European
Cable
Communications
Association

# Report on the Technical Validity of Bit-stream Access

# to Cable Networks for Applying *ex-ante* Regulation

# Executive Summary

European Commission Directives 2002/21/EC and 2003/311/EC make it necessary to decide which markets within the electronic communications sector which might be subject to *ex ante* regulation. The European Regulators' Group (ERG) has adopted a common position on Bit-stream Access and has given guidance to NRAs on whether to include HFC cable network infrastructures within market 12 (wholesale broadband internet access) together with the incumbent copper-based networks. HFC cable networks can only be included in this market definition if they are shown to offer an equivalent service to that of bit-stream access over the copper-based network. When assessing this equivalence, the service offering needs to be technically feasible without requiring significant investment by HFC cable network operators.

The ERG has decided to hold a public consultation to finalise its position on Bit-stream Access. The regulatory core group within ECCA has decided that a formal response should be made to the ERG consultation and has commissioned this technical report to examine whether or not wholesale access to cable networks is equivalent from the user perspective to bit-stream access to the copper-based network.

Section 1 provides more detail of the purpose of this report, whilst Section 2 provides a detailed consideration of the ERG document and concludes that whilst some similar end-user applications can be delivered by bit-stream access to either the copper-based DSL access network or to the HFC cable access network, end-user service parameters are quite different in terms of the available line speeds, the contention mechanisms and the degree of management control required to be imposed by the network operator. Provision of Bit-stream Access to HFC cable networks would also require considerable financial outlay by the network operators. It is therefore concluded that bit-stream access to the copper-based and to HFC cable customer access networks are incompatible from the regulatory point of view. Section 3 examines the network requirements for equivalence and also summarises the new regulatory framework (NRF) for electronic communications in Europe. More detailed conclusions are given in Section 5, following a brief analysis in Section 4 of the current regulatory positions in a number of European countries. A separately available Appendix to the report contains additional information on the regulatory position in Europe and a summary of the regulatory situation in North America (Annex A), whilst Annex B contains a fairly detailed analysis of the new regulatory framework in Europe, though the reader is advised to consult the various Directives for full information.

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# 1. Purpose of Report

Following the European Commission's (EC) recommendation on relevant markets within the electronic communications sector which might be subject to *ex ante* regulation in accordance with Directives 2002/21/EC and 2003/311/EC, the European Regulators' Group (ERG) has adopted a common position on Bit-stream Access that examines the network locations at which bit-stream access may be offered, reviews the National Regulatory Authorities' (NRA) understanding, their regulatory approach, and the remedies and constraints that might be imposed on network operators.

Following its earlier consultation on bit-stream access, the ERG presented a paper entitled 'Bit-stream access to Cable Networks' to its fixed network operators group at the ERG plenary meeting in June 2004. This paper was intended to give guidance to NRAs when considering whether to include cable network infrastructures within market 12 of the EC Recommendation on relevant product and service markets (wholesale broadband internet access), in addition to the incumbent operator's copper-based access network, the consequence of which would be the possible imposition of regulatory measures under the new regulatory framework (NRF). There is a view amongst some regulators and policy makers that such a market definition could facilitate third-party wholesale internet access to cable networks, whilst most network operators believe that this is technically difficult to achieve and that it would involve considerable, unplanned investment in their network infrastructure.

Under the terms of the EC Recommendation on relevant product and service markets, cable networks can only be included in the market definition when they offer the user an equivalent service to that of bit-stream access over the incumbent's copper-based network. When assessing this equivalence, such a service offering needs to be technically feasible without requiring significant investment for the cable operator. The ERG has decided to hold a public consultation to finalising its position on Bit-stream Access. The regulatory core group within ECCA, driven principally by ONO, UGC Europe, Kabel Deutschland, Numericable and Telenet, decided that a formal response should be made to the ERG consultation. ECCA has therefore commissioned this technical report examining the arguments made in the ERG document and which will form part of the submission ECCA intends to make to the ERG.

This document is also intended to examine whether or not wholesale access to cable networks is an equivalent from the user perspective to bit-stream access to the copper-based network and thus whether it can be included in the wholesale broadband market. Section 2 contains a technical analysis and critique of the ERG document, a high level review of the requirements, which would have to be met if cable networks were to qualify as equivalent infrastructures to those of copper-based networks for the purposes of providing bit-stream access, and a brief review of the relevant national regulatory positions in countries where bit-stream access has been or is being considered. Section 3 contains an analysis of the Network Requirements for Bit-stream access to HFC networks and summarises the NRF conditions at some length.

Section 4 of the present document summarises the current regulatory positions in a number of European countries. Section 5 concludes that there are significant technical and regulatory issues regarding the provision of bit-stream access to HFC cable networks and that it would require considerable unplanned financial outlay by the network operators, with no certainty that a demand exists and therefore that operators are unlikely to be able to recoup their investment. It is therefore concluded that bit-stream access to the existing copper-based and to HFC cable customer access networks are incompatible from the regulatory point of view.

A separately available Appendix to the report contains additional information on the regulatory position in Europe and a summary of the regulatory situation in North America (Annex A). Annex B contains a fairly detailed analysis of the new regulatory framework in Europe, though the reader is advised to consult the following Directives for full information -

- Directive 2002/21/EC of 7th March 2002 on a common regulatory framework for electronic communications networks and services (Framework Directive)
- Directive 2002/20/EC of 7th March 2002 on the authorisation of electronic communications networks and services (Authorisation Directive)
- Directive 2002/19/EC of 7th March 2002 on access to, and interconnection of, electronic communications networks and associated facilities (Access Directive)
- Directive 2002/22/EC of 7th March 2002 on universal service and users' rights relating to electronic communications networks and services (Universal Service Directive)
- Directive 97/66/EC of 15th December 1997 on the processing of personal data and the protection of privacy in the telecommunications sector.

## 2. Consideration of the ERG document

This section of the report will consider the definition of bit-stream access in the ERG document, copper and HFC access network topologies, bit-stream connectivity from the ISP to the network operator and service provisioning. It will assess the equivalence of services already being provided over the traditional copper access networks and the hypothetical provision of similar services over HFC cable networks.

### 2.1 Definition of Bit-stream access

2.1.1 Bit-stream access is a wholesale product defined as the provision by a network operator of a high speed access link to a customer's premises and his making bi-directional capacity on this access link available to one or more third parties to enable them to provide high speed data services to their end-customers. Note that this basic definition is completely independent of the network technology used and in this instance we shall consider only HFC cable networks and the traditional copper pair-based local network as the potential recipient networks.

2.1.2 An essential feature of bit-stream access, as defined in the ERG Common Position on Bit-stream Access is the provision of transmission capacity over some part of the network between an end-user and the point of interconnection between his network operator and his service provider allowing the service provider to offer his own, value-added applications to his customers. In order to be able to differentiate these applications from those of other service providers (which may include the network operator), the service provider must have access to the network at a point where he can control certain technical characteristics of the service delivered to the end-user by the network operator, thus being in a position to control the quality or nature of the service supplied to his customer. This definition of Bit-stream Access does not easily allow for differentiation where network topologies are capable of differing functionality, for example, higher speeds or more flexible bandwidth provisioning or where a common access network is shared by many users. These are important issues in considering the equivalence of end-user service capability.

### 2.2 Consideration of access network topologies

2.2.1 The local access portions of the traditional copper-pair based telephony network and HFC cable networks are fundamentally different. Whilst there are various possible architectures available for the core, or backhaul, portions of the networks, these are not greatly different in the two cases and therefore the present report will address only service provider connectivity at the local level.

2.2.2 The access portion of the traditional network is that portion of the former incumbents' networks consisting of dedicated copper pairs between the local telephone exchange and the customers' premises, these pairs being included in cables of varying sizes, directly buried, in underground ducts or carried on poles. There may be several interconnection points along the way and many premises may be served by multiple pairs. This will be referred to as the copper-based access network for the purpose of this report. This network provides little or no resilience but has near universal coverage in Europe.

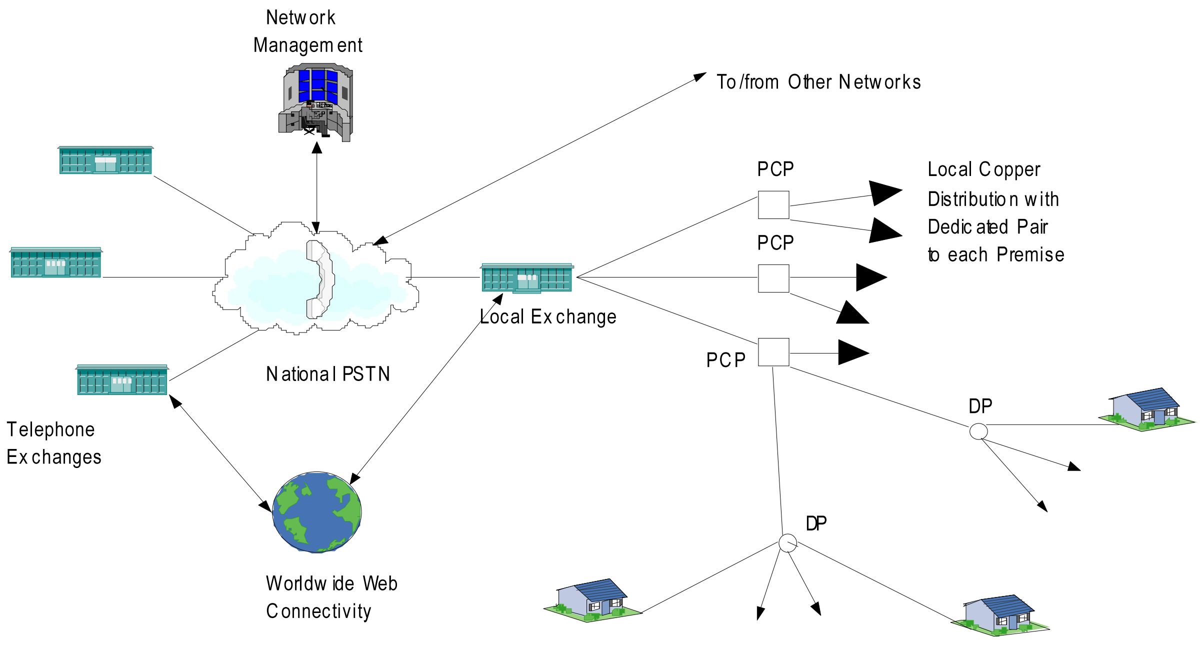


Fig.1 - Typical PSTN Topology

2.2.3 HFC cable networks are formed of optical fibre and co-axial cables. The various operators have a multitude of differing network architectures; differing terminology between operators sometimes confuses the situation even further. These networks were originally designed for one-way, broadcast transmission, feeding signals from the headend (typically serving a city) to end-users, but have mostly been converted to bi-directional operation. Typically, optical fibre rings radiate from the headend to ‘hubs’ and ‘nodes’ and depending on the specific network philosophy signals are transferred to coaxial cables at a hub or node and then carried to the customer location using a ‘tree and branch’ topology. A headend may serve many tens of thousands of customer premises, with substantial resilience in the access network resulting in the need for network power at many roadside locations. It should be noted that the reverse operation of the tree and branch topology means that the noise which is inevitably picked up or generated by the network elements is additive and is presented at the headend together with the wanted signal, potentially affecting service to all customers on that network segment. Cable network operators covering larger areas operate a number of headends interconnected via resilient optical links. This enables them to achieve national coverage, with content being inserted and distributed on a national, regional or local basis as appropriate.

2.2.4 Each optical fibre or coaxial cable in the local distribution network carries signals modulated on to a number of 'carriers' and are said to be Frequency Division Multiplexed (FDM). Depending on network capability, these carriers are usually in the range 50 to 650 MHz, although some networks have been built up to about 860 MHz, providing in excess of fifty carriers. Historically, operators have focussed on carrying television signals and each carrier was used for one analogue television channel. There is a finite limit to the capacity of the network, particularly as parts of the spectrum cannot be used for various reasons. The available capacity was often fully subscribed by the number of television channels offered.

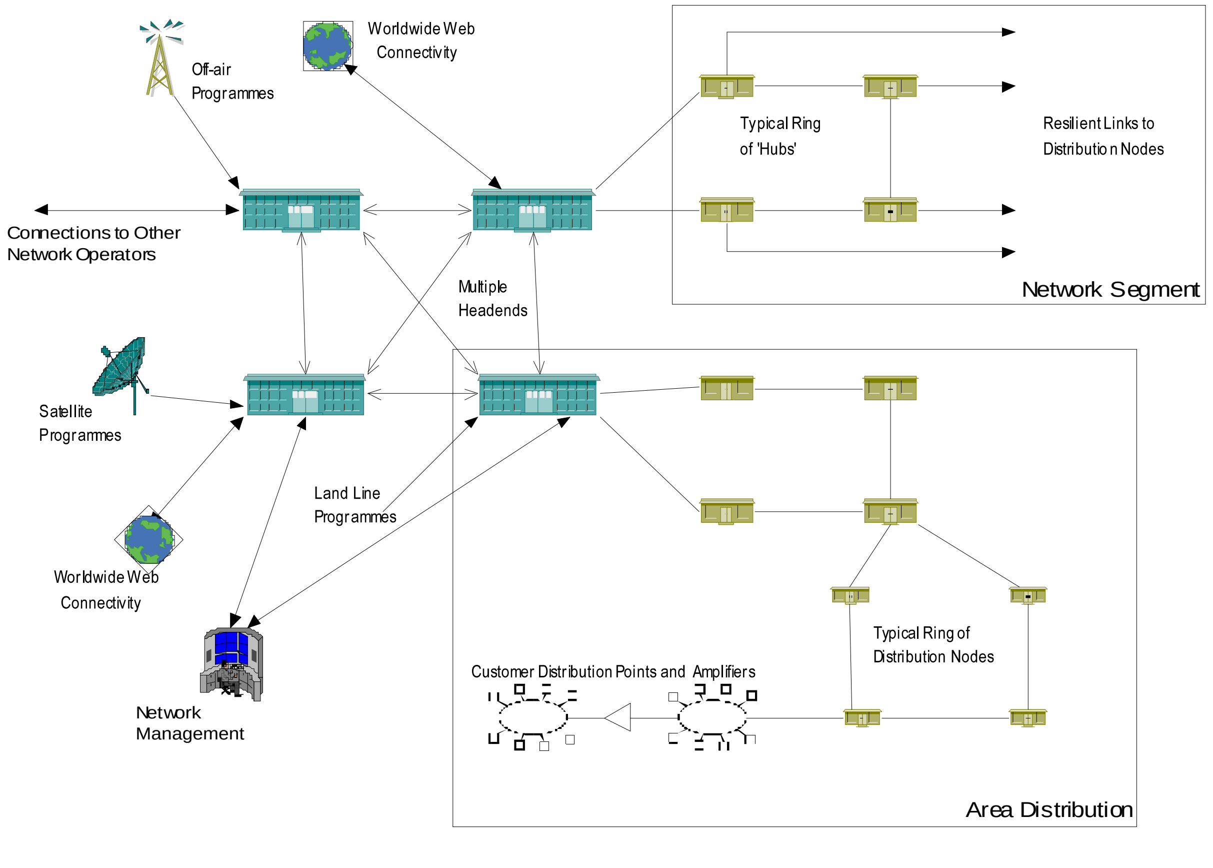


Fig.2 - Typical HFC Cable Network Topology

2.2.5 It should be noted that there is also considerable variation in the frequency assignments used in different networks, partly due to differing national requirements but largely attributable to the differing protocols employed. Most European operators use the Euro-DOCSIS protocol using 8 MHz channel spacing, as opposed the 6 MHz spacing specified in North America. This difference has little bearing on the present report, apart from Euro-DOCSIS providing fewer carriers, each having a correspondingly increased bandwidth capability.

2.2.6 In some cases, usually due to historical or regulatory reasons, ownership of an HFC access network may be divided among two or more network operators, typical boundary points being the interfaces at distribution nodes or building entry points. In these cases, it is the end-provider who controls access to the end-customer.

## 2.3 Access Network Capacity

2.3.1 Local telephone exchanges in the copper-based network typically serve between a few hundred lines in rural areas to several tens of thousands in cities. In principle, there is no limit to the number of copper pairs which can be provided, giving theoretically unlimited data capacity. This network is essentially passive, requiring no network power outside the exchange, and radial, in that each customer circuit runs directly from the exchange to the served premises. Any noise or interference generated on a particular copper pair will generally only affect service to the customer using that pair.

2.3.2 Modern digital modulation techniques have allowed HFC cable network operators to use each carrier to convey six to eight digital television channels, thus greatly increasing the 'downstream' network capacity, albeit still on a single physical path requiring network power. The increased capacity has also allowed operators to offer more targeted applications such as pay-per-view and minority interest TV channels, telephony and high speed data services, meaning that much of the additional bandwidth is already committed. The reverse-path or 'up-stream' capability of the networks enables interactive services or bi-directional data transmission, typically using carriers in the previously unused 20 to 50 MHz range.

2.3.3 It is most important to note that unlike the copper access network, HFC cable networks are a shared medium. In the HFC cable network every served premise in a network segment has a physical connection to all of the upstream and downstream carriers, thus potentially providing access to all the traffic carried in that segment. The cable modem at the customer's location is uniquely configured by the CMTS to allow access only to the services destined for that customer whilst additional security techniques prevent 'hacking' of the network . Nevertheless, any noise generated on the network will be propagated throughout the network segment and will potentially affect all its customers.

## 2.4 Provision of Bit-stream Access

2.4.1 The backbone, or core network, capability of both HFC and copper-based access networks is not dissimilar either in its operation or relative capacities. When properly provisioned, it has no effect on the end-user performance. It will therefore be understood that the differentiation between the two network types and their capabilities is confined to the customer access portions of the networks. Thus, there is no need to further consider the distinction between 'local' and 'remote' bit-stream access, 'local' access being defined as access by the ISP at the end-customer's PSTN exchange site or at the HFC cable network operator's headend.

2.4.2 In the copper-based network, bit-stream access can be provided simply by arranging connection of the relevant data to a suitable modulator (DSLAM) connected to the end-user's copper pair. The design of the DSLAM usually allows it to handle only a very limited number of 'profiles', providing each the customer with a fixed bandwidth, usually 512 kb/s, 1 or 2 Mb/s. Line length may also be a limiting factor in some instances. The upstream rate is normally limited to 256 kb/s, reflecting the usual asymmetric nature of customer traffic. This restriction means that DSL services may not support certain traffic types, for example, web servers, which typically generate a higher than normal level of upstream traffic. There may be any number of different service providers at a PSTN exchange site, with each delivering his traffic to co-located terminal equipment from whence it is connected via individual DSLAMs to his customers.

2.4.3 On the HFC cable network each carrier (or channel) has a Cable Modem Termination System (CMTS) associated with it. Digital signals representing TV programmes, telephony, internet access or any other digital application, are connected to the relevant CMTS; modulated onto its carrier and passed to the shared network as an RF signal. Depending on the application, the output of each CMTS may be fed to one or more network segments, each serving between a few hundred and a few thousand homes, depending on the architecture of the particular network.

2.4.4 Bit-stream access to HFC cable networks cannot be implemented in the same way as in the copper-based network, since the cable network is a single, shared medium feeding multiple services to multiple customers. It is not possible to provision a transparent, point-to-point bearer over an HFC network in the same way as in the copper-based network. The equivalent access point for the ISP traffic to the HFC network is at the input to a CMTS at the headend, or more likely into an IP router with the capability of routing traffic from a number of service providers to a number of CMTSs feeding different network segments.

2.4.5 Although there is a potential for a wider variety of service profiles in the access segment than in the DSL network, the service provider could have no direct control over these without access to the network operator's secure management systems. The network operator could not allow this without compromising his own core business, the reliable transmission of digital TV programmes, and his ability to manage the division of the total available bandwidth in each network segment between the service providers wishing to access it. At some point, connection of further service providers or end-users would become unviable, especially if there was no possibility of adding an extra carrier or further segmenting the distribution network.

## 2.5 Equivalent service test

2.5.1 Generally speaking, an end-user does not care how any particular application is delivered. In the case of the copper-based network, voice telephony and DSL data services can be readily accommodated on a single pair. This is almost always unique to the single customer and service on that pair does not affect, and is not affected by, service on other pairs. Voice and data services provided over an HFC cable network may result in the same end-user perception of his service but neither the exchange end DSLAM nor the customer's DSL Modem is compatible with service over HFC cable networks, which instead use Cable Modem Termination Systems at the headend and Cable Modems at the customers' locations.

2.5.2 The copper-based network offers close to 100 percent population coverage in Europe. A very large part of that network is capable of DSL operation up to at least 512 kb/s; much of the network can support 2 Mb/s with up to 8 Mb/s achievable on short lines, though the customer's service may be limited by his service definition. To limit core network bandwidth requirements, contention ratios of between twenty and fifty to one are imposed at the exchange. This means that 512 kb/s DSL customers have an equivalent continuous bandwidth of between 10 and 25kb/s, considerably less than the speed of a typical dial-up connection.

2.5.4 HFC cable network coverage is limited in many countries to franchised areas and whilst these areas often include a large part of the population, significant minorities may be excluded. Any particular area usually has only one HFC network provider. As detailed earlier, the design and technical performance of networks varies widely within countries, from region to region and even between networks operated by the same company. Thus it may be difficult to establish a single, consistent basis for standardisation of bit-stream access to HFC cable networks, even within one country.

2.5.5 In HFC cable networks, each downstream carrier is capable of carrying about 38 Mb/s (64QAM) or 51 Mb/s (256QAM) shared by up to (typically) 1000 homes in a network segment, giving a continuous equivalent bandwidth of up to about 50 kb/s per home, although this may be restricted by management controls. The relative shortage of shared upstream bandwidth is driving rapid advances in upstream technology and speeds of up to about 15 Mb/s are commonly available; dependent on the network configuration, higher speeds are available in some cases

2.5.6 The full 38 Mb/s (or 51 Mb/s) available in a network segment could theoretically be made available to any one of the homes served. In practice, each customer is allocated a maximum data speed, the aggregate of which may well exceed 38 Mb/s; a degree of contention now having been transferred into the access network and managed by the CMTS. This enables customers to achieve much higher 'burst' speeds, providing them with a differentiated product, on the basis that they are contending with their neighbours for the total segment capacity.

## 2.6 Characteristics of Cable Network Affecting Bit-stream Access

2.6.1 As a shared medium, all the downstream and upstream traffic in a network segment of the HFC cable network is presented to all connected customers. Whilst the management and control mechanisms in the CMTS and cable modems ensure that this is not a significant security problem, the tree and branch topology does exacerbate the problem of noise insertion. All network elements generate some degree of noise. In a single service environment, only the circuit generating the noise is affected by it but in the shared HFC cable network, the noise generated is additive and is ultimately presented to the upstream CMTS. To be correctly decoded, the wanted signal from a single cable modem must significantly exceed the totality of noise from a thousand or more customer premises. Whilst networks are engineered with this problem in mind, it is impossible to legislate for all possible scenarios and a fault on a single connection, or worst still, deliberate action by a rogue customer could disrupt service to a substantial number of customers. This cannot happen in the customer dedicated copper-based network.

2.6.2 HFC cable networks were designed within the given spectral constraints to provide only the capacity required by the network operator for his own services; no additional capacity was included for 'third-party' services, although with hindsight perhaps such capability should have been included, thus providing an additional revenue stream for the HFC network operator. If the limited capacity of the HFC cable network is now to be shared among a number of service providers using bit-stream access, not only would the network operator be deprived of his planned use of the bandwidth, but the overall utilisation of the available bandwidth would be diminished by its being shared into smaller 'pots'. A degree of overbooking can be allowed in the network but such contention requires complex management and due to the nature of this traffic, very serious and self-perpetuating problems occur suddenly when an overload is generated.

2.6.3 Because the HFC cable network does not provide universal coverage, even within a given city, a service provider wanting to access the network will not be able to deliver a ubiquitous service to all his potential customers. This problem is already a major headache to HFC network operators in providing TV services to customers living in unserved areas, particularly those near the boundaries, whilst the HFC cable network is very unlikely to serve those few areas not served by the copper-based access network.

## 2.7 Review of access measures

2.7.1 Provision of bit-stream access to customers on the copper-based network using ADSL is straight forward. Any number of service providers can arrange for direct or indirect connection to the local PSTN exchange site. From that point they can be connected via simple, physical patching facilities to the relevant DSLAM, which in turn is patched to the subscriber line.

2.7.2 In the HFC cable network, a single CMTS serves several hundred or more customers, depending on their services, and defines the service provided to each customer. This arrangement was engineered to support the cable network operator's own perceived service requirements. If additional service providers are to be accommodated, their traffic will have to be aggregated and delivered to the CMTS together with the network operator's own traffic. This will require the inclusion of a high capacity router and/or switch into the network. Alternatively, if a service provider has a demonstrably large bandwidth requirement he will require a dedicated CMTS and a dedicated carrier frequency from among a very limited pool of such resources.

2.7.3 The customer premises equipment (CPE) for termination of services received over the HFC cable network (cable modem) and the copper-based network (ADSL modem) are quite different, each being incompatible with the other network. Their connectivity to the user's own equipment is also likely to differ (Ethernet as opposed to USB) meaning that the technologically challenged user will require expert assistance from the network operator to make the change. An end-user can readily change from one ADSL-based service provider to another, but since his equipment is incompatible with a change from an ADSL-based provider to an HFC cable based provider, there will be a need to incur expense.

2.7.4 The physical delivery of the networks to his premises is also different, necessitating at least some degree of installation work, again incurring costs, ultimately to be borne by the consumer. Thus, whatever the other factors apply, the end-user cannot readily switch from one access medium to the other without additional expense, even if his service provider remains the same

### 2.8 Assessment of shortcomings

2.8.1 Apart from the technical shortcomings raised in the preceding paragraphs, it is inevitable that at some point the bandwidth demanded from the HFC cable network will exceed its total capability. This will occur sooner in a shared network than if only one service provider was involved. When the limited capacity of the network is reached the network operator will be faced with the problem of discontinuing the service provided to one or more of these providers, his customers. Naturally, they will all be unwilling to lose the facility (and potentially their customers). This will lead to a great deal of discontent and frustration, and more importantly will lead to a price war, with the service providers increasing the price which they may be willing to pay. Whilst this may be welcomed to the HFC network operator, it is clearly not in the interest of the end-user.

2.8.2 Theoretically, a second cable could carry a further set of carriers with differing traffic. This would require a huge investment by the network operator, both in time and money, providing additional cables, duplicated street located equipment (hubs and nodes) and, depending on the distribution of content across the parallel systems, many customers would require dual network connections and two (or more) cable modems. Whole networks would need to be upgraded before service could be contemplated even to a single customer.

## 2.9 Technical complexity

2.9.1 The technical complexity of and effort required for managing the limited network capacity available for sharing amongst what could be a substantial number of service providers (probably including the HFC cable network operator) on a fair and equitable basis is not to be under estimated. Likewise, management of the shared medium and the inevitable changes required to service allocations as loading of the HFC cable network develops will be a substantial and ever more difficult task, disproportionate to the returns which will be generated by the service provided in these days of ever cheaper voice and data services.

2.9.3 There is a further issue arising from the way in which the DOCSIS protocol used by the CMTS works. When a cable modem is first connected to the network it will start scanning the carrier frequencies to establish communications with a CMTS and will attempt to communicate with the first CMTS that responds which may 'belong' to another service provider and therefore not hold the configuration data relevant to that customer. This means that every CMTS will need to hold details of every other one on the network in order to allow cable modems to connect with the correct service. This would require major changes to the internationally standardised DOCSIS protocol, since all CMTSs are currently assumed to 'belong' to the network operator. Assuming the changes to the standard could be agreed, its implementation would be costly, expenditure which would necessarily fall on the HFC cable network operator.

## 2.10 Service comparison

The following paragraphs are intended to summarise the preceding paragraphs, giving the salient points developed above, enabling the conclusion regarding the similarity or otherwise of bi-stream access to the traditional copper-based telephony network and the HFC cable network given in the final paragraph.

2.10.1 **Definition of Bit-stream Access -** The definition of 'bit-stream access' which has been developed by the ERG can be satisfactorily applied to either copper-based or HFC cable networks but does not take into account the differing capabilities of the two networks, especially the greater flexibility of service provisioning over HFC cable networks.

2.10.2 **Consideration of Network Topologies -** The access network topologies of the copper-based and HFC cable networks are totally different, which greatly influences the range of end-user service offerings despite the similarities in the core network.

2.10.3 **Customer Connection** - The customer connectivity to the copper-based and HFC cable networks in the access network is completely different. The hardware devices are totally incompatible between the two network types. Due to the inherent flexibility of the cable network, there is the potential for offering a much greater range of products, though substantially more management resources are required to control these. The available data speeds, total possible throughput and the service characteristics provided to the end-customer are widely different. HFC cable networks have limited geographical coverage and in most countries are provided by a number of operators and with no universal service obligation.

2.10.5 **Equivalent service test -** Some potential applications delivered over bit-stream access to the copper-based or to the HFC cable networks may be similar. Cable networks are fundamentally capable of greater throughput than existing copper-based network offerings over a network allowing contention and therefore higher burst speeds. It can be argued that line speeds for copper-pair based services will further increase but we are beginning to see the end of the speed versus range curve, whilst cable networks can, in principle, already deliver much higher speed services with greater flexibility. A limiting factor in the copper-based services is the user contention ratio which is imposed at the exchange, fixing the customer's line speed.

2.10.6 **Characteristics of Cable Network bit-stream access** – The shared medium aspects of the HFC cable network, particularly regarding the noise issue, make it very different from the copper-based access network. Its shared capacity problem also makes it very different from the copper-access network and is a fundamental issue which cannot readily be solved, whilst it inherent lack of universal service will inevitably create service management problems both for the network operator and the service provider.

2.10.7 **Review of access measures** – The electrical and physical aspects of the interconnection are quite different between the two network types and since the customer premise equipment is not compatible, end-users cannot readily switch between services provided over bit-stream access to the copper-based network and those provided over the HFC cable network. Equally, end-users will be prevented in some cases from switching access providers due to lack of network coverage. All these factors suggest that the two network types cannot provide truly competitive services.

2.10.8 **Assessment of shortcomings** – The true exhaustion of network capacity which can be reached in the HFC network and its possible consequences are not paralleled in the copper-based access network.

2.10.9 **Technical complexity** – The complexity of modifying the HFC cable network to provide bit-stream access to a number of service providers would prove extremely costly to an industry which is already seeing decreasing returns in a market where consumer prices are rapidly falling. Due to the variety of network topologies, it is difficult to quantify the costs without looking at a specific network example. It is evident that the provision of bandwidth management and the necessary changes to CMTS functionality would involve considerable expenditure on the part of the HFC cable network operator, with no certainty of obtaining any return from the additional investment.

2.10.10 **Overall Technical Conclusion** – Some similar end-user applications can be delivered over either the copper-based DSL access network or the HFC cable access network However, the end-user service parameters are quite different in terms of the available line speeds, the contention mechanisms and the degree of management control required to be imposed by the network operator. The HFC cable network has a fundamental capacity limit and was designed with only the capacity required by the network operator for his own services. It is therefore concluded that bit-stream access to the copper-based and to HFC cable customer access networks are incompatible from the regulatory point of view.

# 3. Network Requirements to Support Bit-stream access and its implications

## 3.1 Network description

3.1.1 There is huge variation between the network architectures used by the various cable network operators in Europe. Apart from the selection of equipment types, these variations include the overall bandwidth employed, the degree of resilience in the access network and degree of interconnection of the several headends which exist in most operators' networks. The following description will therefore necessarily be fairly. The management systems used by cable operators also vary from top of the range, bespoke, totally integrated customer and systems management platforms to networks where a series of proprietary customer and network management systems are loosely integrated to suit the operator's working practices. Most of these systems recognise only the network operator as a service provider on the network, thus modification of management systems would need to be looked at very carefully before bit-stream access could be implemented.

3.1.2 The key element at the centre of all cable networks is the headend from which the access network radiates and which is connected to programme sources, other headends, other service providers and the public internet. Some network operators operate one national headend (which may be duplicated or have a 'mirror' elsewhere for resilience) whilst others have interconnected regional headends each having the capability of local content insertion. Depending on the network, a single headend may serve anything from a few tens of thousands to several million customers.

3.1.3 The headend houses all the equipment required to receive, process and distribute the programme content for all the broadcast, premium and pay-per-view TV and radio services, the equipment for termination and interconnection of voice telephony services where offered by the cable operator, the network operator's backbone network connections, servers for local content caching and connection to the public internet. Security and law enforcement systems are also usually located at the headend site. Many of the management systems are also located at the headend although these may be operated from a distant control centre.

3.1.4 For the purpose of this study, we are principally concerned with the customer access network, the HFC cable network which connects the customers to the headend. For TV programme distribution the hybrid fibre-coax network only needs to be able to deliver signals in the 'downstream' direction - from the headend to the home. Typically the HFC network has a bandwidth of several hundred megahertz (MHz). Early systems were built using downstream bandwidth from about 50 to 550 MHz, while newer systems operate up to about 860 MHz. All networks have certain 'blackout' frequencies to remove the possibility of interference to various vital radio communications services. Distribution of each analogue TV channel requires (in Europe) a bandwidth of 8 MHz, thus an analogue cable network can carry between forty and eighty TV channels, each on its own 'carrier' frequency. Cable networks have recently been upgraded to carry digital signals. Using modern modulation and compression techniques, several TV programmes can now be delivered on the same carrier frequency, increasing the network capacity by six to eight times.

3.1.5 For voice and data communications, networks must have bi-directional capability. Most HFC cable networks in Europe have now been converted to two-way operation allowing return path traffic to be sent from customers towards the headend, though this bi-directional capability has only been achieved by heavy and sustained investment. Carriers in the frequency range 25 to 60 MHz are normally used for the return (or 'upstream') path and is potentially available for data and voice communications.

3.1.6 From the headend, content is normally carried on optic fibre cables laid in rings (to provide network resilience) via a number of hub-sites back to the headend. From each hub-site, further rings of optic fibre or coaxial cables each feed several network nodes. Depending on the HFC cable network operator, the number of customers connected to each node may range from a few hundreds to several thousands, using a 'tree and branch' co-axial cable network to street or premises located distribution points. It is very important to note that there is no selectivity or switching of content in the network between the headend and the customers' premises; all network content is presented at all locations.

3.1.7 Cable modems are active devices requiring mains power at customer premises and which allow customer access to the cable network. The cable modem is connected to the RF signals from the cable network and may also demodulate the digital TV channels for presentation to the customer's analogue television receiver, it provides an Ethernet (or sometimes USB) interface to link to the customer's computer or local area network device to provide internet connectivity.

3.1.8 From the data perspective, a cable modem is a 64 or 256 Quadrature Amplitude Modulated (QAM) Radio Frequency (RF) receiver capable of demodulating the downstream data from one, shared 8 MHz RF channel and selectively presenting it to the end-user. Data from the user to the network is sent under control of the CMTS on a shared upstream channel, modulated using a Quaternary Phase Shift Keyed (QPSK) or QAM transmitter, at data rates capable of being flexibly configured to match subscriber needs.

3.1.9 The services available from the shared access medium, to an individual customer are controlled by his cable modem which is configured by the relevant CMTS at the head end. Each time the cable modem is switched on it goes through a process of frequency scanning, determination of its designated operating parameters and protocol negotiation, and receives a configuration file that defines its service parameters (downstream and upstream data speeds, QoS, filters, number of clients, IP address, etc.) from a provisioning server and can then be uniquely identified on the network.

3.1.10 The Cable Modem Termination System (CMTS) is the access or concentration device located in the headend and which connects network content to the network. It has an interface to the HFC access network and communicates with the customers' cable modems using one RF carrier downstream and one or more in the upstream direction. On the network side it provides connectivity into the network operators

Ethernet or Asynchronous Transfer Mode (ATM) network. Depending on the network architecture and equipment vendor, CMTSs can operate either at Layer 2 (switch, bridge) or Layer 3 (router). Each RF interface using the Euro-DOCSIS protocol can deliver up to about 50 Mb/s in the downstream direction and receive up to about 15 Mb/s. This is a shared access medium and users connected to the interface have to share this bandwidth, a feature which is managed by the CMTS.

3.1.11 The network operator's backbone network equipment is also located at the cable headend and may interconnect multiple sites in large cable networks, especially where the operator employs multiple headends. The backbone network includes an aggregation point for the cable modem termination systems (typically using Ethernet switches), a multitude of service provisioning, network management, billing and customer relationship management and the various other applications servers required, as well as core routers that connect to other operators' sites, corporate wide area networks and to upstream internet backbones, peering points, etc.

## 3.2 Technical Requirements for Upgrade

3.2.1 **Headend –** At the headend, arrangements will have to be made either to aggregate the new ISP's traffic with that already being applied to the relevant CMTSs by the network operator or other ISPs, which pre-supposes that there is sufficient capacity remaining on the CMTS and that it will not be over-subscribed by the addition of a new tranche of customers, or to provide a new CMTS connected to a new RF carrier dedicated to the new provider, pre-supposing the availability of spare frequencies upstream and downstream.

3.2.2 Depending on the network utilisation at the time of the upgrade, the first of these options is the least unlikely to be practicable. It is extremely unlikely that a spare carrier frequency will be available across any network which has been in service for any significant length of time. If the first option is available, the possibility then arises that if one or more new ISPs are allowed access to the network, that its capacity will soon become exhausted preventing further additions and limiting the growth of the customer base both for the network operator and the new ISPs. This will effectively discriminate against latecomers.

3.2.2 **Network –** Depending on which of the above solutions was adopted in any given case, either additional IP routing equipment or a new CMTS would be needed at the headend. No additional equipment would be required at the network hubs, nodes or distribution points.

3.2.3 **Customer Location -** If an existing customer of the new ISP is to change his service delivery from the copper-based ADSL service to delivery via a cable network, his existing ADSL modem will become redundant. It will not be compatible with the shared access medium cable network; the customer, his service provider or the cable network operator will have to provide a network operator approved cable modem and ensure its proper registration on the network. Depending on whether or not the customer's location has an existing service from the cable network operator, it might be necessary to physically connect the location to its nearest cable distribution point, assuming that adequate capacity exists. Note that to ensure compatibility with the network operator's DOCSIS-based CMTS the customer would require a cable modem for each of his service providers. This raises the issues of their physical connectivity and available signal levels. Networks have been designed for a given signal level at customers' premises and no allowance has been made for signal splitters and the likely 6dB loss these would introduce.

3.2.4 **Management -** The cable network data carrying capacity as built was designed for use by a single service provider, the cable network operator. Consequently, no provision was made in the management systems for sharing of the available resource amongst several ISPs. Management systems vary widely in their complexity but it is clear that investment would be required to ensure that the network sharing was managed in the manner defined by the contracts.

## 3.3 Upgrade costs involved

3.3.1 **Headend –** Due to the wide range of network configuration options, it is almost impossible to estimate the cost of provision of either additional IP routing equipment or CMTSs without considering a specific network configuration. With the possibility of multiple new service providers this figure is likely to run into many millions of €uros for a typical HFC cable network headend.

3.3.2 **Network –** Little or no investment would be required at the network hubs, nodes or distribution points unless the requirements of new service providers for capacity on the network increased the required bandwidth beyond the existing built capacity, in which case the splitting of existing network segments, provision of new nodes and distribution points, accompanied by the digging up of roads to provide new cable routes, etc. would be a huge and impossibly speculative financial burden for the network operator.

3.3.3 **Customer location –** The customer's existing ADSL modem is incompatible with the HFC cable network and will therefore become worthless. An operator approved cable modem can be expected cost between €uro 50 and €uro 80 depending on its procurement (purchaser, vendor, wholesale, retail, etc.). The cost of external works, where necessary, will be extremely variable depending on site conditions, type of customer premises, etc. and could only be determined by survey on a case by case basis but is unlikely to be less than twelve months' gross revenue.

3.3.4 **Management -** Management systems vary widely in their complexity and again it is impossible to predict the cost implications of network sharing except by considering a specific example. What is clear is that all such systems have a high degree of customisation which is geared towards the network operators' original requirements. Many new management tasks will evolve around multiple service providers on a single network, meaning that the existing bespoke systems will need extensive reworking at considerable cost to network operators who will have no certainty of any return on their investment.

## 3.4 Network access complexity

3.4.1 There is a variety of possibilities for the bit-stream handover point between the ISP and the cable network operator. On the basis that the core networks of HFC cable operators and those of copper-based networks are not greatly different, we will consider only the local connectivity from the ISP network to the HFC cable operator's access network. The cable network operator may or may not separately provide connectivity for the ISP from some remote point to the headend but this is not a relevant issue in the discussion.

3.4.2 ISP connectivity may be at the CMTS level in one of two ways, either at the CMTS aggregation point, when the ISP would connect to an IP router or switch feeding the cable operator's CMTS, either sharing it with other data services or if his traffic so warranted, being its only user. Alternatively, the ISP may locate his own CMTS equipment at the cable operator's headend and interface on the RF side to the HFC network; however CMTSs for each ISP would require unique upstream and downstream frequencies from the very limited pool available, so this solution could only work with a very small number of third-party ISPs.

3.4.4 A further option is that of service resale, where the ISP would purchase the entire broadband access product from the cable network operator, with only the ability to 'badge' it differently. Strictly speaking, this should not be classified as bit-stream access as there are no service characteristics that the new entrant can change, other than perhaps providing his own portal.

## 3.5 Network access costs

3.5.1 Local access costs in the first case described above would fall to the cable network operator who would need to provide additional connectivity to his existing CMTS. The cost of this would be extremely dependent on the existing arrangements and could range from virtually nothing if spare router capacity was available up to many tens of thousands of €uro at each headend if new routers had to be procured. In any case, the investment would have to be make in anticipation of possible need for the service with no certainty of any return.

3.5.2 In the case of the ISP providing the CMTS himself there would be a lower cost falling to the cable network operator, though he would have to be satisfied of the compatibility of the third-party CMTS product used with the rest of his network. This might entail undertaking a substantial compatibility testing programme. The cable network operator would also have to be satisfied the bandwidth was available on his network.

## 3.6 Opportunity costs

3.6.1 **Operators' own services** – The majority of HFC cable operators also provide internet access services over their own networks. These are often bundled into the so-called 'triple-play' service, joint provision of TV, telephony and internet access. Operators who are forced to carry third-party internet access will be faced with potential cannibalisation of their own services with no possibility of reciprocal effects on the competing provider. This will inevitably lead to higher consumer costs for the remaining two services due to the lack of economies of scale in customer management, etc. and greater customer churn. Network operator revenues will also be reduced due to the wholesale value of their limited network capacity being less than the total retail value.

3.6.2 **Competing service providers** – New operators will have the opportunity for short-term, predatory pricing unrelated to the actual costs of service provision to attract new customers. When these operators achieve a significant capacity on the cable network they will be in a position to further squeeze the network operator charges, thus further reducing his revenue whilst consumer prices will be increased. Both these factors will adversely affect the end-user costs. Limited bandwidth availability on the HFC cable network will mean that there is little opportunity for real competition between operators in the internet access provision sector.

## 3.7 Existence of demand

3.7.1 There is very little evidence of there being a significant demand from ISPs for bit-stream access to cable networks. Some of the biggest ISPs are closely connected with the major switched network providers and maintain their commercial relationships. These and many other large ISPs see the cable network operators' own ISPs as being their direct competition and prefer to confine themselves to using 'traditional' access providers. Smaller, niche ISPs do not have the need (or resource, in many cases) to pursue alternative means of accessing their users nor would it be cost effective for them to do so due to their small and widely distributed customer base who, by and large, are not deterred by the premium price they pay for their services.

3.7.2 All major European switched network operators now offer ADSL services, mostly on their own account and by providing access for other ISPs to the copper-based access network using a variety of network unbundling arrangements. These services, whilst not ubiquitous, serve a very large proportion of the population, providing a single, convenient means for third-party ISPs to access most of their customers at line speeds of up to 2 Mb/s. The small proportion of users not capable of being served by ADSL based broadband services are mostly in the more remote areas and are therefore very unlikely to be served by HFC cable networks.

3.7.3 ISPs therefore already have access to near universal broadband delivery for their services at a cost which is rapidly decreasing. Their customers invariably already have voice telephony service provided, in most cases, by the copper-based network operator or over his copper pair by another telephony service provider and are content to use the same physical means of access their internet services.

3.7.4 Several major ‘independent’ European ISPs have specifically indicated that they are satisfied with the existing arrangements for regulation of access networks and are content to use the copper-based network in a market sector where it is apparent (for instance, from the latest ECTA figures) that there is already effective competition in broadband delivery.

# 4. National regulatory requirements

This section of the report will briefly address the national regulatory situation in Europe, looking at the existing situation, specific national issues insofar as these have been identified and looking for any possible trends as an indication of future direction. Further information and a brief summary of the confused regulatory situation in the USA can be found in the separate appendix to this report.

## 4.1 Existing situation in Europe

4.1.1 Regulation of telecommunications and data services over HFC cable networks in Europe has been relatively minimal, with emphasis placed on regulation of the fixed line telephony incumbents. Cable network operators have not been considered to have significant market power in telecommunications and as such have faced few specific regulatory obligations. With the advent of the European Union’s new regulatory framework for electronic communications in July 2003, covering 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.

4.1.2 The Relevant Market (Market 12) in question is defined as follows:

*Wholesale Broadband Access - 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.*

4.1.3 Bit-stream 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 bit-stream service may be more briefly defined as the provision of transport capacity between an end-user and the point of interconnection available to the new entrant.

4.1.4 By definition, bit-stream access includes the ability for the ISP or OLO to effect changes to the technical parameters of the service is provided to the end customer. This definition while seemingly written with the traditional copper access network in mind, can only apply to cable networks if it can be shown that the data service provided the cable operator is functionally equivalent to that provided by a fixed line telephony incumbent.

4.1.5 The new framework recognises that network architectures will continue to differ across Europe and between operators. There is therefore is the flexibility for NRAs to agree common network access rules, for example, on bit-stream access. The ERG was asked to develop an agreed position on bit-stream access to cover in particular:

- the provision of bit-stream access by operators with SMP in the relevant market
- the network locations at which bit-stream access is offered
- the remedies, including where appropriate, pricing

This it has done and published in is document adopted on 2nd April 2004.

4.1.5 Bit-stream access over the copper access network can be mandated as NRAs will be empowered to mandate access and impose obligations in accordance with the Access Directive, in cases where an operator is found to have significant market power on the market for wholesale broadband access". There is also the possibility that wholesale broadband access could be provided over other infrastructures, if such networks can offer facilities equivalent to bit-stream services. When: performing the necessary market analysis, NRAs therefore also have to analyse to what extent alternative networks are part of the market in question. In a number of European countries that have extensive cable networks, this analysis will have to determine whether broadband internet access via cable networks competes at the retail, and/or wholesale level with broadband internet access via the copper access network (xDSL).

4.1.6 If it is found that broadband data over cable cannot provide bit-stream services equivalent to xDSL broadband, then the problem arises as to how cable broadband should be considered. The EU Framework directive specifies that NRAs may identify markets differing from those listed in the recommendation and would need to notify the Commission and other NRAs of these 'new' markets and obtain the required approval.

4.1.7 If, following the appropriate analysis, an NRA decides on functional equivalency between data over cable and xDSL, the next step would be to compare bit-stream access as defined for xDSL and to analyze the applicability of the definition to cable networks in order to assess the technical possibilities of providing bit-stream access via cable networks.

### 4.2 Common Position on Bit-stream Access

4.2.1 The European Regulators Group (ERG) has reached a common position on bit-stream access, outlined in a document adopted on April 2nd 2004. The document did not discuss other forms of wholesale broadband access such as unbundled and shared access or deal with bit-stream access for other broadband technologies. It outlines the regulators' understanding of bit-stream access and their regulatory approach. It is not mandatory; NRAs should try to adhere to its conclusions as far as possible when taking decisions, the ultimate responsibility remains with the individual NRA.

4.2.2 The ERG Common Position identified the following key elements defining bit-stream access:

- a high speed access link to the customers premises provided by the SMP operator
- transmission capacity for broadband data in both direction enabling new entrants to offer their own, value-added services to end-users;
- new entrants to have the possibility to differentiate their services by altering the technical characteristics and/or the use of their own network;
- bit-stream access is a wholesale product consisting of the access link and-backhaul services of

the backbone network

4.2.3 Based on this, it appears that HFC cable networks can provide some but not all of the elements of bit-stream access functionality. Therefore, some of the content of the ERG Bit-stream Access document remains valid for 'bit-stream' access to these networks. However, due to the significant technical differences between ADSL and cable network technologies, (particularly in the shared nature of cable's access and its management systems) there cannot be a direct comparison between the two technologies or a straight swap between their regulatory treatments.

## 5. Conclusions

This section summarises the technical, economic, regulatory and other reasons for the conclusion that that bit-stream access over HFC cable networks is not equivalent to bit-stream access over copper-based access networks. In this context it is important to recall that according to the EU guidance to national regulators, HFC cable networks can only be included in the wholesale broadband access market if they are shown to offer an equivalent service to that of bit-stream access over the copper-based network without undue technical complexity or the need for disproportionate investment by the network operator. It has not been possible to evaluate actual costs of implementation due to the widely differing types of HFC cable networks. It is evident, however, that the costs of re-engineering the HFC cable network are unlikely to produce a network capability which is competitive with the ever decreasing costs of ADSL services over the copper-based network.

### 5.1 Technical Issues

The HFC cable network is an active, shared medium with differing downstream and upstream line speed characteristics and contention mechanisms from the passive, dedicated media of copper-based access networks. Control of the end-user's access service is on a per-customer basis under the control of the CMTS which takes into account the limited bandwidth of the access network.

Some degree of bandwidth overbooking can be allowed in the network but such contention requires complex management, without which very serious and self-perpetuating problems will occur very suddenly if an overload is generated. Thus, bandwidth allocation must be under single control and cannot be delegated to service providers unless dedicated carriers are available to them, which is very unlikely to be the case due to the limited capacity of the network.

If the capacity of the HFC cable network is shared among a number of service providers the network operator will be deprived of his planned use of the limited bandwidth. Its overall utilisation will be further reduced by its being shared into smaller 'pots'.

Due to the wide variation in the design and performance of different HFC cable networks it will be almost impossible to establish a consistent basis for standardisation of bit-stream access to HFC cable networks.

HFC cable networks do not provide universal coverage. Service providers wanting to access the network will not be able to deliver a ubiquitous service to all potential customers which will cause a major problem of identifying those living in unserved areas.

True exhaustion of network capacity can be reached in the HFC network and its possible technical and economic consequences are not paralleled in the copper-based access network.

### 5.2 Economic Issues

Implementing bit-stream access on HFC cable networks would involve enormous cost. Headends would require additional IP routing equipment or CMTSs and major modifications to existing management systems. With the possibility of multiple new service providers this figure is likely to run into many millions of €uros for a typical HFC cable network headend.

It is evident that the provision of bandwidth management and the necessary changes to CMTS functionality would involve considerable expenditure on the part of the HFC cable network operator, with no certainty of him subsequently obtaining any return from the additional investment.

Network management systems will need extensive reworking at considerable cost to network operators who will have no certainty of a return on their investment.

Costly changes will be required to the internationally recognised DOCSIS protocols used by the CMTS in order that all CMTS at a headend have full knowledge of the customer and service base. Existing equipment is unlikely to have the capacity for this and may well need replacement.

In the access network itself, investment would only be required when the customer demand for bandwidth exceeded the built capacity, at which time the splitting of network segments, provision of new nodes, distribution points and cable routes would become a huge and impossibly speculative financial burden for the network operator.

The end-user's existing ADSL modem will become worthless and the cost of its replacement with a cable modem and the provision of physical connectivity is unlikely to be less than two years' gross revenue.

### 5.3 Customer (Wholesale) Requirements

There is no evidence of demand of bit-stream access to HFC cable networks and some major ISPs have said they do not need it, mainly because of their existing high penetration via the copper-based network using standard interfaces and partly due to the lack of universal coverage of HFC networks.

Even if it is shown that ISPs do require access to the HFC cable network, the costs involved will be substantially higher than those for the copper based network and difficult to determine due to the shared nature of the HFC network

There can be no common standard for connectivity to HFC cable networks due to the differing network architectures, causing costly management problems.

### 5.4 Customer (End-user) Perspective

Neither the DSLAM nor the customer's DSL Modem is compatible with HFC cable networks, which instead use CMTS at the headend and CM at the customers' locations, meaning that the end-user cannot readily switch from one access medium to the other without additional expense and may be prevented from doing so by lack of HFC network coverage.

### 5.5 Regulatory Perspective

The ERG Common Position identified key elements defining bit-stream access, including new entrants being able to offer their own, value-added services to end users and being able to differentiate their services. This is not possible in the shared medium environment which can only have a single management entity

### 5.6 Shared Medium

The shared medium aspects of the HFC cable network, particularly the noise issue, make it very different from the copper-based access network and its shared capacity problem is a fundamental issue which cannot readily be solved. There is no practical possibility of network unbundling in the physical sense, as is possible in the copper-based network; the concept of some kind of 'virtual unbundling', providing 'chunks' of bandwidth within given network segments, might work with a very small number of ISPs but could quickly result in a nightmare scenario from a network management point of view.

**5.7 Overall Conclusion** – End-user service parameters over copper-based DSL access networks and the HFC cable access networks are quite different in terms of the available line speeds, the contention mechanisms and the degree of management control required to be imposed by the network operator. The HFC cable network has a fundamental capacity limit and was designed with only the capacity required by the network operator for his own services. The electrical and physical aspects of the interconnection are quite different between the two network types and end-users cannot readily switch between services provided over bit-stream access to the two network types and may be prevented in some cases from switching due to lack of network coverage.

**5.8** These factors suggest that the two network types are not competitive substitutes for the purposes of market definition in the New Regulatory Framework. For these reasons it is pertinent to conclude that bit-stream access to copper-based and to HFC cable customer access networks are incompatible from the regulatory point of view and that there cannot be a straight comparison between the two technologies or a 'straight swap' between their regulatory treatments.