* a selling achievement. He sells a product in his own name and with his own billing, which he does not produce." (Neumann (2002), WIK Paper, Nr. 230, Economical Importance of Resale, p. 1) [own translation].

[15] cf. footnote 9 of doc. ONPCOM02-18rev2

with no possibility for the ISP to intervene at any point. The ISP buys the end-to-end link provided by the incumbent and markets the product to the end user without being able (neither contractually allowed nor technically capable) to change the product, whereas the access service is managed by the incumbent.

From the distinction made above it follows, that bitstream access points in the direction of infrastructure competition as the beneficiary controls the characteristics of the product and the use of the beneficiaries' own infrastructure is involved, whereas resale, which has none of these two aspects, is an indication for competition on the service level.

To sum up this part, it became clear that different points of access (points of handover of traffic) exist and that the different points of access entail different degrees of differentiating the product offered to the end user for the new entrant and thus the degree of adding value to the final service (value chain concept). The following part deals with the regulatory implications of this finding.

II. Regulatory issues

In the ONP framework, within EU commitment for the promotion of broadband services deployment, bitstream access services have been already identified as a regulatory issue; it is worth to recall the Communication on unbundled access to the local loop, where the Commission formally considered bitstream access (together with full unbundling and shared access) as a complementary means of access to incumbent's local loop, since "…the availability of only some of these means of access is not enough…"[16].

From a legal point of view, the main difference between bitstream access and unbundled (both full and shared) access is that whereas full unbundled and shared access are both mandated by the Regulation, bitstream access has mostly been regulated using European legislation or the provisions of one/several directives. Under Community law, the legal basis for the provision of bitstream access is the principle of non-discrimination according to Art. 82 of the Treaty of Rome; as far as sector regulation is concerned, Art 16(7) of the Voice Telephony Directive (98/10/EC)[17], as well as Art.4 (2) of the Interconnection Directive (97/33 EC), following on general provisions of ONP-Directive (90/387/EEC), require that SMP operators must meet all reasonable requests for access to their network including access at points other than the usual network termination points.

This had two implications: a) in some cases it may have been very difficult to oblige (or to enforce an obligation based on the non-discrimination principle) the incumbent operator to make a bitstream access offer in the requested form and b) bitstream access has been classified across IRG/Europe in a great variety of ways and thus regulated as different types of services and under different regulatory regimes (in the RUO, in the RIO, as special network access, leased lines, in application of the non-discrimination principle, with various forms of price regulation). It is important to bear in mind these two critical factor, since they are going to be overcome by the new regulatory regime, which came into effect on 25 July 2003.

[16] Communication from the Commission 2000/C 272/10
[17] The latter being questioned by one NRA.

The following table reflecting the current regulatory status of bitstream access is taken from the new document of the Commission on bitstream access (COCOM03-04Rev2, June 2003) and updated by IRG/ERG member information:

Country	Regulation applied to bitstream access by law or through NRA intervention	Points of access / handover
AUSTRIA	Commercial negotiation	Regional PoPs, distant ATM switch (Broadband Remote Access Server = BRAS)
BELGIUM	Transparent fair and non-discriminatory conditions; in practice there is a mandatory reference offer, but limited NRA powers on retail tariffs resulting in allegations of price squeeze	DSLAM or parent/distant ATM switch, minimum one in each of the 8 access areas in Belgium
CZECH REPUBLIC	Not available	
CYPRUS		
DENMARK	Objective, transparent and non-discriminatory terms; cost-orientation	Parent ATM switch
ESTONIA	Bitstream access can be considered as Special access. Price should be calculated on the reasonable and non-discriminating basis	All access points after DSLAM
FINLAND	No price regulation, subject to competition law review	Distant ATM switch
FRANCE	"Special access"; NRA sets prices at level sustainable for efficient new entrants; non-discrimination in access conditions Price control	Parent and distant ATM switch National IP PoPs
GERMANY	Not available	
GREECE	Bitstream regarded as Special access. Price to be reasonable, non-discrimination, transparency.	IP handover to OLO, OLOs are directly connected to the BRAS
HUNGARY	Commercial negotiation	Distant ATM switch

IRELAND	Bitstream regarded as Special Network Access, hence subject to requirements of cost-orientation and retail pricing obligations	IP handover prod. Regional PoPs, distant ATM switch
ICELAND	Not available	
ITALY	Retail minus (50% margin); according to the non-discrimination principle	Parent ATM switch
LATVIA		
LIECHTENSTEIN		
LITHUANIA	Objective, transparent and non-discriminatory terms; cost-orientation, accounting separation	DSLAM-level
LUXEMBOURG	Not available	
MALTA		
NETHERLANDS	Non-discrimination; Defined as (wholesale) leased line. Reasonable pricing	14 (regional) ATM switches
NORWAY	Objective, transparent and non-discriminatory terms	DSLAM and ATM
POLAND		
PORTUGAL	In order to ensure non-discrimination, ANACOM has determined that: (i) discounts should be incorporated on the wholesale monthly fees, representing a reduction of 20%; (ii) for the 512kbps/128kbps offer, the wholesale monthly fee for the access line should not be higher than the retail monthly fee, applied by incumbent ISPs, deducted of 40%.	2 IP handover national PoI at BRAS level (a draft decision on ATM interconnection was published)
SLOVAKIA		
SLOVENIA	Defined as ATM leased lines for all ISP operators	28 (regional) ATM switches
SPAIN	Mandatory offer; Monthly charges per user connection: retail minus (40 – 42% margin), Other charges: cost-oriented.	109 Regional ATM PoPs
SWEDEN	**Proposal** (Feb 5 2004) to require SMP operators to offer bit stream under conditions of non-	DSLAM-level and handover at

	discrimination, cost orientation (LRIC), accounting separation and publication of reference offer.	transmission network level
SWITZERLAND	Mandated by law since April 1st 2003. Commercial negotiation and then decision by ComCom (Federal Communications Commission) if no agreement is reached	Not determined yet (will be done in the contract or by ComCom)
UK	Non-discrimination; retail minus	Parent and distant ATM switch

Source: Annex of document COCOM03-04Rev2 / NRA information

Up to now in most countries only one access product – LLU or bitstream access – has been mainly used by OLOs/ISPs – generally the one made available first – suggesting the two forms of access being substitutes rather than complements. However, in the course of time they could more properly complement each other (e.g. bitstream access may be used to complete coverage), according to EC predictions. Already in the 2000 Communication on ULL (2000/C 272/10), the Commission concluded that "these three means of access to the local loop [that is: full unbundling, shared access and bitstream access] identified in point 2 **complement** each other". Also, Martin Cave[18] describes this feature with his picture of the ladder, the steps of which stand for the different forms of access. Thus new entrants can climb up the ladder by migrating from one form of access to the next higher step, continually adding more own value when going deeper into the value chain by investing more and more in own infrastructure. Thus bitstream access is as full and shared access to the unbundled local loop a means to promote infrastructure competition.

Therefore, it is important that legislation provides for the possibility to enforce both offers at the same time. Also NRAs must examine in detail the effect of the technical restrictions of incumbents' access offers on new entrants, particularly as regards the point of access. The assessment regarding the appropriate point of access should be made from the perspective of the beneficiaries, who should be able to define the product.

With the new developments, the economic differences between the two forms of access may turn out more clearly, i.e. they may fit different as input products for different business models or for different phases of market entry. Bitstream access may be called a "low-cost option" as less investment is required, but new entrants can nevertheless use their networks (without having to roll-out to the MDFs as is the case for unbundled access). With bitstream access, new entrants participate in the economies of scale (e.g. they use the DSLAM installed by the incumbent) thus levelling off the economies of scale of the incumbent. This has to be kept in mind as bitstream access might be the more appropriate access product in times of dry capital markets. The change of the financial market climate makes funding for new operators much more difficult.

[18] Cave, M. "The Economics of Wholesale Broadband Access",
Proceedings of the RegTP Workshop on Bitstream Access – Bonn – 30 June 2003
publ. in MMR-Beilage 10/2003 (MultiMedia und Recht Vol. 6, 16 Oct. 2003), pp. 15

In order for the “ladder model” to work, i.e. to allow the “climbing of the ladder of infrastructure competition” it is crucial that the prices of the different access products are consistently regulated (if price-control measures are in place), thus consistency of relative prices of access products must be ensured by the regulator if he imposes price controls. Of course all regulatory measures aim at promoting consumer benefits by making available a greater choice of services through competition. Therefore regulatory measures should ensure the right balance between infrastructure and service competition. Also, regulatory measures should not preclude competition on the backhaul market.

In different countries, the demand of new entrants for a particular bitstream access product (a specific handover point) may therefore vary according to the business model chosen as well as over time (depending on the market stage). Also, the offer of different bitstream access products (points of access as well as number of points) depends on the network architecture, which may differ across countries. Therefore, national circumstances may lead to the need for different bitstream products. When intervening “NRAs must take account of these varying technical and operational conditions, resulting from differing network architectures, as well as the level of competition in the market”[19].

The new regulatory framework now in place, taking advantage from recent developments in the broadband access market and following on the complementary approach, explicitly favours a strong regulatory approach.

First of all, the Recommendation on Relevant Product and Service Markets (C(2003)497, published on Febr. 11th 2003) explicitly identifies bitstream access as part of the wholesale broadband access market (market no. 12) to be analysed for possible ex-ante regulation[20]. Further steps will be then national market analyses in order to designate eventual SMP operators and subsequently define an appropriate set of remedies (e.g. based on the nature of the problem, proportionate and justified in the light of NRAs basic objectives laid down in Art. 8 of Framework Directive[21]); nonetheless, the first assessment whether ex ante regulation would be justified in the light of recital 7-15 of the Recommendation has to be considered already dealt with by the Commission for all relevant market defined in the Recommendation. All of the 18 relevant markets already identified by the Commission cannot be considered as “new emerging markets”, in the light of recital 15 of the Recommendation.

Document COCOM03-04Rev1 the Commission elaborated on how bitstream access is to be treated under the new framework. Bitstream access can be mandated under Art. 8 - 13 of the Access Directive (2002/19/EC) as “NRAs will be empowered to mandate access and impose obligations in accordance with Directive 2002/19/EC (the Access Directive), in cases where, as a result of market analysis, an operator is

[19] COCOM03-04rev1

[20] Cf. Explanatory Memorandum, p. 24. Furthermore (still on p. 24) according to the principle of technology neutrality, the Commission also considers possible alternative solutions for broadband access provision – cable, satellite, WLL, digital broadcast systems and powerline networks – concluding that, at the present situation, those access solutions are not yet sufficiently developed and/or reliable, thus emphasizing the crucial role of bitstream access services for the promotion of competition within market no.12.

[21] Cf. Explanatory Memorandum, par. 3.4., p. 13.

found to have significant market power on the market for wholesale broadband access"[22]. This also includes access to ancillary services such as collocation.

Such regulatory architecture overcomes the first crucial issue in the former ONP framework; the new framework foresees ex ante regulation, providing both clear procedures and specific remedies, which go well beyond the mere application of non discrimination principle. Thus bitstream access can be mandated according to national requirements according to Art. 12 AD and if considered necessary price controls can be imposed according to Art. 13 AD.

As far as the need for harmonization (which emerged as the other critical issue in the ONP framework), the application of such new framework itself, specifically tailored to promote a common approach to regulation, seems to guarantee a harmonized approach across Europe; it is just worth recalling, out of many other harmonization provisions, since it is specifically focused on remedies, Art.7 (2) of the Framework Directive, specifically asking NRAs to agree on the types of instruments and remedies best suited for particular types of situations in the market place.

Putting together the above statements and drawing the conclusion it follows that "there is a clear role for direct intervention by national authorities concerning bitstream access"[23], but NRAs have to take account of varying national circumstances resulting from different network architectures as well as the different market situations across Europe. As the provision of bitstream access is essential to the development of competition in the wholesale broadband access market as well as in the retail services market, NRAs should mandate a bitstream access product[24] according to national needs. As stated in the Explanatory Memorandum of the Recommendation "the point in the network at which the wholesale broadband access market will need to be supplied will depend on the market analysis and in particular on the network topology and the state of network competition"[25]. Given the differences in network architectures and market conditions requiring different bitstream access products, a "one-size-fits-all" regulatory approach would not be appropriate. In order to guarantee a coordinated approach as much as possible as NRAs should apply similar remedies in similar situations, an effort should be made to follow the same principles as regards e.g. SLAs or migration rules (e.g. effective migration schemes for beneficiaries from resale to bitstream products) and others (such as how to ensure the non-discriminatory use of the incumbent's economies of scale for new entrants). Regarding price regulation, it is important that the NRA ensures a consistent price structure of all regulated access products as competition along the entire value chain should be enhanced and the choice between the different forms of access might otherwise be distorted.

III. Conclusion

Where the provision of bitstream access is essential to the development of competition in the wholesale broadband access market, NRAs should mandate a

[22] COCOM03-04rev1, until the new framework is implemented, obligations regarding bitstream access imposed under the current framework must be maintained and enforced.
[23] COCOM03-04rev1
[24] preferably as a generic obligation on the basis of a reasonable request.
[25] Explanatory Memorandum, p. 25

bitstream access product according to national needs. The point in the network at which the wholesale broadband access will need to be supplied will depend on the market analysis and in particular on the network topology and the state of broadband competition. When defining the appropriate point of access, NRAs should take the perspective of market parties.

IV. Cable Bitstream Part

1. Introduction

1.1 Background

This part of the CP examines the technical aspects of providing wholesale broadband access via cable in the light of the new European electronic communications networks and services (ECNS) regulatory framework.

It deals with whether and in what ways it is possible to implement cable bitstream equivalent access only in a case a cable operator is found to have significant market power (SMP) and consequently was designated as a SMP operator as the result of a market analysis and the imposition of an access obligation according to Art. 12 Access Directive is considered to be justified and proportionate.

In 2003, the European Commission published its *Recommendation on markets within the electronic communications sector* that were susceptible to *ex-ante* regulation. In relation to the market for 'wholesale broadband access' identified in the Recommendation as Market 12, it is stated that:

"This market covers 'bit-stream' access that permits the transmission of broadband data in both directions and other wholesale access provided over other infrastructures, if and when they offer facilities equivalent to bit-stream access."

The explanatory memorandum (p. 25) to the Recommendation adds that:

"*The question is whether the alternative infrastructures which compete are sufficiently widespread to justify the inclusion of this market in this Recommendation, that is whether cable, fibre optic, satellite and wireless networks which provide wholesale broadband access are sufficiently widely deployed or developed in the Community. While these networks are well deployed in some member states in most they are not. If alternative infrastructures continue to be developed and upgraded and competition increases, this market could become effectively competitive but for the moment alternative infrastructures are not available and so this market must be included in the initial recommendation. While wholesale broadband access on alternative infrastructures to the PSTN are in principle covered by the definition of wholesale broadband access, the extent to which such alternatives are part of the market that is analysed in detail by the NRA will be limited by, amongst others, supply substitution considerations."*

Cable operators in a number of European countries have successfully deployed broadband data services to millions of subscribers. Data over cable is primarily used for broadband Internet services. In some countries broadband connections via cable modem are comparable to or even higher than the number of digital subscriber line (DSL) connections. This being the case, the conclusion drawn in the explanatory memorandum may not hold in all cases. Achieving infrastructure-based competition is a desirable goal but the existence of several infrastructures alone will not automatically result in infrastructure competition.

All existing broadband-capable infrastructures as well as their impact on the broadband market should be assessed. Therefore an exercise ought to be carried out, being mindful of the principle of technology neutrality, to analyse whether broadband access over cable is indeed equivalent to that provided by DSL and if so, what regulatory measures could, or should be applied. NRAs are empowered to mandate access and impose obligations in accordance with the Access Directive, in cases where, as a result of market analysis, an operator is found to have significant market power in the market for wholesale broadband access. The question to be answered is: does cable offer facilities equivalent to DSL? This analysis would also include a green field approach, i.e. looking at all infrastructures in the absence of regulation. While at present this discussion is focussed on cable as the predominant alternative to DSL, eventually the possibility that wholesale broadband access could be provided over other broadband technologies that could become widespread infrastructures (fixed wireless access, fibre, 3G, WiFi, WiMax, others) needs to be looked at.

In common with the ERG Common Position on the approach to appropriate remedies in the new regulatory framework (NRF), the following analysis focuses primarily on the 3rd stage of the process set out in the NRF with respect to regulatory obligations linked to significant market power (SMP). It does not assume a certain market definition nor does it in any way predetermine an outcome of a the market definition or SMP assessment exercise. It does not preclude or replace the market review to be run by the individual NRA taking adequate account of national circumstances[26].

If, following the appropriate analysis, an NRA concludes that functional equivalency between data over cable and DSL does indeed exist, then the next step would be to compare bitstream access as defined for DSL and to analyze the applicability of the definition to cable networks in order to assess the (technical) possibilities to provide bitstream access via cable networks.

1.2 Data over Cable Overview

In the mid-90s, development began on cable modems. These made the most of the high bandwidth capacity inherent in cable hybrid-fibre coaxial networks to allow the two-way transmission of high-speed data. Since that point in time, many cable TV operators have been upgrading their networks to permit bi-directional communications in order to become multiple service operators (MSOs) and provide “triple-play” services – video, voice and data.

[26] E.g. the existence of other important broadband infrastructures.

Initially, while cable modem technology matured, each vendor provided proprietary systems that would not interoperate with those from another. However, the cable operators did not appreciate being in a situation where they could potentially be held hostage by a single supplier and market pressures resulted in a standards group – under the auspices of CableLabs[27] – being set up to devise and manage the development of a data-over-cable standard. This led to the Data Over Cable Service Interface Specification (DOCSIS).

DOCSIS was rapidly adopted as the industry standard, with all the major vendors producing equipment that was supplied to CableLabs for qualification and certification. Due to the importance of the European cable TV market, which used slightly different technical parameters from North America, a European flavour of DOCSIS was developed – EuroDOCSIS. Advances in technology meant that to date, three versions of the DOCSIS standard have been released – DOCSIS 1.0, 1.1 and 2.0 – each with the EuroDOCSIS equivalent. In theory any certified DOCSIS/EuroDOCSIS cable modem can interoperate with a qualified cable modem termination system (CMTS).

1.3 Regulatory Background

In Europe, not much regulatory attention was given to cable initially, with emphasis being placed mainly on fixed line telephony incumbents. Regulatory treatment was mainly reserved for the audiovisual aspect of cable.

With the advent of the new regulatory framework for electronic communications in July 2003 that covered all electronic communications networks (including cable) and services, in which the principle of technology neutrality was enshrined, a number of relevant markets have been identified including one for wholesale broadband access. Applying the key elements defining bitstream access as identified above, it appears quite possible, that a data over cable network will be able to provide each and every one of the key elements of bitstream access functionality. Most of the content of the ERG Bitstream Access document will remain valid for cable networks. However, since the networks were initially deployed for different purposes, significant technical differences between DSL and cable exist, restraining a ”straight swap” between the treatment of the two technologies. However, it follows from the principle of technological neutrality that the regulatory aspects should apply consistently.

1.4 Description of the Relevant Market

The Relevant Market (Market 12) in question is defined as follows[28]

Wholesale Broadband Access

This market covers “bitstream” access that permits the transmission of broadband data in both directions and other wholesale access provided over other infrastructures, if and when they offer facilities equivalent to bitstream access.

[27] http://www.cablelabs.org/
[28] Official Journal of the European Union, L 114/48, 8.5.2003

Bitstream access is defined as *"the situation where the incumbent installs a high speed access link to the customer premises and then makes this access link available to third parties, to enable them to provide high speed services to customers. The incumbent may also provide transmission services to its competitors, to carry traffic to a "higher" level in the network hierarchy where new entrants may already have a point of presence. The bitstream service may be defined as the provision of transport capacity between an end-user connected to a telephone connection and the point of interconnection available to the new entrant".*[29]

Bitstream access grants the beneficiary (OLO, ISP) the ability to effect changes to the technical parameters with which the service is provided to the end customer.

This definition in the Recommendation can apply equally well to cable networks **if** it can be illustrated that the data service provided by a cable operator is functionally equivalent to that provided by a fixed line telephony operator.

When performing the market analysis in order to define markets, NRAs therefore also should analyse to what extent alternatives form part of the market in question. In a number of European countries that have extensive cable networks, analysis should consider whether broadband access via cable networks competes on the retail and/or wholesale level[30] with broadband access via PSTN (xDSL) taking into account both supply side as well as demand side substitutability considerations.[31]

[29] ONPCOM01-18Rev1

[30] And accordingly may or may not be included in the market.

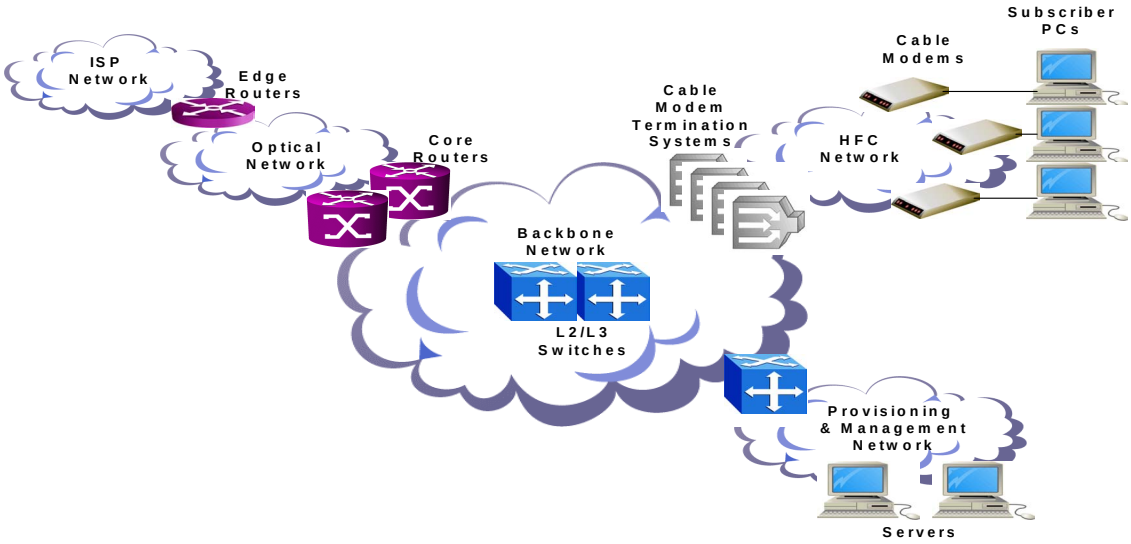
[31] In case the analysis leads to the conclusion that broadband access via cable is not in the same market as broadband access via the PSTN, there would be a need to justify the definition of a separate market, subject to the 3-criteria-test described in the Recommendation on relevant markets (2003/311/EC) being met and notified according to the Art. 7 FWD procedure.

2. Technical Considerations

2.1 Typical Data-over-Cable System

The diagram below illustrates the typical layout for a data-over-cable network. The various elements are also described.

Figure 1: Typical Data over Cable Network Architecture



HFC Network: this provides access to the homes passed by the cable operator. For television purposes the hybrid fiber-coax network only needs to be able to deliver signals in one “downstream” direction – from the cable operator “headend” to the home. Typically the HFC network has a bandwidth of several hundred MHz. Older systems have about 550MHz of bandwidth available while new systems operate provide about 860 MHz. Since each analogue TV channel requires (in Europe) 8MHz, a cable system can accommodate around 50 to 100 channels. If the system can handle digital signals, due to their more efficient nature, several digital channels can be “squeezed” into a single analogue channel by using an appropriate modulation and compression scheme. This means that several hundred digital channels can then be transmitted over the network.

For data however, the communications need to be bi-directional. By adding certain elements to the HFC network, the system can be converted to “two-way” operation where signals can also now be sent from homes to the headend. The frequency range available for this is usually between 30 and 60 MHz. This is referred to as the “upstream” channel for communications.

The HFC network is normally divided into “nodes” each served by a device that acts as the optical-electrical interface between fiber and coaxial copper. Anything between a few hundred to several thousand homes may be connected to each node.

Cable Modems: are devices that allow high-speed access to data services such the Internet via a cable television network. While similar in some respects to a traditional analog modem, a cable modem is significantly more powerful, capable of delivering data approximately 500 times faster. A typical modem would have an RF interface to connect to the cable network and an Ethernet or USB interface to link with a PC or other LAN device.

In a cable network, data from the network to the user is referred to as *downstream*, whereas data from the user to the network is referred to as *upstream*. From a user perspective, a cable modem is a 64/256 QAM RF receiver capable of coping with up to 10 Mbps of data in one 6[32] or 8-MHz cable channel. Data from a user to the network is sent in a flexible and programmable system under control of the CMTS. The data is modulated using a QPSK or QAM transmitter with data rates from 64 kbps up to 10 Mbps. The upstream and downstream data rates may be flexibly configured to match subscriber needs. For instance, a business service can be programmed to receive as well as transmit higher bandwidth. A residential user, however, may be configured to receive higher bandwidth access to the Internet while limited to low bandwidth transmission to the network.

When a typical cable modem is switched on it goes through a multi-step process of frequency scanning, RF operating parameter determination, protocol negotiation, receiving a configuration file (say through trivial FTP) that determines service parameters (downstream/upstream speeds, QoS, filters, number of clients etc) from a provisioning server as well as obtaining an IP address via DHCP (Dynamic Host Configuration Protocol).

Cable Modem Termination System: is the access or concentration device. In effect it has two sets of interfaces - one on the HFC side that can communicate using the same protocols as the cable modems in the homes and another on the network side that provides connectivity into say an Ethernet or ATM network. CMTSes can be either Layer 2 (switch, bridge) or Layer 3 (router) devices. Each RF interface can, using the DOCSIS protocol, deliver up to 50Mbps in the downstream direction (using 256 QAM) and 10 Mbps in the upstream direction (using 16 QAM). Users connected to this interface would clearly have to “share” this bandwidth.

Backbone Network: is typically located at the cable operator’s “headend”. It may also span and interconnect multiple sites if the operator’s network is large. The backbone network includes an aggregation point for the cable modem termination systems using typically Ethernet switches, a multitude of service provisioning, network management, billing and customer relationship management and various application servers required as well as core routers that connect to other operator sites, ISP networks, corporate wide-area networks or to upstream Internet backbones.

3. Technical Solutions

When considering the technical aspects of cable “bitstream”, two main issues need to be focussed upon

[32] North American systems use 6 Mhz while those deployed in Europe tend to operate at 8 MHz.

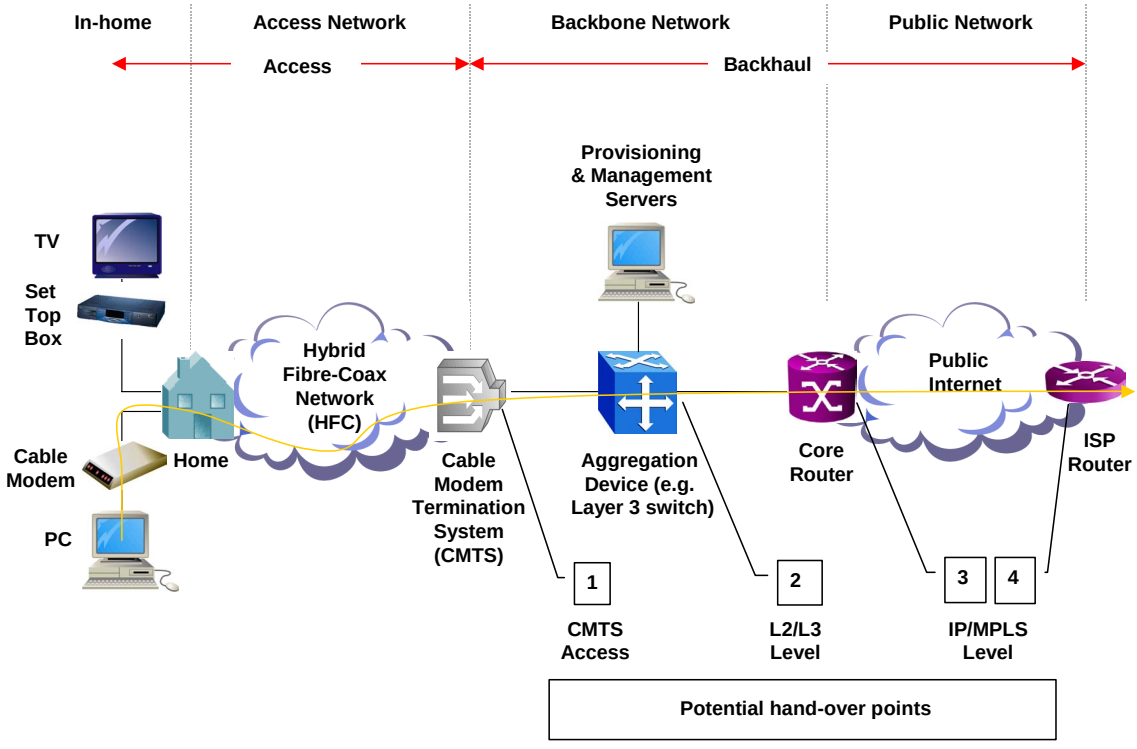
- the point of interconnection of third parties with the cable operator's infrastructure;
- the technical solutions that allow correct "matching" between a subscriber and the appropriate service provider.

3.1 Possible Points of Interconnection

The diagram below illustrates a typical end-to-end network architecture for Internet access via a data over cable system. The arrow illustrates how traffic traverses the network from the user to the upstream ISP. As can be seen there are a number of potential points of interconnect. These will now be described and an assessment of their suitability made.

3.1.1 CMTS Access

This can actually be accomplished in either one of two ways. An alternate operator may decide to actually co-locate CMTS equipment at the cable operator's headend and interface on the RF side to the HFC network. This is technically possible. However, CMTSes for each operator would need to use distinct frequencies in both the upstream and downstream portions of the spectrum of the HFC network. While this may be simple to achieve in the downstream, upstream spectrum is very limited, so potentially this could only work in a limited fashion with a small number of third parties.



Another problem derives from the way the DOCSIS protocol operates. A cable modem that is newly connected to a network will start scanning downstream frequencies and

ranging to establish communications with a CMTS. This means that an attempt will be made to communicate with the first CMTS that responds. Some further work will be required to devise a system whereby the cable modem, if "belonging" to another operator's CMTS, will be given instructions to use that frequency pertaining to the other operator. For example cable modems may be "pre-configured" to search for a certain downstream frequency. Another way of potentially interconnecting at the CMTS is to handover at the network side, although no simple way of achieving this can be thought of presently.

Of course this type of solution almost echoes a "shared access" or "local loop unbundling" scenario. The alternate operator would either have to co-locate all other network devices required to provide service or would have to backhaul all traffic to their own network over leased lines or an optical backbone. This allows the new entrants the greatest degree of freedom in selection of network equipment, system parameters and service differentiation.

3.1.2 Interconnection at the aggregation point

This would assume that the alternate operator or ISP would use the "incumbent" cable operator's access network but install via co-location equipment within the backbone network that would handle all customer traffic destine to, or originating, from that particular ISP's network. Use can be made of either the Layer 2 or Layer 3 solutions described previously for traffic segregation past the CMTSes. This traffic segregation allows the new entrant to design its own service offerings. Once more, backhaul can be effected to the new entrant's own network at this stage. Alternatively OAM&P (Operations, Administration, Maintenance and Provisioning) servers can be installed within the incumbent's own network and managed remotely. This solution also gives the new entrant a significant amount of ability to differentiate its offerings from the incumbent.

3.1.3 Handing over at the service provider edge

This would imply using the incumbent cable operator's access and backbone's networks and management and provisioning servers. Due to the tunnelling facility described previously, a service level agreement can be contracted between the new entrant and the incumbent to ensure that the new entrant's service is guaranteed. Minimal service differentiation would be possible at this point apart from the type of upstream Internet connection that the new entrant decides to implement and any particular value-added services that can be implemented within their own networks.

3.1.4 Resale

Effectively here the new entrant is purchasing a wholesale broadband access product that includes ISP-services from the incumbent and can only "badge" it differently. This would not allow a new entrant to change any service parameters and can thus not be classified as "bitstream" access.

3.2 Solutions for Identifying Subscriber Traffic

3.2.1 Layer 2 Solutions

Layer 2 solutions mirror those typically used by PSTN operators for digital subscriber line (DSL) services. This type of architecture can also be used to support subscriber self-provisioning, open access for ISPs, and security within a data over cable deployment. There are three possible options – PPPoE (point to point protocol over Ethernet), L2TP (Layer 2 Tunnelling Protocol) and DHCP (Dynamic Host Configuration Protocol). The first two rely on the installation of a PPPoE/L2TP client or the use of operating system clients on the subscriber's PC within the PC operating system while the other method relies on a 'trusted' DHCP server providing addresses for all served ISPs.

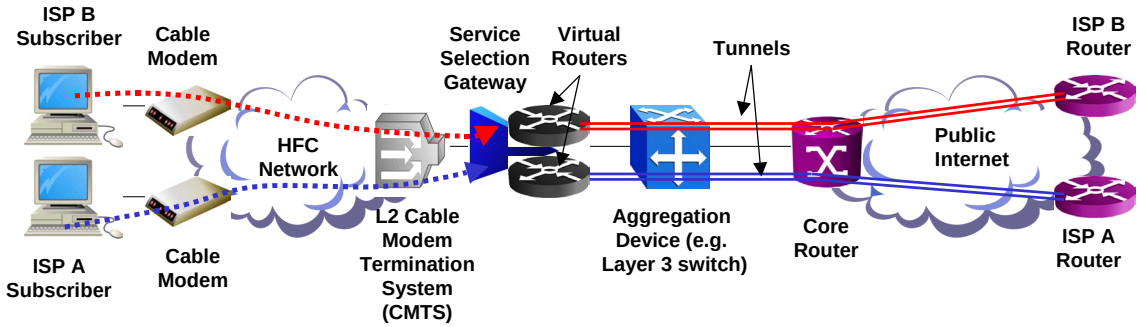


Figure 2: Multi-ISP Traffic Segregation in Layer 2 Access Environment

A key device here is a "Service Selection Gateway" (SSG) or "Broadband Services Node" (BSN) that allows identification of a client and the application of a set of service parameters to that particular user. This device would typically be located behind the CMTSes in the operator's backbone network. Upon a subscriber "logging on" i.e. launching the PPPoE client software, this would establish the protocol with the SSG/BSN. This could then provide the appropriate IP addressing, service policies and security tailored to that particular user's service contract. PPPoE allows a Layer 2 "Service Selection Gateway" or "Broadband Services Node" owner to map the subscribers to local ISP contexts (virtual routers) as well as into L2TP tunnels, while the DHCP architecture supports contexts. In this way, access to multiple ISPs can be provided since a "tunnel" exists between the subscriber and the ISP of choice.

Although PPPoE and LT2P are field-proven solutions, cable operators see three major drawbacks. First, client software is typically required on the end-user's PC, forcing them to log in for each online session, and thus, eliminating the "always on" benefit of cable modem connections. Additionally, service providers must provide technical support for the software, a costly proposition. Second, the use of tunnels adds overhead to packets, eating up valuable network capacity. Finally, the network provider cannot see the traffic contained in PPPoE or L2TP tunnels, preventing them from offering application-specific enhancements, such as guaranteeing bandwidth or latency for IP telephony or video services. Furthermore, these protocols typically cannot traverse a Layer 3 device and hence if the CMTS is router-based, these methods cannot be used. On the other hand, if older, proprietary cable modem termination systems are used that are based on bridge or ATM technology, these

solutions could provide a mechanism for allowing secure third-party access to a cable infrastructure.

3.2.2 Layer 3 Solutions

Layer 3 solutions are more promising and in general have superseded Layer 2 offerings. These solutions encompass policy-based routing (PBR), multi-protocol label switching (MPLS) and IP-VPNs. All major router and CMTS vendors offer Layer 3 solutions for the implementation of open access. As the name implies, PBR involves implementing policies and rules in IP routers or switches to manage network traffic and services. By using these kinds of policies, a network operator can sell various levels of service to different ISPs and their subscribers. Technically, policies that require specific QoS treatment are implemented through DOCSIS 1.1 (which, unlike DOCSIS 1.0, supports QoS) controls on the cable modem access network, and then on the core network with standard IP techniques like multi-protocol label switching (MPLS) and Diff-Serv, or ATM virtual circuits (VCs). The latest version of DOCSIS – 2.0 – further enhances QoS and security aspects.

Again the principle here is customer identification, the packaging of traffic to and from that subscriber within some form of “tunnel” e.g. a label switched path, the application of service parameters according to a service contract and the delivery of that to and from the selected ISP.

One of the main challenges associated with layer 3 solutions is scalability. It must be ensured that the network can handle the additional routing and switching load caused by the incremental processing that needs to be carried out. High-performance routers are required on the network since applying complex policies consumes far more processing power and memory than traditional destination-only routing. However, the solution can scale. For example a single gateway router can be used on the metro-sized network to manage service flows via PBR and interconnect with ISPs. However, to handle tens thousands of cable modem subscribers without service degradation, PBR functionality must eventually be distributed to the network edge, preferably in an integrated DOCSIS CMTS and IP switch/router environment.

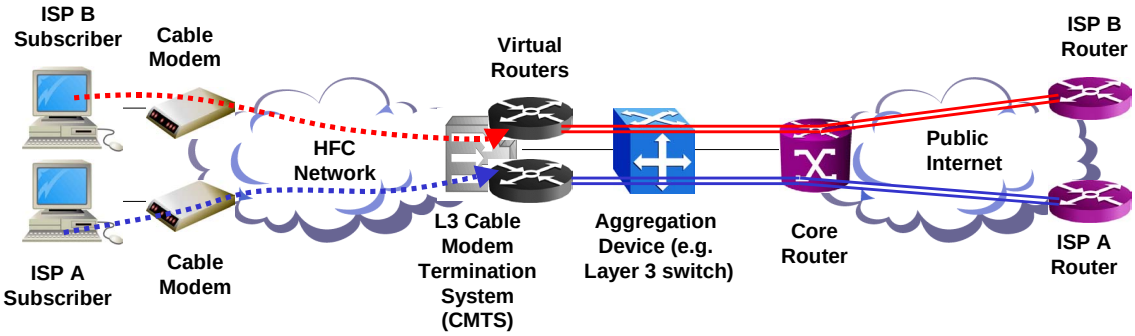


Figure 3: Use of Layer 3 Solution to separate multi-ISP traffic

This arrangement has several advantages including the fact that MPLS can be used to provide QoS and Traffic Engineering (TE). IP address renumbering is not necessary. Independent routing of traffic is maintained again through the use of “virtual routers”. Another advantage of these types of solution is that the

interconnecting ISPs do not have to make significant changes or upgrades to their networks and do not need to take any extra steps in provisioning their clients.

4. Conclusions

The part of the CP dealing with the application of the BSA definition to cable networks illustrates that various technical solutions exist for cable operators to provide "bitstream" type services to third parties as shown above. This can be demonstrated and confirmed both by the fact that all major cable data equipment vendors provide comprehensive solutions for accomplishing this, but also by the fact that wholesale broadband access offers exist in Europe according to NRAs. Outside Europe "open access" can be found above all in Canada, Israel, and some operators in the US. It is fair to note that the inherent structure and architecture of a cable network may render these solutions more complex than in the case of DSL though as technology develops these complexities may diminish. As indicated at the start of this chapter, the need or desirability of such cable access requirements is not a matter addressed in this document.

From the expenditure point of view, again, regulatory remedies do come at a price and any intervention on the relevant market would need to pass a proportionality test set out under the new framework. The implementation of any one of the technical solutions described earlier would require an additional investment but of course, the cable operator would be able to reflect these costs in any cost-oriented wholesale offer.

If following market analysis, cable network operators are found to have SMP, it follows from the principle of technological neutrality that dominant PSTN and cable network operators must be treated where appropriate in a similar way, i.e. an obligation to provide BSA may be imposed on both types of operators if such an obligation is considered proportionate and justified in the light of the Art. 8 FWD objectives.

5. Glossary (cable BSA part)

ADSL - (Asymmetric digital subscriber line) allows broadband data services to be carried on conventional copper pair telephone cables, with a higher data rate on the downstream link
ATM - Asynchronous Transfer Mode. Network technology based on transferring data in cells or packets of a fixed size. The small, constant cell size allows ATM equipment to transmit video, audio, and computer data over the same network, and assure that no single type of data hogs the line. ATM creates a fixed channel, or route, between two points whenever data transfer begins.
Bandwidth - Bandwidth is the difference between the highest and lowest frequencies available for network signals. It is also used to describe the amount of data that can be transmitted in a fixed amount of time.
CMTS - Cable Modem Termination System, a system of devices located in the Cable Head-end that allows cable television operators to offer high-speed Internet access to home computers. The CMTS sends and receives digital cable modem signals on a cable network, receiving signals sent upstream from a user's cable modem, converting the signals into IP packets and routing the signals to an Internet Service Provide for

connection to the Internet. The CMTS also can send signals Downstream to the user's cable modem. Cable modems cannot communicate directly with each other; they must communicate by channelling their signals through the CMTS.

DHCP - Dynamic Host Configuration Protocol is a TCP/IP protocol that enables a personal computer or workstation to get temporary or permanent IP addresses from a pool on a centrally-administered server.

DOCSIS - Developed by CableLabs, Data Over Cable Service Interface Specification defines interface standards for Cable Modems and supporting equipment.

HFC - Short for Hybrid Fiber Coax, a way of delivering video, voice telephony ,Data and other interactive services over Coaxial and Fiber optic cables.

IP - Internet Protocol. The Internet Protocol provides a connectionless service between networks. The protocol provides features for addressing, type-of-service specification, fragmentation, reassembly, and security.

L2 - Layer 2. This is also referred to as the OSI (Open Systems Interconnection) Data Link Layer. It provides the means for synchronizing the bit stream flowing to and from the physical layer and for the detection of errors due to transmission problems.

Latency - In networking, the amount of time it takes a packet to travel from source to destination.

MPLS - Multi Protocol Label Switching. MPLS has been developed to speed up the transmission of IP (Internet Protocol) based communications over ATM (Asynchronous Transfer Mode) or optical networks. The system works by adding a much smaller “label” to a stream of IP datagrams allowing “MPLS” enabled ATM or optical switches to examine and switch the packet much faster.

PPPoE - Point-to-Point Protocol over Ethernet. PPPoE is a specification for connecting the users on an Ethernet to the Internet through a common broadband medium, such as a single DSL line, wireless device or cable modem.

QAM - Quadrature Amplitude Modulation. Modulation technique using two amplitude modulated RF (Radio Frequency) carriers that are out of phase by 90 degrees. Information transfer is achieved using a mixture of phase and amplitude changes.

QPSK - Quadrature Phase Shift Keying. Phase shift keying in which four different phase angles are used.

QoS - Quality of Service. The performance of a communications channel or system is usually expressed in terms of QoS (Quality of Service).

Router - A router is a device that determines the next network point to which a packet should be forwarded towards its destination. The router is connected to at least two networks and decides which way to send each information packet based on its current understanding of the state of the networks it is connected to.

VPN - Virtual Private Network This is a private network link, which is carried on a public network through the use of tunnelling. It is likely that the communication will utilize encryption techniques.