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# An assessment of IP interconnection in the context of Net Neutrality

BEREC Report

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# 1 Introduction: Scope and outline of the project

There is unanimous consent that the Internet has greatly contributed to growth and innovation in our economies. This was facilitated by the separation of network and application layers enabling competition and allowing service innovation to take place in particular at the edges of the network.[1] It has implied low entry barriers on the open platform of the Internet that have provided particularly fertile ground for new content, applications and services to develop.

In BEREC's '*Response to the European Commission's consultation on the open Internet and Net Neutrality in Europe*' Net Neutrality was described as follows:

"A literal interpretation of Network Neutrality, for working purposes, is the principle that *all electronic communication passing through a network is treated equally.* That all communication is treated equally means that it is treated independent of (i) content, (ii) application, (iii) service, (iv) device, (v) sender address, and (vi) receiver address. Sender and receiver address implies that the treatment is independent of end-user and content/application/service provider.

There have been and will continue to be deviations from this strict principle. Some of these deviations may well be justified and in the end-user's interest but other forms cause concern for competition and society. To assess this, NRAs will need to consider a wider set of principles and regulatory objectives."

BEREC has set up a work programme dealing in with different aspects relevant to Net Neutrality to come to such an assessment. The project on IP-interconnection is part of a larger work-stream on Net Neutrality also analysing other aspects of Net Neutrality such as transparency, quality of service and competition issues.[2]

Net Neutrality is mainly a principle in the interest of the end-user entitling to access and distribute information or run applications and services of their choice according to Art 8 No 4 lit g FD.

The potential impact on competition, innovation and the welfare of end-users resulting from departures from Net Neutrality at the initiative of ISPs that employ differentiation practices in the retail markets of providing broadband access, and connectivity to the Internet will be analysed in the BEREC report on competition issues related to Net Neutrality. For the purposes of this report the definition of Net Neutrality is very close to the widespread application of the best-effort paradigm. The best-effort paradigm however is intrinsically linked to the nature of the IP protocol governing transmission of packets of IP networks.

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1 See BEREC (2010a) BoR (10) 42 and also ERG (08) 26final, in particular A.5.1

2 See also other BEREC papers on Net Neutrality: BEREC (2011) *"A Framework for Quality of Service in the Scope of Net Neutrality"* (BoR (11) 53); BEREC (2011a) *"Guidelines on Transparency as a Tool to Achieve Net Neutrality"* (BoR (11) 67); BEREC (2012) *"A view of traffic management and other practices resulting in restrictions to the open Internet in Europe*" (BoR (12) 30) May 29, 2012; *BEREC (2012a) "Guidelines for Quality of Service in the scope of Net Neutrality" (BoR (12 131); BEREC (2012b) BEREC report on differentiation practices and related competition issues in the scope of Net Neutrality"* (BoR (12) 132).

3 According to Art 2 lit b AD Interconnection "means the physical and logical linking of public communications networks used by the same or a different undertaking in order to allow the users of one undertaking to communicate with users of the same or another undertaking, or to access services provided by another undertaking". Interconnection needs to be contrasted with access-products like bitstream, where one operator uses the facilities of another operator rather than connecting different networks to provide any-to-any connectivity, which are not dealt with in this paper even if the interface may technically identical . See ERG (08) 26 final, p. 70. These markets are not dealt with in this paper.

The present paper will therefore focus on the wholesale level of interconnection between ISPs and other intermediaries in the Internet value chain and analyse how deviations from Net Neutrality may or may not be reflected at the interconnection level[3] governing transmission of packets across the Internet as a collection of different networks (autonomous systems[3]).

BEREC noted in its Response to the Commission that interconnection arrangements between networks are not directly related to Net Neutrality as long as all traffic flows are treated equally. A violation of the Net Neutrality principle is therefore considered unlikely if all traffic is treated in a best-effort manner. The best effort principle is reflected in today's interconnection agreements across IP-networks taking the form of transit and peering agreements.

However a disruption of interconnection at the wholesale level could still occur in a best-effort world leading to a situation in which end-users cannot reach all destinations on the Internet and, thereby potentially impacting Net Neutrality. However such instances have been few and have to date been solved in a relatively short time without regulatory intervention – also thanks to competitive pressure of end-users at the retail level.

In BEREC's Response to the Commission Questionnaire on Net Neutrality (BEREC (10) 42) the following points with regard to IP interconnection were made:

- *BEREC has highlighted the fact that the Internet connectivity market and hosting services have grown from zero to a multi-billion-Euro business in fifteen years on a commercial basis.*[4]

- *[Peering and transit] interconnection arrangements developed without any regulatory intervention, although the obligation to negotiate for interconnection applies to IP networks as well. These agreements have been largely outside the scope of activity of NRAs. This appeared justified in particular due to the competitiveness of the transit market on IP backbones.* [5]

This perception is also reflected by the fact that wholesale Internet connectivity is not part of a listed market of the Recommendation on relevant market as it is deemed to function well without regulation:

- In its Explanatory Note to the Relevant Market Recommendation[6] the Commission *stated that "global connectivity can be arranged in a number of ways. It can be purchased from a network that is in a position by its own arrangements to guarantee such connectivity. It can be obtained by interconnecting and exchanging traffic with a sufficiently large number of networks so that all possible destinations are covered."*

- With regard to the market for Internet connectivity the Commission reasoned "*Entry barriers to this market are low and although there is evidence of economies of scale and that the ability to strike mutual traffic exchange (peering) agreements is helped*

3 An autonomous system (AS) is a set of connected routers under single technical administration, thus having a single and clearly defined routing policy (BoR (11) 53, Ch. 4.1). An AS might be the set of all computers owned by a company. An autonomous system number (ASN) It is a unique number identifying those groups of networks to the outside world. The Internet consists of thousands of interconnected AS. The Border Gateway Protocol (BGP) ensure end-to-end connectivity across several AS. Having an ASN implies using BGP and applying peering/transit. Having an ASN does not imply that services are offered to the public. However, an AS number is not only assigned to network operators but may also be used by Content and Application Providers (CAPs). In practice, about 80 % of ASNs belong to CAPs or eyeballs ISPs.

4 See BEREC (2010a) p.14.

5 See BEREC (2010a), p.15.

6 *Commission Staff Working Document: Explanatory Note to Commission Recommendation on Relevant Product and Service Markets.*

*by scale, this alone cannot be construed as inhibiting competition*." Thus, it concluded that "*there is no a priori presumption that ex ante market analysis is required*" and *no market for wholesale Internet connectivity (or delivery of incoming packets) was identified.*

NRAs powers are thus currently limited to non-SMP instruments unless a three-criterion test is run and a market subject to ex-ante regulation outside the recommendation list is established. These instruments include a general obligation to interconnect on a non-discriminatory basis codified in Art 5 AD. This could be applied in case a disruption of interconnection took place.[7]

The discussion on IP interconnection in the context of net neutrality takes places in the wider context of ongoing debates between stakeholders on charging mechanisms used for IP-interconnection, including around the revision of the International Telecommunication Regulations (ITRs). Thus, aspects of the ITR debate related to this paper are addressed in Ch. 4.8. Although the BEREC and ITU processes are completely independent from each other, they both deal with the common theme of charging principles for IP interconnection, and both attach great importance to maintaining the freedom of the Internet and ensuring a multi-stakeholder approach.

*Background*

Earlier on ERG/BEREC has worked quite extensively on IP interconnection in the context of transition from PSTN towards NGN (ERG (07) 09, ERG (08) 26 ERG Report on IP interconnection, ERG Common Statement IP-IC NGN Core). Many of the major points addressed then are still at the core of the discussion on Net Neutrality today, namely the separation of *network and application layers*, best-effort versus quality of services (QoS) assured services and the charging principles used:

*Separation of network and application layers*

- "*A core feature of IP networks is the separation of the main functional levels, i.e., generally, a distinction can be made between transport and service. This distinction potentially allows competition along the value chain more easily than in the PSTN world. A crucial point is the adoption of open and standardised interfaces between each functional level in order to allow third parties to develop and create services independent of the network.*

  "*What is key for competition, however, is that the separation should allow transport and service to be provided by different parties. Service provision by independent third parties becomes possible, independent of transport technology and type of network access. This approach requires open interfaces for third parties. The ERG is convinced that such a separation between transport and service would contribute to and promote the development of new and innovative services.*"[8]

- The expression "transport and services" is often referred to as "network and application layers" in the BEREC reports related to Net Neutrality since this is common terminology used in the Internet community. Network layer corresponds to "transport" while application layer corresponds to "services". The latter may also help to clearly

[7] Art. 20 FD provides for the resolution of disputes between undertakings providing electronic communications networks or services and also between such undertakings and others that benefit from obligations of access and/or interconnection. As pointed out by BEREC dispute resolutions provide the option to address some specific – maybe urgent – matters (BoR (10) 42, p. 8). Furthermore, NRAs also have the option of defining a relevant market.

[8] Ibid, p.15.

distinguish higher layer applications (e.g. web or VoIP) from lower layer services, i.e. electronic communications services.[9]

*Charging principles*

- "*Interconnection arrangements in IP-based networks exist either in the form of transit [or] peering … . The* direction *of traffic flows does not play a role for these arrangements.*

  *The way transit and peering agreements work implies that the access provider is not entitled to any payment when taking over traffic at his agreed PoI and physically terminating a data flow, e.g. a VoIP call on its network. Such a wholesale regime, where each network bears the costs of terminating traffic coming from other carriers itself, is called Bill & Keep. The carrier will bill these termination cost on its network and any payments for upstream connectivity to its customer. As long as there is sufficient competition for broadband access at the retail level, the access provider has an incentive to keep transit cost low, since too high a cost, if passed on to the end-user, may induce the latter to change supplier*."[10]

- *Bill & Keep prevents exploitation of the termination bottleneck if retail markets are competitive thus reducing the need for regulatory intervention.*[11]

*Quality of service*

- *"Quality of service (QoS) is potentially gaining importance in the interconnection of IP / NGN. …. [QoS traffic classes introduce] a potential for anticompetitive behaviour. This relates to the fact that there might only be a willingness to pay for a premium traffic class in case the best effort class quality is "bad enough". … Therefore, it could be an important focus for NRAs because it could enable new forms of discrimination between a larger operator's services and those provided by interconnecting competitors. … NRAs should have the possibility to recommend or even set minimum levels of quality of service if this is unavoidable to achieve sufficient end-user service quality.*" [12]

*Aim of the project*

The project aims at providing a better understanding of interconnection arrangements between IP networks. More specifically, it provides a rationale for the emergence of more recent forms of IP interconnection and new business models and their interrelationships, identifying possible reasons for these developments. The project will result in a report covering qualitative information on the different types of the commercial IP interconnection agreements. Recent developments of the related markets will be assessed and economic effects will be analysed. This relates to the developments such as the increase in traffic volumes while at the same time the cost of equipment has fallen significantly.

[9] Network and application layers are further elaborated upon in Ch. 2.2.2 of BEREC's "Guidelines for Quality of Service in the scope of Net Neutrality". In the discussion on the separation of layers sometimes a distinction is made between SoIX (service-oriented interconnection) and CoIX (connectivity-oriented interconnection). In ERG (2008), BEREC had already explained the differences between the concepts of SoIX/CoIX and the separation of network and application layers. See also ERG (2007), Ch. A.1.3.

[10] ERG (2008), p. 5/6.

[11] See BoR (10) 24 Rev1.

[12] ERG (2008), p. 16.

The paper will link the topics mentioned with regard to IP interconnection, namely the separation of network and application layers, the relevance of charging principles used and QoS for IP interconnection to the differentiation practices looked at in the context of Net Neutrality.

Some differentiation practices employed by ISPs potentially constituting departures from Net Neutrality may be reflected at the wholesale interconnection level in a departure from the best-effort principle whereas others need not. Finally the regulatory context of IP-interconnection will be assessed with regard to preserving Net Neutrality in the context of IP interconnection.[13] It is (inter alia) assessed whether/under what conditions Art. 5 AD may be applicable. It opens the possibility to intervene when end-to-end connectivity is at stake.

The paper is set up as follows:

- Chapter 2 describes the different players across the value chain (end-users, namely content and application providers as well as content and applications users, Internet Service Providers and Content Delivery Networks) and relating them to definitions used in the Framework.
- Chapter 3 describes different types of interconnection such as peering and transit
- Chapter 4 describes recent changes regarding traffic evolution, pricing developments, revenue flows, changing role of players and new types of interconnection agreements.
- Chapter 5 focuses at the regulatory context.
- Chapter 6 concludes with some hypotheses.

A draft version of this report was published for public consultation on 29 May 2012 until 31 July 2012.[14]

Note: This paper does not intend to explain or define certain general terms and architectural concepts of the Internet (e.g. Border Gateway Protocol, AS, IP address/prefix). For these terms and concepts the reader is referred to BEREC (2012a).

[13] See also BEREC Internal Report on Net Neutrality, BoR (10) 60, December 2010.

[14] BoR (12) 33. This document was published for consultation by BEREC together with two other BEREC draft reports also related to net neutrality. The arguments brought forward by stakeholders and BEREC's considerations are published in a separate Consultation Report, see BoR (12)139.

# 2 Players and business models in the Internet ecosystem

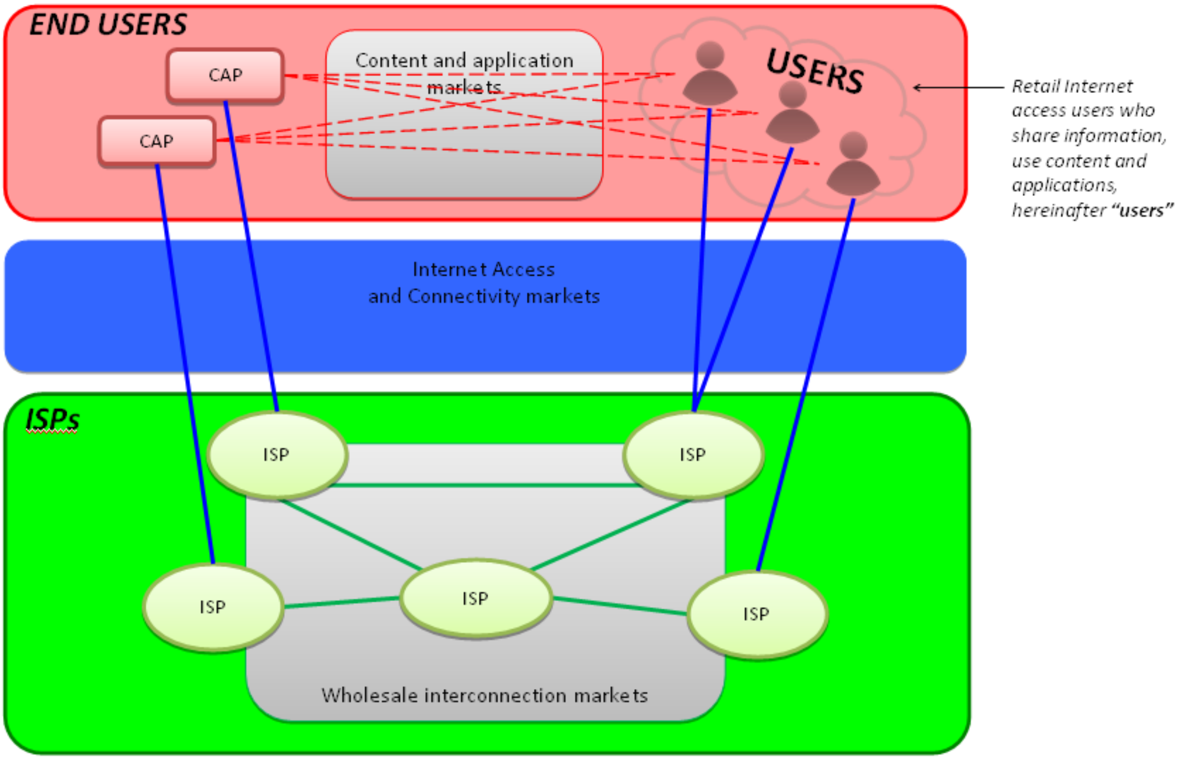
We will look at the whole value chain, including retail markets, to put interconnection and changes in the interconnection pattern into context.

The focus of this paper will however be on the activities of players on interconnection markets, which can generally be described as wholesale rather than retail markets.

In this chapter, players are described in a very stylised fashion concentrating on specific functionalities such as Content and Application Providers (CAPs[15]– Ch. 2.1) and (Content and Applications) Users (CAUs[16] – Ch. 2.2), different types of Internet Service Providers (ISPs[17] – Ch. 2.3) as well as Content Delivery Networks (CDNs[18] – Ch. 2.4).[19]

Actual players will usually perform different combinations of functionalities (e.g. content and applications users may at the same time provide content and applications) along the value chain. This depends on whether or/ to what degree an operator's business model implies vertical integration along the value chain. The following figure illustrates contractual relations between these players:

*Figure 1: Categories of electronic communication services in the value chain*

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15. CAPs create and aggregate content (e.g. web pages, blogs, movies/photos) and/or applications (e.g. search engines, messaging applications). In order to make the content accessible for the users they need to buy connectivity. They may also want to use hosting services

16. The term CAU is used in this report to refer to both, residential (private) users and business users of a broadband/Internet access in their function of passively consuming content.

17 Generically, the term ISPrelates to operators who sell broadband access (network access) and connectivity to the Internet at the retail level which is called Internet access service and at the wholesale level through transit and other forms of interconnection.

18 CDNs serve as aggregators of content usually on behalf of CAPs. They deliver content closer to the terminating network. CDNs typically use their system of caching servers enabling a more local distribution of content to the CAUs.

19 See also BEREC (2012b).

Source: BEREC

The figure above displays in a stylised way commercial relations between different players. In particular it provides in a very condensed manner the main functionalities performed by different players with the red lines indicating an interaction between players on the application layer and the blue lines illustrating an the relationship between end-users and ISPs at the network layer.

- Both CAPs and users interact as producers and users on the "content and applications market" (indicated by the red lines);
- ISPs as network providers sell connectivity to CAPs and users (indicated by the black lines) through "Internet access and connectivity markets" (blue area);
- ISPs interact with each other on "wholesale interconnection markets" (green area, green lines);
- It should be noted that CDNs will be introduced in Figure 2 in Ch. 2.4 below specifying their interactions with other player in the value chain.

In this document the term end-user will be used in the wide sense defined in 2(n) FD[20] as *"a user not providing public communications networks or publicly available electronic communications services"*. This definition encompasses – as illustrated in Figure 1 – different types of end-users, namely those that produce content and applications (CAPs) and users.[21] Note that the term user – as applied in Fig. 1 – relates to persons/entities that, in general linguistic usage, are often called residential users, who mainly *consume* content but who may also *produce* content. Furthermore, users need to have an Internet access.

In order to distinguish more precisely between the generic functionalities performed by different players, Ch. 2.2 introduces the term "Content and Application User – CAU" referring only to the function of passively consuming content and applications. Thus, if such a consumer of content also *provides* content or applications, he provides the function of a CAP.

The way CAPs and users connect to the Internet is basically the same as both have to buy upstream connectivity from an ISP. However, one may generally expect that in case of the CAPs the traffic load is significantly higher in the upstream direction, while users mostly *receive* traffic, unless they also provide peer-to-peer applications. Also some ISPs focus on CAPs as customers (also offering services such as hosting), while other focus on users (the so-called eyeball ISPs).

The retail service of connectivity allowing end users to access all destinations of the Internet presupposes that the Internet is fully interconnected.

The Internet ecosystem is built up by interconnected networks (or Autonomous Systems - AS) forming a common network layer for traffic exchange between Internet end points, i.e. CAPs and users. This separation of application and network layers is intrinsic in IP technology and has more recently been termed "over the top" provision. It implies that CAPs and users can interact with one another at the application layer - including "interconnecting" their applications - without the involvement of the network providers.

The strict separation of application and network layers has also led to a conceptual change with regard to the relevance of distinguishing between "termination" and "origination" as known from the PSTN world. Since, within the network layer of IP networks, incoming and

[20] Art. 2(n) FD *"end-user means a user not providing public communications networks or publicly available electronic communications services"*.

[21] See also the explanatory Note to the Commission's Relevant Market Recommendation not distinguishing between different types of end users when elaborating that retail Internet access consists of two parts, broadband access and Internet connectivity provision (mostly offered as a bundle).

outgoing packets are treated equally, the direction of data flows is of no importance for charging. Consequently, there is no need to differentiate between termination and origination on the network layer. Furthermore, there is usually no possibility of determining at the interconnection point the network of origination or termination of a connection; this implies that the concepts of origination and termination cannot be used for charging purposes.[22] Such a distinction between termination and origination would be relevant only in those cases where the interconnection of applications is considered (e.g. voice over IP).

In this document we deal only with interconnection relating to the physical and logical linking within the network layer.

Art. 2 b AD defines interconnection as the physical and logical linking of public communications networks used by the same or a different undertaking in order to allow the users of one undertaking to communicate with users of the same or another undertaking.[23]

BEREC reiterates that the following illustrations of different players and business models is very stylised. It is also acknowledged that in practice players will often perform different functionalities and/or that categories of players may even overlap.

## 2.1 Content and Application Providers

Content and application providers (CAPs) create and aggregate content (e.g. web pages, blogs, movies/photos) or applications (e.g. search engines, messaging applications).

In order to make the content accessible for the users they need to buy connectivity. They may also want to use hosting services[24].

### *a) Service: core functionalities*

The creation and aggregation of content (or applications) is the “core” functionality provided by CAPs.

### *b) Further functionalities*

CAPs may vertically integrate along the value chain as they get bigger. They may establish (for example) their own hosting capabilities, deploy their own network infrastructures or may provide CDN services themselves. The decision whether/or not to provide such further functionalities reflects the “make or buy” decision a CAP is confronted with. If a CAP is big enough it may be an economically viable option to incur the additional expenses from vertical integration as these are outweighed by enhanced economies of scope. Additionally, they allow more control on the quality of the transmission service.

### *c) Revenues*

The provision of content and applications can be either for free or paid for by the users. A payment from user to CAP for the provision of content can occur independently of the net-

[22] ERG (2008), Ch. B.2.2; see also Ch. 3.3 below.
[23] CAUs and CAPs both constitute end users in the sense that they are intrinsically defined as neither providing ECS nor operating networks.
[24] The core functionality of a hosting service consists in the the provison of server capacity.

work (over the top) reflecting the separation of network and application layers as a fundamental principle governing the Internet. Content and applications can be monetized by CAPs in different ways: either – at the retail level – through “direct” payments, direct subscriptions or e-commerce activities or – at the wholesale level – by, for example, selling data and/or advertising.

### *d) Costs*

Generally, content providers are interested in having highly reliable Internet access and they have an incentive to minimise their expenses.[25] CAPs buy upstream capacity and hosting services from ISPs and/or CDNs. Typically, they do not currently make direct payments to the ISPs providing connectivity to users.

### *e) Examples*

CAPs encompass a wide array of different players: These may be players such as (for example):

- Platforms enabling transactions: e.g. Amazon, eBay.
- Social platforms: e.g. Facebook.
- Search engines: Google, Bing.
- Newspapers (e.g. *The Times*). For newspapers the provision of online content can be complementary (or in fewer cases be a substitute) to the printed version, similarly travel agencies.
- Live and on-demand radio and video services, e.g. broadcasters.
- Entertainment services: e.g. Youtube, Dailymotion, myvideo.
- Application providers: e.g. Skype.
- Video on demand: e.g. Netflix.
- Non-commercially driven providers of content through blogs and other Web 2.0 applications (such content may be provided by players who act predominantly as CAUs as described below).

## 2.2 Content and Application User

| The term CAU is used in this report to refer to both residential (private) users and business users of a broadband/Internet access in their function of passively consuming content. |
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### *a) Service: core functionalities*

Typically, CAUs mainly request downstream traffic volume in consuming the content provided by CAPs. They use free or paid content and services/applications.[26] This can be provided by over-the-top providers or by the ISP of the CAU.

### *b) Further functionalities (resp. vertical integration)*

There may also be an overlapping between the model of CAUs and CAPs. Players that predominantly act as CAUs may also in certain cases act as CAPs and *provid*e content and

[25] Hosting services mainly constitute the provision of server capacity. Since this service is not directly relevant for out analysis we do not focus on it. See also Dhamdere (2009), p. 2.

[26] The terms application and service and its relationship with the Internet access service are specified in BEREC (2012a).

services/applications such as Peer-to-Peer[27] applications, Youtube videos, Internet blogs etc. This may dramatically change (ceteris paribus) the relation between traffic downloaded and uploaded.

Furthermore, the consumption of content may facilitate CAU's participation on product markets facilitated by the Internet (e-commerce), which are however outside the scope of this analysis. The Internet therefore enables everyone connected to the Internet to be an actor on numerous markets, without direct involvement of the network itself.

#### *c) Revenues*

By definition, CAUs of an Internet access use ("consume") the service.

However, they may still generate revenues as they can use their Internet access (for example) for being active on different product markets, e.g. by selling on ebay. The Internet also enables business users to sell products and services. Similarly, government agencies provide services over the Internet (e-Government). In a wider perspective also tele-workers generate "value added" as they work over the Internet and save on transmission cost.

These different types of users provide their services and products over-the-top as this is done independently from the connectivity functionality provided by their ISPs. To put it differently, this provision of services/products would not have been possible without the Internet and its characteristic feature: the separation of application and network layers.

#### *d) Costs*

CAUs incur expenses as they buy network access and Internet connectivity from their broadband access provider/ISP. These payments cover both upstream and downstream transmission of data. Pricing is often on a flat-rate basis; however, other pricing schemes, e.g. based on a maximum capacity, are also applied (especially on mobile).

#### *e) Examples*

Retail CAUs are private households whereas business users may range from small to large business and industry users.

### 2.3 ISP (network providers)

Generically, the term ISP[28] relates to operators who sell broadband access (network access) and connectivity to the Internet at the retail level which is called Internet access service and at the wholesale level through transit and other forms of interconnection.

In practice, this term - ISP - encompasses a variety of players who provide services at different parts along the value chain.

[27] See the Annex to BEREC 2012b for a comprehensive description of the peer-to-peer concept.

[28] The category of ISPs that provide broadband access (network access) and connectivity to the Internet encompasses fixed and mobile network operators as well as mobile virtual network operators (MVNOs).

ISP provide connectivity for different types of customers, e.g. for CAUs and CAPs. Sometimes the main customer group of an ISP is used as a means to classify them.

- "Eyeball ISPs"[29] predominantly sell connectivity to CAUs (residential/business) on the retail broadband and Internet access market as their core functionality.
  - Core functionality:
    - Sell connectivity to CAUs. The retail Internet access market is considered quite competitive, with incumbents' market shares around 43% according to the CoCom statistics in July 2011.
  - Further functionalities:
    - Often, ISPs provide services over the user's broadband connection bundled with the Internet access that compete with for example over-the-top providers. Those facilities-based services are called specialised services[30]. They are electronic communications services that are provided using the Internet Protocol and operated within closed electronic communications networks.[31] The provision of such *additional* services can be a means of increasing customer loyalty. ISPs may also provide their own over-the-top content and applications.
    - Sell connectivity to CAPs.
  - Costs[32]
    - To provide connectivity eyeball ISPs need to buy upstream capacity through transit and/or peering, so that their customers can access content from distant non-affiliated CAPs connected to other ISPs.
  - Revenues
    - The provision of connectivity for users encompassing the transmission of upstream and downstream traffic is the main source of revenue.
    - More revenues may be generated from specialised services as well as the provision of connectivity and/or hosting to CAPs.

- Other ISPs predominantly provide connectivity to CAPs.

  They may also offer services such as hosting[33], proxy servers or DNS services. The hosting market is a complex market of its own that will not be investigated in this paper. This market also comprises a number of pure hosting providers.

  These ISPs generate revenues from the provision of connectivity to CAPs and need to buy upstream capacity through transit and/or peering so that the content of their customers can be accessed from CAUs. This is similar to the case of "eyeball" ISPs.

  Examples: 1&1, Strato.

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[29] Examples of eyeball ISPs are incumbents such as BT, France Télécom, etc. However, competitors can also act as eyeball ISPs.

[30] See BoR (11) 53 *"A Framework for Quality of Service in the Scope of Net Neutrality"* (Chapter 4.5).

[31] For details see BEREC (2012a)

[32] Obviously, an ISP that provides an (access) network also incurs costs for its network.

[33] Note: The fact that these ISPs sometimes provide not only connectivity but also hosting services was the reason why in BEREC (2012b) used the term "hosting and connectivity providers" (HCP).

- Backbone ISPs provide transit service for other ISPs.[34] Generically, they only provide wholesale services for third parties (peering and transit). However, they may also vertically integrate along the value chain, e.g. by providing connectivity to large users.

  Examples: Level3, Global Crossing, Cogent

## 2.4 Content Delivery Networks

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|---|
| CDNs serve as aggregators of content usually on behalf of CAPs. They deliver content closer to the terminating network. CDNs typically use their system of caching servers enable a more local distribution of content to the CAUs. |

### *a) Service: core functionalities*

Generically, a Content Delivery Network (CDN) is a system of servers, deployed at the edge of (or within) the terminating ISPs network, that CAPs can use to distribute their content. CDNs do not interfere with the network layer of the ISPs. They do not provide connectivity but operate on top of the network layer on upper layers and in that sense can be qualified as a CAP (such as caching, server load balancing) on the Internet (grey CDN box).

Figure 2 below additionally shows CDN coloured in grey/green. This represents the case of CDNs that do not only provide the core functionalities of CDNs at the application layer but also operate their own network and therefore do not need to buy connectivity[35] from an ISP. This is indicated by the partially green area in the grey CDN box.

The CDNs' servers are strategically placed at various locations at the network edges to enable rapid, reliable access from any CAU location. By doing so, CDNs provide better performance through caching or replicating content over the mirrored servers in order to deal with the sudden spike in content requests. Stored content is kept current and protected against unauthorised modification.

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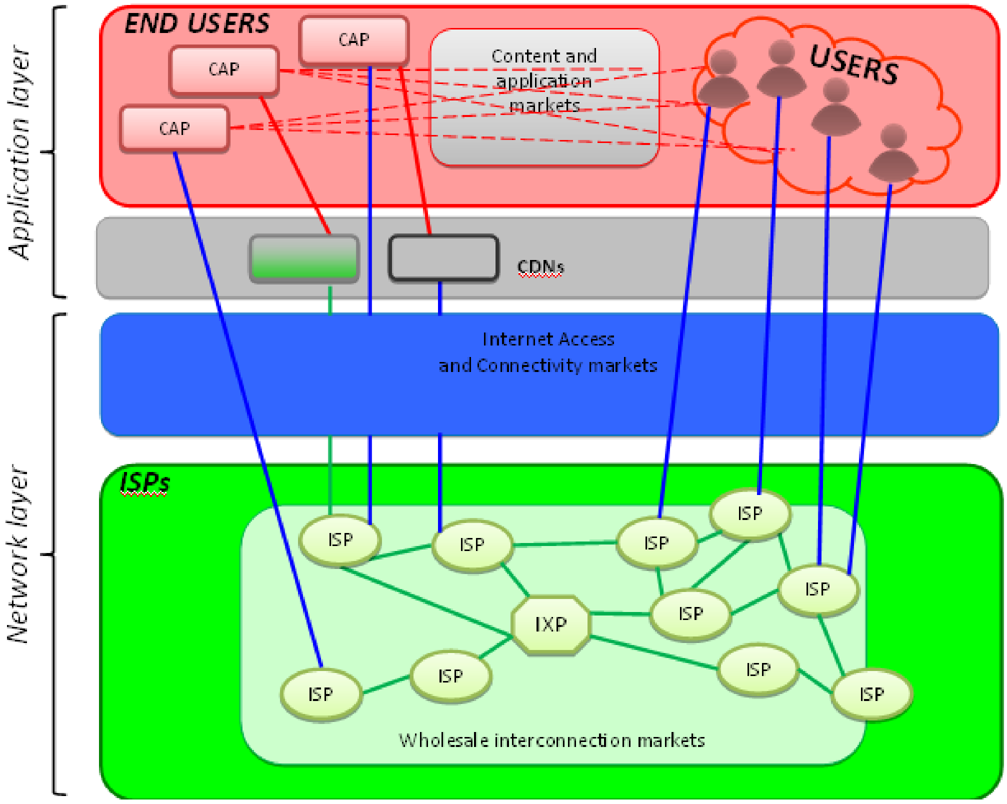
[34] Such backbone ISPs can be of a different size (tier 1 ISPs / tier 2 ISPs).

[35] Thus, for these „grey/green CDNs" the blue line does not cross the blue area „Internet access and connectivity markets". All other players need to buy connectivity and thus the blue line crosses that blue area.

*Figure 2: Categories of electronic communication services in the value chain*




Source: BEREC

The users are redirected to the caching server nearest to them. Thus, the CAU ends up unknowingly communicating with a replicated server close to it and retrieves files from that server. This approach helps to reduce network impact on the response time of user requests.

By reducing the network's impact on the overall (end-to-end) quality, CDNs increase the CAU's perceived service quality when for example web browsing[36] watch videos.

### b) Further functionalities

Nowadays, CDN offer value-added services such as conditional access, digital rights management (DRM), region-restricted delivery, etc.

The different services provided by CDNs are targeted at the different types of content (e.g. video services, game services, software distribution updates, webpage proxying and application acceleration) which the content providers want to distribute. Each type of content has its own characteristics (amount of data, up- and/or downstream, peak traffic, hard- and software to speed up programs) for which different CDNs can provide added value.

In some cases a more infrastructure based business model may be chosen whereby a CDN – in addition to its core functionality – also operates a network, thereby connecting its servers. Level 3 and Limelight are examples of such CDNs.

[36] For detailed information on the effects of network performance on end-user QoS, see BoR (11) 53 "A Framework for Quality of Service in the Scope of Net Neutrality", chapter 4.

### *c) Legal classification of CDNs*

Since CDNs have evolved only recently and the contractual situation is often unclear there are still a number of open and challenging questions with regard to the legal classification of CDNs under the Regulatory Framework. Some of these questions have been addressed by recent studies carried out by/for PTS[37] ARCEP[38], and NPT[39]. Based on these studies, some preliminary arguments are put forward in this section with regard to a possible legal classification of CDNs. More specifically the following questions are raised:

- Do CDNs offer electronic communications services (ECS)[40]?
- Do CDNs operate a telecommunications network (ECN)[41] in the sense of Art. 2 FD?

A number of criteria evolve from the legal definition of ECS in the FD that help identifying such services: ECS therefore have to be normally provided for remuneration and to consist wholly or mainly in the conveyance of signals on electronic communications networks. The studies from PTS, ARCEP and NPT have construed this latter criterion as containing a requirement that the ECS provider has control over, or is responsible for the transmission.

With regard to its core functionality, a CDN offers CAPs to bring their content to various server locations at the network edges, where it is stored and kept current and thus enables a rapid, reliable access from any CAU location.

This service by the CDN is publicly provided and normally paid for, but would not consist wholly or mainly in the transmission of signals. The CDN runs servers and buys connectivity to the Internet for transmission between its servers like any other application provider. In this sense, it is using the Internet but not providing transmission infrastructure for this service itself and thus may not be held responsible for it. Therefore – following the criteria developed in the survey by NPT – there are some reasons that the core functionality of a CDN may not be held to qualify as an ECS. For the same reasons, such a core-functionality CDN could not be classified as a network operator either, since it uses the Internet merely as a transmission infrastructure like other content and application providers.

In an infrastructure-based model, the CDN also runs the infrastructure to connect its servers and,in addition to its core functionality, offers to transmit the CAP's data via this infrastructure. With regard to this offer for transmission services – which is provided in addition to the core service that CDNs provide – both ARCEP and NPT found that this service could qualify

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37 PTS-ER-2009:12, Which services and networks are subject to the Electronic Communications Act? http://www.pts.se/en-gb/Documents/Reports/Internet/2009/Which-services-and-networks-are-subject-to-the-Electronic-Communications-Act/

38 Étude sur le périmètre de la notion d'opérateur de communications électroniques, carried by Hogan Lovells and Analysys Mason on behalf of ARCEP, June 2011. http://www.arcep.fr/uploads/tx_gspublication/etude-Hogan-Analysys-juin2011.pdf.

39 See NPT report "Content Delivery Networks - regulatory assessment", May 2012.

40 Electronic communications services are defined as "*a service normally provided for remuneration which consists wholly or mainly in the conveyance of signals on electronic communications networks, including telecommunications services and transmission services in networks used for broadcasting, but exclude services providing, or exercising editorial control over, content transmitted using electronic communications networks and services; it does not include information society services, as defined in Article 1 of Directive 98/34/EC, which do not consist wholly or mainly in the conveyance of signals on electronic communications networks* (Art. 2 lit c FD).

41 Art. 2 lit a defines electronic communications networks as *"transmission systems and, where applicable, switching or routing equipment and other resources, including network elements which are not active, which permit the conveyance of signals by wire, radio, optical or other electromagnetic means, including Satellite networks, fixed (circuit- and packet-switched, including Internet) and mobile terrestrial networks, electricity cable s<stems, t the extent that they are used for the purpose of transmitting signals, networks used for radio and television broadcasting, and cable television networks, irrespective of the type of information conveyed*". The provision of such network is defined is defined as "*the establishment, operation, control or making available of such a network*" (Art. 2 lit m FD).

as an ECS, since this additional offer consisted wholly or mainly in the conveyance of signals.

According to the studies by ARCEP and NPT, such an infrastructure based model a player could qualify not only as a CDN, but also as a network operator, since the transmission system might constitute an ECN in accordance with Art. 2 lit a FD. However, it remains unclear whether these ECNs are also public electronic communications networks. While NPT held that the providers of such CDN services in most cases only used the transmission capacity "in-house", and therefore the network could not be regarded as a "public communications network" (Art. 2 lit d FD), ARCEP's study came to the opposite conclusion since the additional CDN communication services provided over the network were available to the public. In this case the player would execute core functionalities of both a CDN and a network operator, which would lead to an overlapping of functionalities.

### *d) Revenues*

CDNs generate revenues from CAPs for whom they provide services. Services are often billed on a Mbps basis[42] or per Mb consumed but other approaches such as billing on a per-click basis also apply. Value added services (e.g. Digital Rights Management, regional restricted delivery) may in some cases generate more than half of a CDN's revenues.[43]

### *e) Costs*

Typically, CDNs need to manage their local storage servers (e.g. by buying hosting capacity) and buy transit or manage their network infrastructure.

### *f) Examples*

There is great variety of CDN providers ranging from:[44]

- *pure* CDNs: e.g. Akamai (servers only)
- those *also* operating a network: e.g. Limelight,
- network providers and ISPs: e.g. Level 3, AT&T
- CAPs: e.g. Google, Amazon (Cloudfront)
- equipment and solution vendors are also positioning themselves in this market:[45] e.g. Cisco, Juniper, Alcatel Lucent

CDNs also differ with regard to their geographic footprint. CDNs can provide services on an international, national or regional level.

[42] http://blog.streamingmedia.com/the_business_of_online_vi/2011/11/cdn-pricing-stable-in-q4-down-about-20-for-the-year.html: it is reckoned that 60 % of contracts for video are based on a Mbps basis.
[43] Cisco, Global CDN market forecast
[44] See also Ch. 4.4.4.
[45] IDATE (2010), slide 10.

# 3 Types of IP-Interconnection

In this section we will look at different types of IP-interconnection also drawing on previous ERG documents on IP interconnection[46]. They can be mainly classified into transit and peering agreements, the latter also occurring with the facilitation of Internet Exchange Points (IXPs). All of these types of interconnection are typically based on the best-effort principle. A final section looks at the status of interconnection arrangements involving some form of QoS assurance.

The basic strategy of IP interconnection differs fundamentally from interconnection of legacy telephone networks because of the underlying switching technology used. IP networks are packet switched whereas legacy telephone networks are circuit-switched:

- In a circuit-switched environment end-to-end connections (calls) are set up by interconnecting circuits (lines). Given that the transmission characteristics of all interconnected lines are matching, an end-to-end transmission channel allowing, for example,. voice communication is created. This process needs to be initiated for each call. Hence, interconnection of circuit-switched networks is call-based and billed accordingly.
- Packet-switched networks do not rely on end-to-end channels but transfer the information in separate independent pieces of information (packets). Each packet is routed through the network autonomously and thus the transport network has no information on the end-to-end relationship of the packets transferred, i.e. it is application-agnostic. At the interconnection point packets are simply exchanged without taking into account packet-forwarding strategies followed within the interconnected networks. [47]

The end-to-end control of the communication functions of end user services (e.g. voice telephony) is inherently integrated in the circuit-switched network through the use of fixed end-to-end transmission channels. Packet-switched networks on the other hand, have these functions implemented in end points (hosts) connected to the network. Transferring packets is the only function left to the network. Therefore, interconnection of packet-switched networks cannot rely on service-based information or service instances (calls). The criterion for charging of IP interconnection is generally the capacity at the interconnection point. Consequently, interconnection agreements only involve conditions of access to and the capacity of the interconnection interface.

Traffic from distant (non-affiliated) content/application providers connected to other ISPs generally reaches the eyeball ISP through peering/transit interconnections in IP networks. Interconnection between the networks of the different ISPs has developed in multiple forms (peering, transit, paid peering, partial transit etc.).

[46] For details see for example ERG (08) 26final, Ch. B.2.2 “Interconnection in existing IP-based networks” and Ch. B.2.3 “Differences between interconnection in the PSTN and in IP-based networks”.

[47] The Internet protocol is a connection-less protocol. This means that at the IP layer there is no information available on the relationship of a flow of packets. Consequently IP networks nodes cannot interfere with application/service functions in order to, for example, identify and process voice calls. The introduction of such mechanisms in interconnection nodes would require the implementation of additional packet inspection functions. This would add an artificial complexity that is alien to the IP system and thus would hamper its effectiveness.

## 3.1 Transit

Transit is typically a bilateral agreement whereby an ISP provides full connectivity[48] to the Internet for upstream and downstream transmission of traffic on behalf of another ISP or end user including an obligation to carry traffic to third parties.[49] It sells access to all destinations in its routing table.[50] Transit is a wholesale product against a payment.

Typically, the rationale of transit agreements is "bill your customer and pay your upstream-provider". The end-user pays his ISP for connectivity to the Internet. Therefore as long as there is sufficient competition at the retail level, the ISP has an incentive to keep transit cost low. Too high a cost, if passed on to the end user, may induce the latter to change supplier.[51] An access provider however is not entitled to any payment when taking over downstream traffic at his agreed PoI and physically terminating a data flow as this is paid for by the end user."[52]

Whereas transit typically provides *full* connectivity, in other cases "partial transit" is applied which is a more limited form of transit whereby an ISP provides access to only some part of the global Internet, e.g. to a certain region or to a given subset of AS.

***Costs and revenues***

Payment for transit services used to be based on peak capacity (Mbit/s). Typically, the maximum of both directions determines the price for the transit service provided. However it increasingly becomes a metered wholesale service where the "*direction of traffic flows does not play a role. For billing purposes, there is no need to distinguish between origination and termination.[53] In transit agreements, the Internet/broadband access provider pays for connectivity to the upstream network for upstream and downstream transmission of traffic."*[54] Payments for transit cover both outgoing and incoming traffic.[55].

Often, a 95th percentile measurement is applied to determine the volume of traffic exchanged for billing transit services.[56] With this scheme, traffic samples are taken at intervals of (for example) five minutes. At the end of the billing period (typically a month), the samples are ranked by size and the top 5 % of traffic is discarded and the 95th percentile is billed.

The decision between transit and peering follows an opportunity costs rationale and is subject to optimisation by the provider requesting the service. Whereas transit involves (in particular) variable costs, fixed costs are predominant with peering (see below Chapter 3.2.1).

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48 In this paper the term *connectivity* is used for the product that ISPs sell to their customers (i.e. to CAUs or CAPs, see figure 1) whereas transit is provided *between* ISPs (wholesale level). The technical background of connectivity is given in RFC 4084. It should be noted that in some papers the connectivity and transit are used synonymously, as they provide both connectivity to the "whole" Internet.

49 See ERG (2008).

50 It should be noted that in practice transit does not imply that the ISP can guarantee access to *every single* IP address, see WIK-Consult (2008), p. 71, footnote 134.

51 ERG (2008), p. 6.

52 ERG (2008), p. 6, note: this also holds for peering (see next section).

53 Note: Since there is generically no distinction between origination and termination of data flows in IP networks (see above at p. 11) this also holds for peering, see next section.

54 ERG (2008), p. 5, 6.

55 ERG (2008), p. 48.

56 WIK-Consult (2008, p. 71) points out that the 95th percentile approach was often used in the mid-1990s.

## 3.2 Peering

| |
|---|
| Peering is a bilateral agreement between ISPs to carry traffic for each other and for their respective customers. Peering does not include the obligation to carry traffic to third parties. The exchange of traffic typically occurs settlement free. |

Peering is a business relationship whereby companies reciprocally provide access to each other's customers (each other's customer's customer etc). Thus, unlike transit, peering does not provide full connectivity to the Internet.

In more technical terms peering constitutes a non-transitive relationship. If A peers with B, and B peers with C, then A gets access only to the customers of B but not the customers of C.[57]

### 3.2.1 Rationale for peering

***Peering requirements***

Traffic is typically exchanged settlement free subject to a number of requirements set out in the peering polices of an ISP. Peering policies are generally classified according to the degree of "openness":[58]

- Open peering policy: peering with anyone
- Selective peering policy: peering with some requirements
- Restrictive peering policy: not generally interested in peering with anyone else (beyond those peering relationships already in place)
- No-peering policy: no peering at all.

They may encompass requirements such as:[59]

- Specification of a ratio between outgoing and incoming traffic. In practice, such a traffic ratio is typically one of several factors when operators decide whether to peer with other operators.

- Traffic volume and/or capacity: peering policies may require a certain traffic volume, which is often based on the size of the networks. The peering policy of an ISP may require a minimum capacity for the links of a prospective peer.

- Geographic reach: the geographic scope often is a relevant requirement as it relates to the investments made by an ISP.

  When two peers exchange traffic the principle of hot-potato routing applies. The network from which the traffic originates from will hand over this traffic as early as possible to the other network (and vice versa). Thus if a "small" network X hands over its traffic to a "big" network Y, the latter will have to carry that traffic over a greater distance (than in the opposite case: traffic from "big" to "small" network). In order to exchange traffic the big network Y would (ceteris paribus) have to make bigger investments than the smaller network. This would imply that the small network free-rides on the big networks infrastructure. This is also the reason why typically a larger network

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[57] See for example Laffont, Marcus, Rey, Tirole (2001), Internet Interconnection and the Off-Net-Cost Pricing Principle, 23 April 2001, p. 3.

[58] www.drpeering.net.

[59] See Faratin et al (2008), p. 56; Analysys Mason (2011), Annex A.2.3; WIK-Consult (2008), p. 74.

is not inclined to peer with a smaller network or requires its partners to hand over the traffic at particular points.

In practice, ISPs sometime do not simply require a balance of traffic flows. Instead, in particular large networks may require a rough bit-mile parity, the rationale being that the costs of an ISP are driven by the amount of traffic carried, multiplied by the distance it is carried.[60] The bit-mile concept is primarily used by backbone ISPs peering with other backbone ISPs.

- Geographical requirements: it may be foreseen that traffic must be exchanged in multiple locations across the country (number and location of peering points) or even worldwide. This requirement aims at a more balanced distribution of traffic and helps to keep local traffic in the same region.

- Consistent announcements: an ISP may require consistent Border Gateway Protocol announcements across the peering links.[61]

- Marketing considerations: ISP X may not be inclined to peer with ISP Y if Y is a potential transit customer for X. Moreover, if two potential peers compete for the same customers in the CAU market, ISP X would not be inclined to peer with Y if the latter derived greater advantage from a peering agreement.[62]

- Other aspects: factors such as the number of customers, specific service level requirements or the number of IP addresses served may also become relevant although they are not directly related to the costs of deploying the network infrastructure. These factors rather aim at ensuring that enough traffic is exchanged to warrant the transaction costs incurred.[63]

If a network hosts content which is valuable for the CAUs of another network this also affects an ISP's propensity to peer. On the one hand the ISP has an interest that its CAUs can access valuable content. On the other hand this may lead to very imbalanced traffic flows (see below paid peering).

Generally, if the peering policies of two prospective peers are compatible so that they peer with each other, it is (roughly) ensured that both parties derive a similar value from peering.

***Costs of peering***

Even when peering is applied on a settlement free basis, peers face some costs. The decision whether to peer or to buy transit follows an economic rationale. Several cost components apply with peering; for example:

- costs for transmission to the peering point
- collocation costs (space, power)
- port costs
- equipment costs.

Besides these transaction costs for building and supervising a peering relationship occur. Given the CAPEX incurred for these cost positions and the transaction costs involved it is

[60] WIK-Consult (2008), p. 74.
[61] Faratin et al (2008), p. 56: "*Consistent announcements allow a peer to hot potato traffic, inconsistent announcements force a peer to cold potato traffic.*"
[62] WIK-Consult (2008), p. 74.
[63] WIK-Consult (2008), p. 74, Footnote 140.

plausible that peering requires traffic volumes to be big enough so that unit costs are lower than in the case of transit.

***Peering motivations***

If two operators agree to exchange traffic on a settlement-free basis, this can be interpreted as arrangement to save transaction costs of exactly measuring and billing traffic flows.

ISPs may also have an incentive to peer with other ISPs in order to reduce transit costs. Directly exchanging traffic with another ISP that is willing to peer avoids the costs of having to buy transit otherwise.

However, peering may also be the preferred option because it contributes to an improved performance. If two operators mutually agree to exchange traffic on a peering basis this induces lower latency than traffic which otherwise would have to be routed via a transit provider before being handed over to the peer.

Peering may also allow ISPs to have greater control over the routing path and performance of traffic. If a poor performance path is preferred by the routing protocols, an alternative path can be configured.[64]

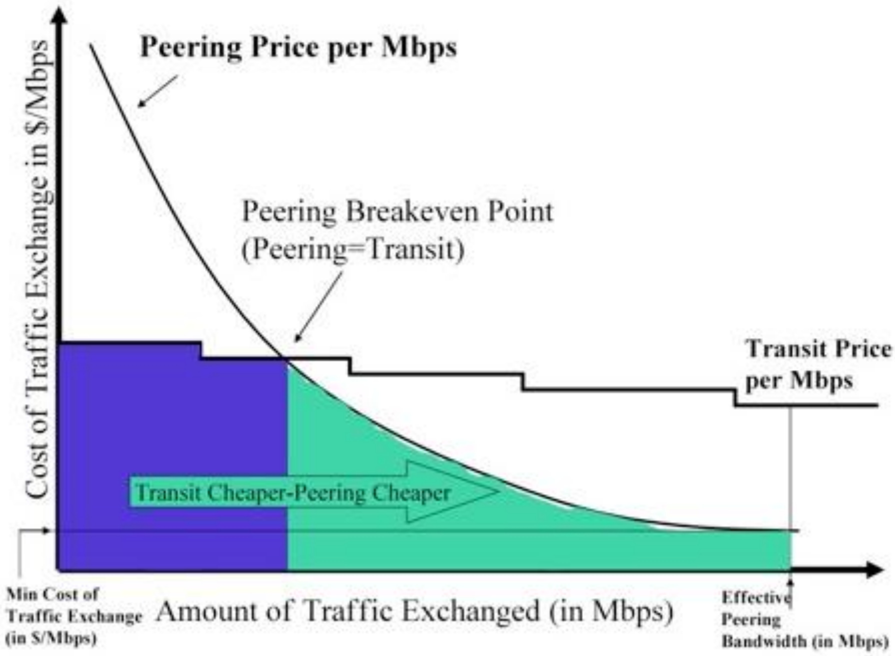
Whereas transit is a provider/customer relationship peering is rather of a symmetrical nature. Two parties will typically agree to peer with each other only if both expect to be better off than without peering. In this respect, an agreement to peer implies a Pareto improvement for the involved parties. Peering is ultimately a barter exchange which is mutually beneficial for the parties involved.

***Decision to peer or to buy transit:***

ISPs that fulfill the requirements for peering can choose between peering and buying transit and therefore are able to substitute between these two forms of interconnection. The decision whether to peer or to buy transit is a matter of network planning and cost optimization, as transit causes costs for conveying traffic but saves CAPEX investments in one’s own network infrastructure and hence saves operating costs while simultaneously assuring an appropriate performance level (see Figure 3 below).

[64] Norton (2003).

*Figure 3: Peering vs. Transit*[65]




Source: Dr. Peering
http://drpeering.net/AskDrPeering/blog/articles/Ask_DrPeering/Entries/2012/9/18_The_Great_Remote_Peering_Debate.html

The Peering Break Even Point in the figure above is defined as the point where the unit cost of peering exactly equals the unit cost for transit.

In most instances, operators will employ both transit and peering arrangements, i.e. they can also be used as complements.[66]

ISPs that do not fulfil requirements for peering must buy transit. Transit can be viewed as a default option.

The peering market is generally taken to function more or less competitively as long as ISPs have a choice of transit providers.[67] The price decline, both for peering and transit, can be interpreted as reflecting the close relation between these two options.[68]

### 3.2.2 Further Types of Peering Arrangements

***Secondary / Donut / Regional Peering***

In the early days of the Internet peering when there were only a few providers, everyone peered with everyone. When the number of providers increased and different tiers of provid-

[65] Note that this figure presents the costs of transit and peering in a very stylised way. Given that transit is often paid on peak capacity (Mbit/s), the line indicating transit prices would not be horizontal but rather sloping downwards but by far not as steep as peering.

[66] ERG (2008), p. 49., see also WIK-Consult (2008), p. 72.

[67] ERG (2008), p. 6.

[68] "Dr Peering" reasons that peering has a "gravitational pull on transit prices" (http://drpeering.net/AskDrPeering/blog/articles/Ask_DrPeering/Entries/2012/1/27_Peering_Gravitational_Pull on_Transit_Prices.html).

ers emerged (tier 1, 2, 3), peering applied primarily between tier 1 backbone providers. With secondary peering two lower tier ISPs (i.e. who are no tier 1 providers) directly exchange traffic[69]. If two users exchange content on a peer-to-peer basis it is economically for the involved ISPs to directly exchange traffic instead of buying transit. This saves transit costs and reduces latency.

For example, Google – while building out its own networks – increasingly peers directly with tier 2/3 providers or eyeballs. About 60 % of Google's traffic is handled without using transit.

In practice sometimes smaller or regional networks (but also content providers operating networks) directly exchange traffic among each other. In this case there is a chain of bilateral peering agreements. This is called donut peering. With this form of peering the involved ISPs circumvent to route traffic via tier 1 ISP. Donut peering may be considered a reaction to the fact that tier 1 ISPs typically are not inclined to peer with other networks (restrictive peering policy).

***Paid Peering***

Unlike settlement-free peering, with paid peering (also called settlement based peering), the exchange of traffic is paid for. However, the way of announcing prefixes and forwarding traffic is the same as with settlement-free peering (this also applies to transit).

In practice, paid peering may apply where the traffic imbalance exceeds a certain threshold.[70] Whether or not payments are justified may depend not only on the traffic ratio (im)balance but more generally on the bit-mile parity (see 3.2.1 above) and possibly other factors that constitute peering requirements.[71] Bargaining power of the parties involved may play a role in practice.

Whereas settlement-free peering usually requires some ratio of traffic flow to be fulfilled reflecting the value of the flow for the operators involved, it is claimed that paid peering gains relevance where traffic flows are increasingly asymmetric.[72] This was the case with the rise of video content on the Internet. It is estimated that a three-minute video on YouTube generates 35 times more downlink than uplink traffic implying that there is significantly more traffic from the content providers towards the ISP than in the opposite direction.[73] It should be noted that, as of 2011, only 0.27% of peering contracts are paid for.[74] However, this does not allow an absolute assessment of the quantitative relevance of the volumes exchanged under paid peering contracts, in other words, the volumes handled under paid peering may exceed 0.27%.

### 3.2.3 Internet Exchange Points (IXPs)

An Internet Exchange Point (IXP) is a place where multiple ISPs interconnect their respective networks.[75]

[69] Analysys Mason (2011, p. 32) uses secondary peering and direct interconnection as synonyms.
[70] Analysys Mason (2012), p. 33
[71] If, for example, a CDN or hosting provider routes its traffic on a cold-potato basis, this impacts not on the (im)balance of traffic but on the bit-mile parity.
[72] Faratin (2008), p. 60; Analysys Mason (2011) p. 24. However, owing to the "private" nature of peering agreements, evidence on whether there is a trend towards paid peering is rather anecdotal.
[73] Analysys Mason (2011) p. 24.
[74] Weller/Woodcock (2012), p. 62.
[75] Norton (2012).

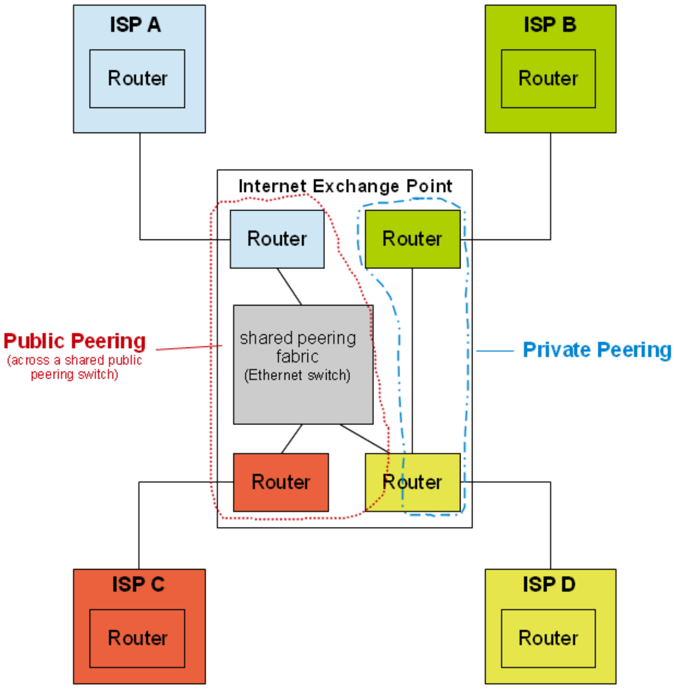
Internet Exchange Points (IXPs), or as they were used to be called Network Access Points (NAPs), constitute another institutional setting for the exchange of traffic, where ISPs can voluntarily participate and where they agree to interconnect at a multilateral peering point to exchange their traffic without needing to buy transit from an upstream provider and thus reducing costs as there are usually no payments for the exchange of traffic [76]. The Internet players have long adopted this interconnection model whereby many ISPs meet to exchange their traffic with other providers, each bearing the cost of transmitting the IP traffic to the IXP/NAP.[77] Moreover, Internet Exchanges may also improve network resilience.

More specifically IXPs can be used as/for:

- a) Multilateral peering point: using the shared peering fabric, peering is public.
- b) Bilateral peering point: using the shared peering fabric, peering is public.
- c) Bilateral private peering: not using the shared peering fabric.
- d) Transit.

Public and private peering can be distinguished as follows:[78]

*Figure 4: IXP model*




Source: Norton (2012)

***Public peering:***

Public peering involves several operators peering across the shared peering fabric (Ethernet switch). This fabric interconnects the respective edge routers of the ISPs which peer. This form is most common at an IXP.

Internet Exchanges often allow a multilateral form of peering arrangements. If several players are involved in an IXPs peering arrangement network effects play an important role. The more operators are connected to the IXP and the more traffic is exchanged at this point the more attractive it gets for other operators to peer at that IXPs as well.

76 Costs may be covered by annual or monthly fees, depending for example on transmission speeds used.
77 ERG (08) 26, p. 49/59.
78 Norton (2012).

***Private peering:***

With private peering two operators exchange traffic at the IXPs across a dedicated cross-connect between them. In practice, IXPs often support both, public and private[79] peering.

***Further functionalities IXPs may provide:***

Besides their generic function of enabling public or private peering IXPs may provide a variety of services/functionalities such as (e.g.): route server, DNS and root name servers and routing tools. IXPs may also provide interconnection for specific services. For example, the DE-CIX has launched "DE-CIX NGN"[80] enabling the exchange of VoIP and NGN services across platforms. "DE-CIX NGN" also provides federation services. The members of such an interconnection federation can exchange services with each other based on their community's rules instead of signing individual contracts. Furthermore, some IXPs have started establish partnerships thereby allowing the exchange of traffic among their respective members.[81]

***Costs:***

If several players are involved in peering this causes significant transaction costs. In this respect the IXP model can be interpreted as a means of economizing the transaction costs of concluding bilateral peering agreements with many individual players. Generally, the IXP model involves significant set-up costs but low variable costs

More specifically, peering at an IXP involves the following cost items:[82]

- Transmission fees for getting the traffic to the exchange point:
  Monthly costs for the physical/data link media interconnection into the peering location. These transmission costs are not metered but billed on a fixed-capacity basis.

- Collocation fees:
  Expenses for operating network equipment in a data centre suitable for operating telco equipment.

- Equipment fees:
  Costs incurred for the equipment needed;

- Peering port fees on the exchange point's shared fabric:
  Monthly recurring costs associated with peering across a shared peering fabric.

Examples for such IXPs are the AMS-IX in Amsterdam, the LINX in the London or the DeCIX in Frankfurt. Typically, IXPs in Europe are operated on a non-profit basis.[83]

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79 Within the context of this chapter the term „private peering" refers to the exchange of traffic at the IXP via a dedicated cross-connect. However, there are also private peerings where the involved operators directly interconnect without using the IXPs facilities.

80 http://press.de-cix.net/press-releases/, 20. September 2012

81 For example between AMS-IX and NAMEX (see http://www.namex.it/en)or between TOP-iX/VS-IX/LyonIX (see http://www.top-ix.org/en/internet-exchange/ ).

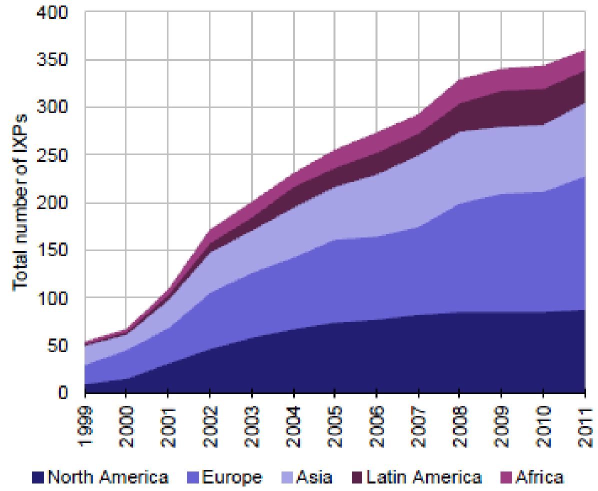
82 Norton (2012).

83 Norton concludes that "(P)*ricing in Europe for IX services tends to approximate a cost-based pricing model*" (http://drpeering.net/white-papers/European-Vs-US-Internet-Exchange-Point-Model.html).

***Developments:***[84]

According to Analysys Mason there is a tendency towards a regionalisation of IXPs as in all regions of the world there is an increase in the number of IXPs over time:[85]

*Figure 5: Number of IXPs in the world (by region)*




Source: Packet Clearing House, Analysys Mason estimates[86]

More specifically, in Europe the number of IXPs has increased over time. In 2011 there were 144 operating IXPs in Europe.[87] Generally, for recent years, growth has continued although at a lower rate.

This development seems plausible as more regional IXPs (ceteris paribus) implying a more local exchange of traffic, improves latency and saves on payments to upstream providers as tromboning is reduced.[88] Furthermore, the price for regional connectivity has also fallen significantly, making intra-regional traffic more affordable.[89]

### 3.3 QoS interconnection

<u>QoS traffic classes on the Internet?</u>

Given the connection-less nature of the Internet protocol, IP packets are forwarded independently within the IP-layer of the networks, i.e. IP networks are concerned with traffic forwarding irrespective of the context. This network-centric view implies a network design and transfer functions focused on most efficient capacity utilisation of the overall network infrastructure avoiding occasional traffic peaks. The traffic management strategy to be applied is to transfer and aggregate traffic in such a way that traffic peaks at local spots are avoided and that aggregated packet flows are exchanged using the most effective routes.[90]

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84 See Ch. 4.1 addressing the regionalization of traffic
85 Analysys Mason (2012), Ch. 4.2.1
86 C.f. Analysys Mason (2012, p. 16)
87 Euro-IX (2012), Ch. 2.1
88 Analysys Mason (2012, Ch. 4.2.1 and 4.3.5. Accordingly, the establishment of the Kenya Internet Exchange Point (KIXP) eliminated tromboning saving Kenyan ISPs USD 1.5 million p.a. on international connectivity charges (p. 30).
89 Ibid, p. 16
90 The algorithm used for calculating the interconnection point to be used is based not only on purely technical aspects (e.g. choosing the shortest route, less congested route) but also on economic factors such as price for transit routes.

There are several technical mechanisms available for doing so. The important aspect – compared with legacy circuit-switched network strategies – is that there is no end-to-end view. The networks act autonomously focusing on resolving local (network-to-network and segment-to-segment) traffic demands.

Interconnection takes place at the backbone segment of the ISP's infrastructure. The traffic transferred within the backbone and exchanged with other networks is highly aggregated. Because of the aggregation the backbone traffic is independent of traffic variations of individual end user accesses and therefore the actual amount of backbone traffic to be dealt with can be easily estimated based on the mean traffic demand of the majority of access lines. The traffic characteristics are statistically stable, i.e. there is no significant traffic peak load variation over time. This allows for adequate planning of the interconnection capacity needed. There is no need to implement additional traffic management mechanisms to cope with traffic variations (load peaks) at the interconnection point.

The previous sections have addressed different types of IP interconnection such as peering or transit. These arrangements relate to the current Internet ecosystem that consists of interconnected independent networks (autonomous systems) via edge/border routers. The interconnection SLAs (Service Level Agreements) includes rules on availability, throughput capacity and resilience of the edge/border routers, i.e. the interconnection connection at the interconnection interface. Any arrangements on the quality conditions of the exchanged traffic (i.e. forwarding performance of single packets or streams of packets between end points) across interconnected networks are not part of the peering and transit agreement. Each ISP manages the traffic transfer within its network autonomously.[91]

The backbone networks transfer the aggregated traffic received from the access and aggregation networks between the edges of the backbone networks. Neither the final source and destination of the contained packets nor the kind of application of the packets is of relevance within the aggregated stream. Within the backbone network traffic is routed based on the ingress and egress points of the backbone network or – in case of interconnection – of the interconnected backbone networks. Label switched traffic management strategies (such as MPLS) are used in order to reliably exchange data between the edges of the backbone networks. QoS – being an end point-to-end point concept – cannot be applied across these networks since no end point information is transferred across backbone sections. This would be possible only by implementing additional connection-oriented protocols into the network nodes in order to create an additional communication control layer on top of the IP layer. However, this would significantly increase complexity and needlessly overstress the system. At the same time, it would also increase costs, thereby making the return on investment unclear compared to extra capacity roll-out.

Therefore, QoS-assured interconnection did not play a role within the context of peering and transit. Despite this, there has been a discussion about QoS interconnection with guaranteed traffic classes across networks for some years now. However, it needs to be considered that the economic rationale for implementing QoS and its welfare implications hinge very much upon the scarcity of resources. While such scarcity may exist in access networks, this is not

[91] BEREC (2011), See chapter 4.1

the case for backbone networks. Within this paper interconnection issues are addressed, thus, the focus is on backbone networks (i.e.not on access networks.) [92]

The following explanations provide some further insights into these issues of QoS in the context of IP networks:[93]

With the migration from legacy circuit-switched networks towards packet-switched IP technology, telcos hold that QoS agreements across networks are necessary in order to maintain the established high quality level of traditional telecommunication (telephony) services.

QoS interconnection aims at enabling guaranteed end-to-end IP services, i.e. the transfer of user generated traffic between network termination points over (several) interconnected IP-based networks with guaranteed end-to-end performance objectives. The term end-to-end when used within an interconnected IP network environment differs slightly from the boundaries normally implied by the phrase end-to-end. Traditionally – especially with legacy circuit-switched networks – end-to-end quality has rather a user-centric than a network-centric perspective. It is related to the performance of the whole communication system, including all terminal equipment (e.g., for voice services, end-to-end is equivalent to mouth-to-ear quality).

Both QoS and QoE[94], from the broad end-user service point of view, include many parameters which are beyond the control of the ISP offering connectivity, such as the terminal equipment and local network (e.g. home network) as well as end-user expectation and context – as opposed to the Internet access service it is delivering.

This concept cannot be maintained on the Internet, since the network layer is decoupled from the application/content layer. The “CAU service” is delivered on top of the IP network. Thus the end-to-end quality in terms of article 22(3) USO D relating to the practices of operators is concerned only with the IP packet transfer at the network layer, i.e. the network performance. Network performance is the concept used for measurement of the performance of network portions under the control of individual providers[95]. When interconnecting several IP networks the performances of the single networks are summed up to an end-to-end network performance from UNI (user network interface) to UNI[96]. The end-to-end network performance (UNI-to-UNI) is referred to as end-to-end IP service or traffic class.

Therefore, IP interconnection within the Internet ecosystem relates to the interconnection only at the network layer, not at the application layer (e.g. interconnection of voice application domains). QoS interconnection is related to the quality of IP traffic classes and their maintenance across networks.

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92 In access networks the IP packet transfer capacity is limited per end user because of headline speeds of the access lines and the dimensioning (overbooking) of the aggregation network. The default traffic transfer strategy used is the best-effort principle. Together, both factors – limited access resources and best effort communication – imply varying transmission conditions. The individual end user may encounter congestion and therefore, it could be reasonable to implement QoS by means of various traffic management technologies. These can be application-agnostic or application specific (for further detail see BEREC (2012a), Ch. 3.3.1.) These measures are of no relevance in the backbone network since the aggregated amount of traffic is stable and not time varying. The backbone networks needs to be dimensioned accordingly. All the more because for fibre technology bandwidth is not a limiting factor.

93 Note: A more detailed analysis of these issues will be provided in BEREC (2012a)

94 Note that the quality-related definitions QoS and QoE are based on the ITU recommendations. However, the Internet community uses a slightly different terminology. IETF defines Quality of Service as “a set of service requirements to be met by the network while transporting a flow” (RFC 2386) which is similar to ITU’s definition of network performance. See BoR (11) 53 “A Framework for Quality of Service in the Scope of Net Neutrality” (Chapter 4.2).

95 See BEREC (2012a)

96 The concepts of end-to-end quality and layers of IP networks are described in detail in BEREC 2011 Chapters 4.2 and 4.3

IP traffic classes are expressed in terms of performance objectives for IP packet transfer parameters (typically mean and variance of delay, and the likelihood of packet loss). These objectives are applicable at the interfaces between two reference points, normally the ingress and egress points of the network or network segment under consideration. There are several traffic management mechanisms[97] and protocols (e.g. DiffServ, IntServ, MPLS) available to support traffic classes between these reference points. These mechanisms, however, are valid only within the specific network or network segment. Within the IP layer there is no native control function to maintain such traffic classes across networks. Therefore QoS interconnection cannot reliably be implemented across networks at the IP layer.

While the creation of traffic classes *within* IP based networks (intra-network performance) is common, the agreement on traffic classes *across* interconnected networks is either not or hardly available in practice. QoS Interconnection with guaranteed traffic classes across networks has been discussed for many years by telecommunications network providers intending to migrate their networks towards NGN[98]. It requires agreement on harmonised traffic classes and end-to-end implementation of protocols for, for example, allocation of performance budgets and "QoS signalling" (e.g. priority marking) for management and aggregation of IP packet streams. The challenges of providing QoS across interconnected networks have been described in some detail by ERG 2008 (Chapter. B.3.5 and Annex 3.1).

In particular, there are a number of reasons why QoS interconnection has not gained relevance up to now:[99]

- QoS is an end-to-end concept that is not natively supported by the connection-less Internet protocol. Adding such functionality would require the implementation of additional protocols on top of the IP layer. Also, control layers have to be integrated into the network architecture. This would significantly increase the technical complexity of the system, involving additional cost and thereby increasing the maintenance and administration effort.

- The *transaction costs* associated with negotiating QoS-sensitive interconnection arrangements with a large number of interconnection partners, and of monitoring compliance with the terms of those agreements, have been insurmountable.

- There is a lack of transparency about what constitutes a "premium" quality level and whether the customer is actually receiving this level of quality end-to-end. End-to-end SLA, auditing and reporting including billing and settlement processes are costly to implement.

- Network externalities[100] imply that the value of higher quality services increases as more destinations are reachable using the service. To put it differently, there needs to be a sufficiently large penetration to get past the initial adoption hump. Operators may be confronted with a prisoner's dilemma, where no individual party has an incentive to be the first assuring QoS in its network.

- While not providing a guaranteed quality level of data delivery, the best-effort approach of the Internet does not imply low performance. Given this, it may not have been an economically viably strategy for operators to implement QoS guarantees across networks.

[97] Traffic management issues of QoS issues are dealt with in BEREC (2011) Chapter 4.4) and BEREC 2012a
[98] See, for example, ITU-T concept for international IP data communication services and framework for achieving end-to-end IP performance objectives (ITU-T Rec. Y.1540 – Y.1543).
[99] Marcus (2006), Ch. 3.2.2.
[100] See also BEREC (2011), Ch. 4.3.2.3

Best-effort Internet results in most cases in a (relatively) high quality of experience for users, even for delay-sensitive applications such as VoIP.[101]

- Given the best-effort transmission characteristics, other mechanisms for improving end-to-end traffic exchange performance have developed:
  - Endpoint based congestion control for reduction of the traffic load in order to limit the congestion and avoid overloading the network;[102]
  - Internet Exchange Points, increased use of peering in order to improve routing;
  - CDNs are used in order to store data more locally thereby reducing latency. This ultimately improves the CAU's perception of an application's quality (QoE – Quality of Experience).

- Customers are consequently unwilling to pay much of a premium for better service.

- Traffic classes using prioritisation introduce an incentive to decrease the quality of the "best effort" class vis-à-vis premium classes to create a willingness to pay for premium quality. This creates the need for more regulatory control including the potential need for a minimum quality of service, introducing additional monitoring requirements.

- Given the high cost of implementation possibly adding capacity has continued to be the strategy of choice. Thus, the question whether implementing end-to-end QoS across networks is economically a viable strategy in the future is largely affected by the costs of simply adding more bandwidth.[103]

Summing up over the internet a guaranteed end-to-end QoS offer is neither commercially nor technically realistic. Differentiated services, which fall just short of guaranteed end-to-end QoS, exist but continue to be exceptional, for the reasons listed above and not because they are anywhere prohibited)

<u>QoS interconnection for specialised services</u>

Specialised services are electronic communications services that are provided using the Internet Protocol[104] and operated within closed electronic communications networks e.g. by allowing for end-to-end control of these communication services.

- Specialised services do not directly interfere with the best effort Internet or other IP networks. These closed IP networks rely on strict admission control and they are often optimised for specific applications based on extensive use of traffic management in order to ensure adequate service characteristics.[105]

- For specialised services the network layer and the application layer are no longer separate to enable end-to-end control available at the application layer.

- For the offer of specialised services (such as business VPNs and IPTV offers), end-to-end control is inevitable. This is brought into force by the implementation of QoS traffic classes within the network architecture.

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[101] The fundamental underlying principle is that the application compensates for the variable and non-guaranteed traffic exchange characteristic of the best effort Internet and thus ensures high end user perceived quality. In other words, the strict network performance constraints that are mandatory for circuit-switched networks by design are not required in packet-switched networks.

[102] See BEREC (2011) Chapter 4.4.

[103] See Ch. 4.2.1 below.

[104] Specialised services may also comprise non-IP-based services such as cable television or circuit switched telephony, but the focus in these guidelines is on IP-based service provisioning.

[105] For details see BEREC (2012a)

- The provision of specialised services such as IP-TV does not necessarily require traffic classes across interconnected networks if the service is provided within one operator's network.

- In case a competitor uses Bitstream access to provide a specialised service, the whole-sale bitstream product will need to allow for QoS features.

Today the complete range of quality techniques is used for specialised services, from best-effort corporate networks and VPNs to IPTV and VoIP with guaranteed QoS.

- Telco operators across Europe currently discuss or implement interconnection regimes for voice frequently as a specialised service using Session Border Controllers. Interconnection between such voice service networks would typically rely not on the Internet connectivity but on dedicated interconnection of these network resources across different voice networks. However, network operators more or less independently determine limits for the network performance to be achieved within their network and agree to abide to the limits. However at this stage they do not foresee negotiation of binding transmission QoS performance objectives ensuring end-to-end control for voice services. Some operators want to use the established Calling Party Network Pays systems for this kind of interconnection.

Therefore, differentiation practices that potentially imply a deviation from Net Neutrality may occur with or without out impacting on interconnection agreements that are concluded at the network layer.

<u>QoS interconnection and deviations from Net Neutrality</u>

- If traffic classes were implemented across networks this would need to be reflected in interconnection agreements at the network layer.
- Differentiation in the treatment of specific traffic categories such as P2P (e.g. throttling or blocking) constituting a potential deviation from Net Neutrality generally takes place in the network controlling access to the CAUs. In such cases it is not reflected in IP interconnection across networks.
- Potential violations of Net Neutrality such as blocking and throttling of traffic typically occur in the eyeball ISP's network and are therefore not reflected in IP interconnection across networks.
- If higher-layer applications used by CDNs are employed by some CAPs, this will lead to a different QoE for the CAU from applications not employing such techniques. Even a CDN operating its own network to connect server locations employing QoS does not require QoS interconnection across networks. This will therefore typically not be reflected in interconnection agreements at the network level.

# 4 Recent Changes

## 4.1 Traffic evolution

Generally, two factors impact on the increase in traffic:

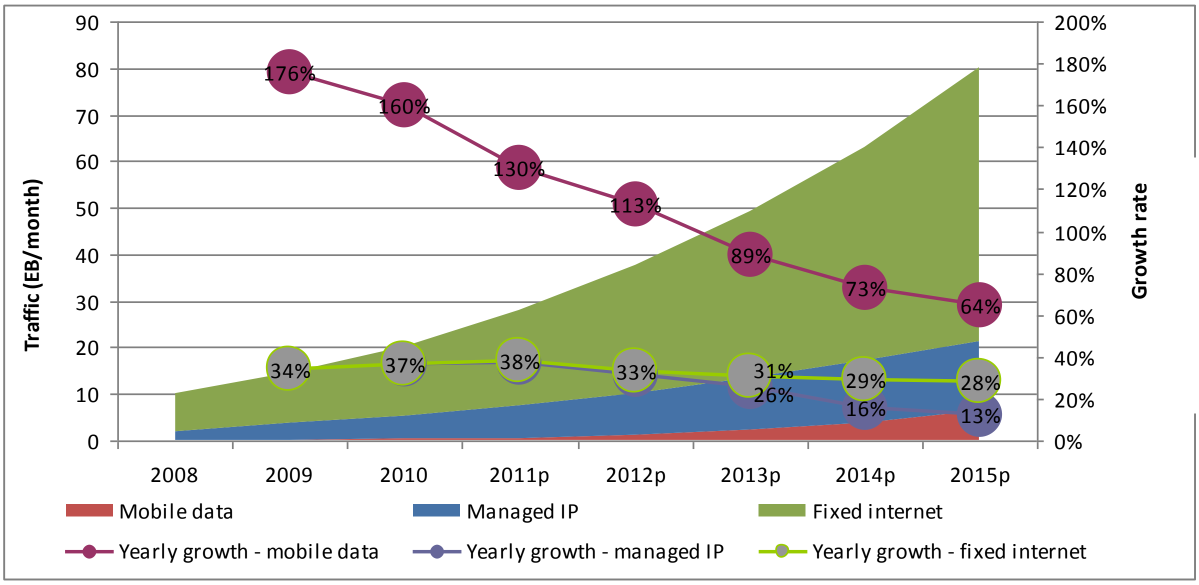
- the increase in the number ofsubscribers and
- the increase in traffic per subscriber.

While the absolute number of fixed broadband subscribers is still increasing, the rate of growth shows a slight decline.[106]

It can be shown that the growth of total IP traffic is particularly driven by the traffic growth per subscriber whereas rate of growth in number of subscribers plays a smaller role.[107] This underlines the importance of keeping best-effort performance in line with use.

The following figure shows that volume of total IP traffic is still increasing; however, the growth rate is declining. Cisco forecasts a slowing down of the annual rate of growth of total global IP traffic to 27 % in 2015 (28 % for fixed Internet). For Europe, the annual growth rate of international bandwidth usage levelled off to approximately 50 % in 2010. [108]

*Figure 6: Global IP traffic developments*




Source: Cisco

For mobile data traffic, the rate of growth is higher than for fixed data traffic. However, this is particularly because the increase in mobile traffic starts from a significantly lower level. In 2011, mobile had a share of approximately 2 % of total IP traffic. Whereas the growth rate for global mobile data traffic was about 130 % in 2011, it is expected to decline to 64 % in 2015.[109] Analysys Mason expects mobile to grow at an annual rate of 29 % from 2012 to 2017 and points out that Western Europe has the lowest growth rate in mobile data out of 8 worldwide regions.[110]

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106 WIK-Consult (2011), Ch. 2.5, likewise Telegeography.
107 For details see WIK-Consult (2011), p. 35/36.
108 Telegeography (2011).
109 WIK-Consult (2011, p. 31/32) based on Cisco and WIK calculations.
110 http://www.analysysmason.com/About-Us/News/Insight/Mobile-data-growth-Sept2012/

- **Changing traffic types**

  - The increase in those types of traffic that are rather sensitive to latency and are bandwidth intensive, i.e. video) contributed to the rising use of CDNs. As more content is stored closer to the consumer, using CDNs allows the need for transit to reduce.

  - In 2010 P2P traffic represented the largest share of Consumer Internet traffic in 2010 (approximately one third). However, its share is declining. Cisco estimates a share of P2P traffic as 22 % for 2012.[111]

  - Increase in streaming and direct download: While the share of P2P traffic is likely to decline, it is forecast that Internet video streaming and direct download will grow to nearly 60 % of all consumer Internet traffic in 2014. Cisco had projected that, by the end of 2010, global Internet video traffic would surpass P2P traffic. [112]

    For example, Carpathia Hosting, a provider of managed hosting services – accounts for 0.5% of all traffic. Spotify has chosen Carpathia Hosting to provide hosting services for the US start of Spotify.[113]

- **Regionalisation of traffic**

  In Europe 20% of content is produced (and hosted) nationally, around 25% within Europe and 25% in the US. The percentages of total Internet traffic in Both US and Europe growing. The regionalisation of traffic is particularly due to the following factors:

  - A large part of content is provided nationally (language based).[114]
  - The way content is stored and forwarded contributed to the regionalisation of traffic. CDNs operate a system of distributed caching servers allowing for a more local distribution of content. At the same time the use of CDNs implies a circumvention of tier 1 providers.
  - The trend towards peering arrangements between operators other than tier 1 backbones contributed to this regionalisation of traffic as (ceteris paribus) more traffic is conveyed circumventing the networks of global backbone providers.
  - Regionalisation contributes to improved network performance and also saves transit costs.

BEREC considers that all of these factors contribute to a further regionalisation of traffic. These factors may also relate to each other, e.g. CDNs may also serve as a mean to store and forward national content (i.e. language based). Very generally, regionalisation (ceteris paribus) lowers the cost of distributing content and – at the same time – enhances the quality provided.[115]

On a global scale, Analysys Mason points out to shifting traffic patterns such that the majority of traffic originates within a region. Whereas in 1999 about 30% of European Internet traffic went to the US (or Canada), this percentage had fallen to roughly 15% in 2011.[116] The same trend also holds for Asia, and – with some delay – also for Africa.

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[111] Cisco (2010) p. 11.
[112] Ibid, p. 9, see also Labovitz et al (2009) also predicting that P2P will be eclipsed by streaming and direct download.
[113] http://de.nachrichten.yahoo.com/spotify-beauftragt-carpathia-hosting-mit-einf%C3%BChrung-den-usa-000000992.html.
[114] See Boston Consulting Group (2012).
[115] See also Analysys Mason (2012), p. 15.
[116] Analysys Mason (2012), Ch. 4.2.3 and 4.3.1.

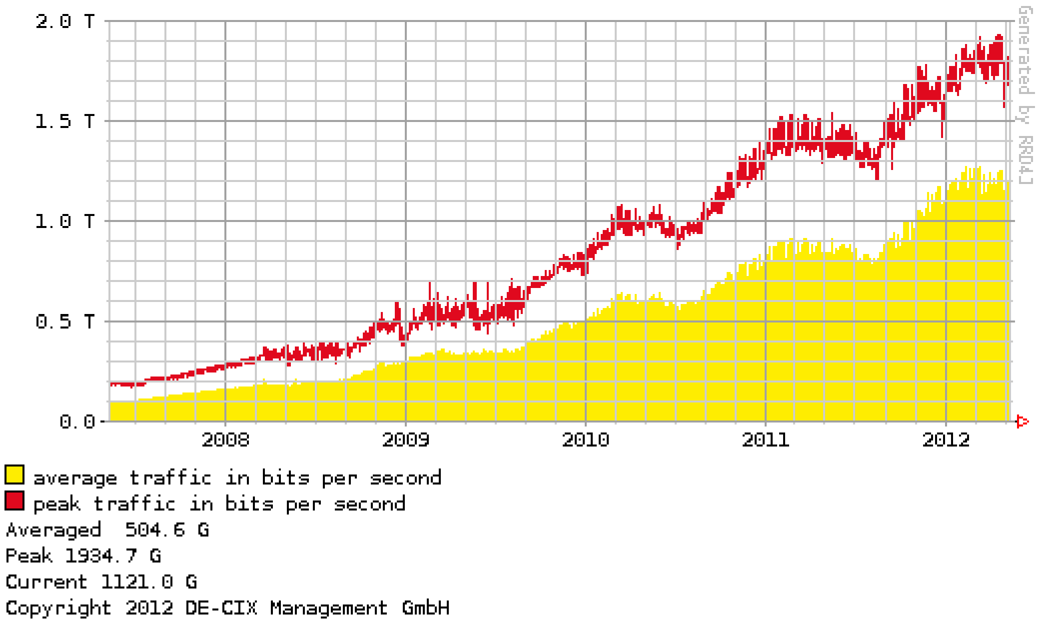
- **Development of IXPs**

Generally, the traffic volumes at the biggest European IXPs – DE-CIX, AMS-IX, LINX – are characterised by a constant growth.

For example, average traffic throughput at the DE-CIX reached approximately 500 Gbit/s at the end of 2010, approximately 800 Gbit/s at the end of 2011 and approximately 1.250 Gbit/s at the end of April 2012.

Next to the growth in traffic, some IXPs have started to form partnerships thereby allowing the exchange of traffic among their respective members.[117]

*Figure 7: Traffic development at the DE-CIX, 5 year graph*




Source: http://www.de-cix.net/about/statistics/

The current average throughput of the AMS-IX is 1.041 Gbit/s (April 16, 2012)[118] whereas it was about 750 Gbit/s at the end of 2011. For the LINX the corresponding figures are 745 Gbit/s[119] (18 March 2012) and approximately 600 Gbit/s at the end of 2011.

IXPs in Europe are typically operated on a non-profit basis. It is noteworthy that among the largest IXPs the largest *pure* US IXP ranks 12 with an average throughput of 100 Gbit/s (18 November 2011). [120] Equinix, which ranks third among the largest IXPs, is also a US corporation; however, it operates IXP facilities not only in the US but also in Europe.

[117] For example between AMS-IX and NAMEX (see http://www.namex.it/en) or between TOP-iX/VS-IX/LyonIX (see http://www.top-ix.org/en/internet-exchange/ ).

[118] http://en.wikipedia.org/wiki/List_of_Internet_exchange_points_by_size.

[119] http://en.wikipedia.org/wiki/List_of_Internet_exchange_points_by_size.

[120] http://en.wikipedia.org/wiki/List_of_Internet_exchange_points_by_size.

## 4.2 Pricing and costing developments

### 4.2.1 Decreasing costs in core and backhaul networks

The overall cost position of network operators for backhaul and core networks[121] is mainly driven by two factors:

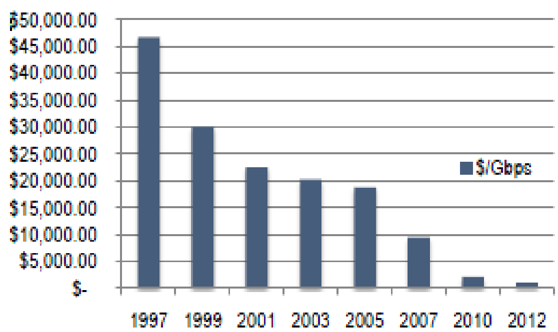
- the increase in overall traffic volumes: Generally, increasing traffic volumes – both in fixed and mobile networks – imply higher absolute costs for network operators if they have to invest in additional equipment. Cisco forecasted a volume increase of 35 % in Europe for the 2010-2013 period;

- technological improvements impacting both, overall and particular per-unit costs of a network operator. Moore's law provides an interesting illustration that technological progress leads to significant performance improvements. In 1965 Gordon Moore stated that the number of integrated circuits on a computer chip was doubling every 18-24 month.[122]

With regard to technological progress there is ample evidence of falling equipment cost; for example:[123]:

- In the core network costs for routers and optics showed significant declines over the years. The following figure from Cisco illustrates that the costs per Gbps for its routers decreased at an annual rate of 23 %: (1997-2012).[124]

*Figure 8: Router costs $ per Gbps*




Source: Cisco (2010a) *"IP NGN Backbone Routers for the Next Decade"*

- A presentation by Deutsche Telekom provides a similar picture,[125] pointing out to "tremendous achievements in transmission & router performance". Building upon Ovum's figure, it observes a "constant decline of transmission cost per Gbit/s and km" and a router performance exceeding Moore's Law forecast.

- Costs for routers and DWDM optics are major cost drivers affecting the usage-based costs of fixed core networks. The costs per gigabyte for DWDM optoelectronic equipment was also subject to a continuous price decline whereas the total DWDM capacity is

[121] Note that we do not look at costs for the last mile as those are mainly driven by the number of users rather than by traffic volumes. As pointed out by WIK-Consult Moore's Law is much less relevant at the edge of the fixed network.

[122] Originally, Moore had assumed a doubling every 12 months.

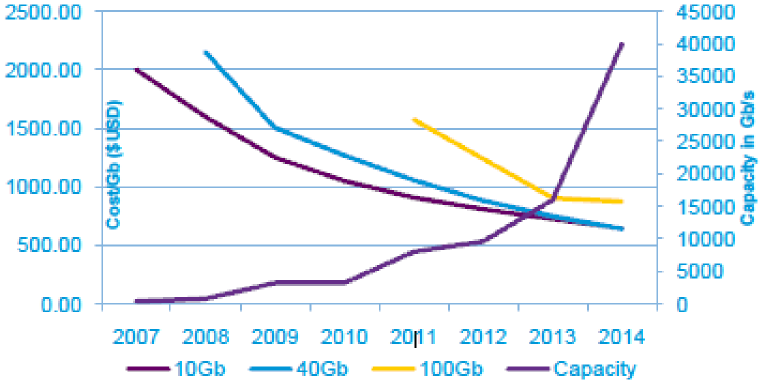
[123] Further evidence is summarised byKenny (2011)

[124] Similarly, WIK-Consult (2011, p. 18) states that the unit price of high-end routers declined over the period 2006-2011 by 26 % on average per year.

[125] Orth (2011), slide 13.

expected to rise significantly in the near future (2012-2014). Other cost items such as labour costs are much less usage-sensitive. Overall, large economies of scale are involved when capacities are increased. [126]

*Figure 9: DWDM optic cost and DWDM capacity*



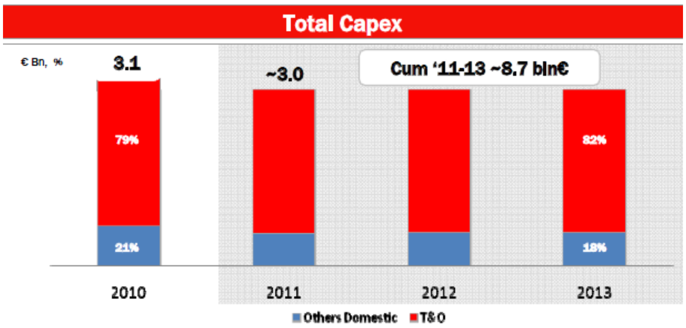

Source: Cisco (2010a) *"IP NGN Backbone Routers for the Next Decade"*

- Transit prices have fallen approx. 36 % annually since 1998.[127]

Taking account of volume and equipment cost developments, CAPEX projections of operators for the financial community do not seem to indicate a significant cost increase following from the expected increase in traffic, see for instance:

- Telecom Italia[128] foresees a slight decrease in CAPEX until 2013

*Figure X: Total CAPEX 2010-2013*




Source: Telecom Italia (2011)

- FT Orange[129] expects the CAPEX (excluding FTTH) to decrease from 12.6 % of revenues (2011-2012, p.a.) to 10 % (2014-2015);
- And between 2006 and 2010 investments made by French operators "remained fairly stable" as pointed out by ARCEP.[130]
- Arthur D. Little[131] expects CAPEX spending by telecom operators to remain remains relatively stable with a 0.7 % CAGR 2010-2014.

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[126] WIK-Consult (2011, p. 18) estimates that the average annual price decline per unit over the period 2006-2011 is about -16 %.

[127] http://drpeering.net/white-papers/Internet-Transit-Pricing-Historical-And-Projected.php

[128] Telecom Italia (2011), slide 15. FY10 Results & Plan Update, Franco Bernabe, Febr. 25 2011, slide 15 http://www.telecomitalia.com/tit/en/investors/presentations/2011/2010reults-plan-update.html

[129] FT Orange (2011), slide 21

[130] ARCEP (2012), p. 23

[131] Arthur D. Little (2011), Telecoms Infrastructure Supplier Outlook, cited (21. Sept. 2012) from: http://teletimesinternational.com/articles/3945/are-suppliers-poised-for-a-turnaround

The period 2007-2010 showed an annual increase in IP traffic (Western Europe) of 52 % while CAPEX for Western Europe declined overall by 6 % between 2007 and 2010. This would not give rise to expectations of significant CAPEX increase to accommodate a projected traffic increase by 35% between 2010 and 2013.[132]

A number of studies and models have generated results with regard to the relationship between volume increase, equipment cost and CAPEX required accordingly. Most studies provide evidence that we may rather expect cost improvement to outweigh traffic growth than the other way around and therefore no dramatic increase of CAPEX is to be expected.

- Studies from WIK[133] or Plum do not foresee a cost explosion due to the traffic increase. Moreover they conjecture that in fixed networks the decrease in unit-costs is not overcompensated by the increase in volume implying that there is no substantial increase in overall costs.

- AT Kearney has modelled the CAPEX required to meet the expected increase in traffic of 35 % for European fixed Internet traffic 2010-2014 (based on Cisco projections).[134] AT Kearney concludes that approximately €10 billion of additional CAPEX spending is required to accommodate the (fixed Internet) traffic forecast.[135]

  In order to better assess whether the €10 billion of additional CAPEX calculated by AT Kearney for the period 2010-2014 is a "high" or "low" figure, the CAPEX figure has been put into context. Given this period of 5 years the average incremental CAPEX p.a. amounts to €2 billion. Compared with the overall CAPEX of 14 European telcos, which amounted to €46.2 billion in 2011 (Bloomberg data) this implies that less than 5 % of overall CAPEX is needed as incremental investment in order to accommodate the expected increase in traffic. This figure indicates that the traffic increase – while implying significant CAPEX requirements in *absolute* terms – does not lead to "exploding" CAPEX requirements.

  One of the crucial assumption for deriving this result hinges on the moderate rate of 15 % cost improvement in the unit cost of capacity each year. There is evidence (see above) that this estimate may be too low.[136]

- WIK has built a software-based analytical cost model emulating a national core and backhaul network. Model applications for the case of Germany have been conducted, including cost estimates for increasing traffic demand[137] in accordance with Cisco estimates[138]. The results show that both concentration and core networks display significant decreases in average costs (CAPEX) when traffic is increasing. Enormous economies of scale exist in particular for the links (layer[139] 0 and layer 1 investment) whereas layers 2 and 3 costs also inhibits economies of scale albeit limited to the system capacity available in the market.

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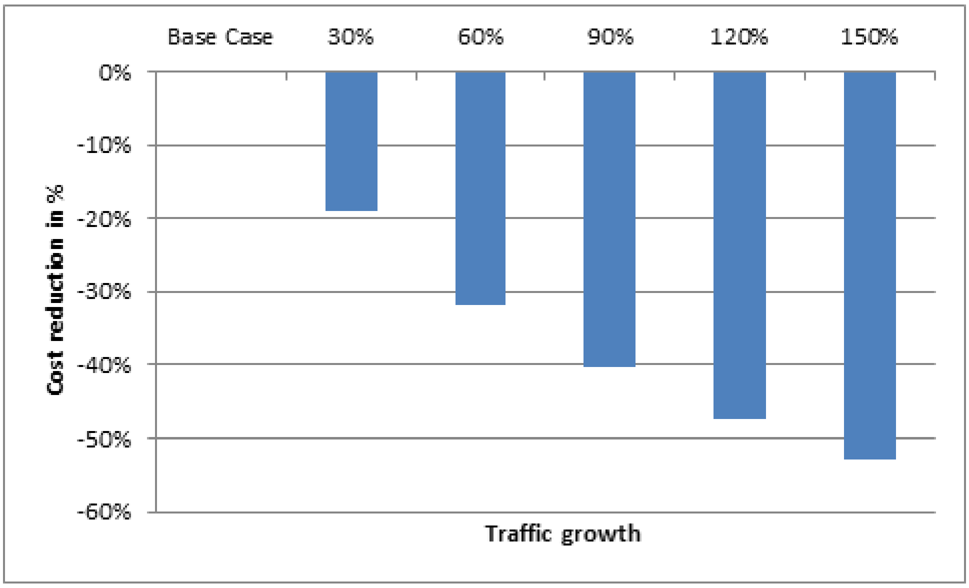
[132] See Kenny 2011 , Fig 2 refering to Berenberg Bank (2011)
[133] WIK-Consult (2011), see Ch 2.3 and Plum Consulting(2011, Ch. 2.2)
[134] AT Kearney, "A viable Future Model for the Internet" (2010), Ch. 3.2.3
[135] Ibid, p. 17
[136] For a detailed critique of this study, see Kenny (2011).
[137] Traffic increase was induced by a higher bandwidth used per customer rather than an increase in customer lines.
[138] WIK (2012b) These cost calculations were based on WIK's "Analytical Cost Model for the Broadband Network". A linear traffic growth of 30 % p.a. (related to the base year) for busy hour traffic for private and business customers was assumed. As a starting point, 100 kbit/s (busy hour) for DSL was assumed for 2012. WIK has calculated network costs by elements using a Total Element Long Run Incremental Cost (TELRIC) methodology.[138]
[139] These layers correspond to the ISO/OSI reference model

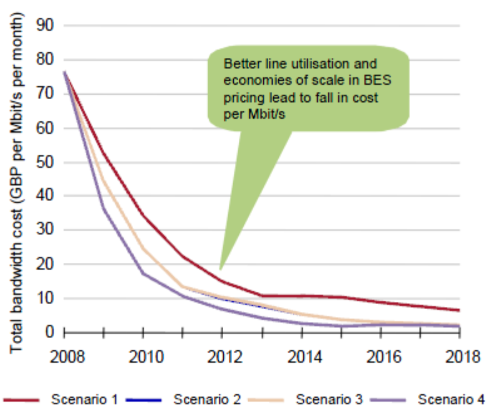
*Figure 10: Cost decreases: layer 0, 1, 2, and 3 from MPoP to top core level nodes*




Source: WIK

- A report from Analysys Mason addressing the effects of delivering high-quality video services online[140] shows that the cost of bandwidth falls significantly for the period considered. This is because of economies of scale from higher-capacity circuits and improved line utilisation.[141] According to Analysys Mason "LLU-based operators can exploit economies of scale in the backhaul network that will allow traffic to grow significantly, with minimal impact upon costs."[142]

*Figure 11: Total bandwidth cost per Mbit/s for an LLU operator*



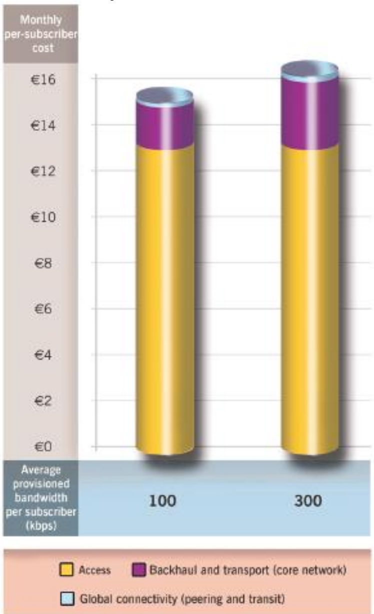

Source: Analysys Mason (2008), Figure 6.9, p. 44

- ARCEP have calculated incremental network costs for a new entrant providing fixed Internet access on the basis of regulated wholesale products, both, for a baseline scenario with an average consumption per user of 100 kbit/s (busy hour) and for an-

140 Analysys Mason (2008)
141 Ibid, p. 43.
142 Ibid, p. 44.

other with 300 kbit/s.[143] The calculations covered access networks, backhaul and backbone networks and costs incurred for ensuring global connectivity[144]. ARCEP concludes that so far, the long-term trend has been characterized by decreasing incremental unit costs for traffic as a result of technical progress thus offsetting the effects of traffic increases.[145]

*Figure* 12*: Change in monthly cost per subscriber depending on average consumption for a generic operator*




Source: ARCEP (2012)

The figure above displays the overall results for the two scenarios showing that overall, network costs only increase to some extent if traffic volumes are increased by factor three.[146] Given that the costs for the access network account for approx. 85% of network costs and that (lower) backhaul and backbone costs are only partially traffic sensitive, an increase in average consumption per user from 100 to 300 kbit/s does only imply an increase of overall network costs of 6-12%.

***Mobile networks:***

- In mobile networks, capacity restrictions play a greater role than in fixed networks because of spectrum limitation and the density of base stations. Latest mobile technolo-

[143] ARCEP (2012) has used its regulatory model for unbundled access costs and backhaul costs. Costs for deployment of next generation access networks were not looked at. Backhaul cost are based on a mixture of regulated wholesale product prices for LLU (87%) and bitstream (13%). For Bitstream access the wholesale access prices imputed in the model are based on different technologies with widely differing prices (25% Ethernet 6 €, 25% IP and 50% of ATM 70€),

[144] Fixed access network costs amount to €13 per subscriber per month (= roughly 85% of network costs).and "virtually unaffected" by traffic volumes. Backhaul and backbone network costs are €2 per subscriber per month. To some extent these costs are traffic sensitive. The scenario with 300 kbitps implies an increase of €1-1.5 per subscriber per month. Costs for global connectivity are very low, at approximately €0.1 per subscriber per month. Furthermore, as these costs correspond to transit costs which are subject to price declines, increases in traffic volumes are generally offset. More important, this cost position does only account for a very small part of the overall costs.

[145] ARCEP (2012), p. 22

[146] These overall results assume an operator providing 87% of its users through unbundling and 13% through bitstream. The latter induces high costs for backhaul and transport networks than unbundling. If 30% of subscribers were served through bitstream this would increase costs by €2 per subscriber per month as a result of a traffic increase to 300 kbitps (ARCEP (2012), p. 92/93).

gies imply significant decreases in costs for a given capacity compared to current mobile technologies.[147] This is because of spectrum efficiency improvements as well as lower costs of carrying traffic. For example, compared with basis W-CDMA technology, LTE leads to a cost decline of 94 %.[148] More specifically, Analysys Mason reasons that the improvements in spectral efficiency have contributed to a decline in mobile networks unit costs of approx. 30 % p.a., expecting this trend to continue.[149] Analysys Mason concludes that, given its mobile traffic growth rate forecast (29 % p.a. in Western Europe for 2012-2017), this implies a decrease in costs.

Nevertheless, in absolute terms the (incremental) costs of conveying one byte of Internet traffic via mobile networks is significantly higher than via fixed networks. ARCEP has made some calculations to indicate (roughly) that, although fixed traffic still far exceeds mobile traffic, the traffic sensitive costs of conveying all mobile Internet traffic are about 10 times higher than conveying all fixed Internet traffic, at a national scale.[150]

Traffic volumes in mobile networks increase at a higher rate – however, from a significantly lower level in absolute terms – than in fixed networks. The provisioned capacity per subscriber is significantly lower in mobile than fixed networks.

Mobile operators respond to these traffic developments and to their relative capacity disadvantage compared with fixed networks by typically offering capped flat rates for mobile Internet usage whereas fixed operators (typically) offer unlimited flat rates.

Taking together the evidence provided above BEREC considers that the expected volume increase will not require a significant CAPEX increase in fixed network. Summing up, there is no evidence that cost are skyrocketing because of traffic increases[151] In fixed networks usage-based costs - accounting for 10-15 % of total costs for fixed broadband networks – are roughly stable.[152] Thus, if technological progress leads to cost improvements (on a per unit basis) which outweigh the increase in traffic volumes then there would be no negative effect (ceteris paribus) on the overall cost position of a network operator.

Usage-based costs basically follow the growth in the number of fixed network subscribers.[153] And this subscriber growth implies corresponding revenues per subscriber. Acknowledging technological differences between fixed and mobile networks, also the latter are subject to significant cost declines, and mobile operators react by offering tariff plans to ensure that they can cover their overall costs.

The following section on price developments supports the evidence of this section and the observable price-per-unit declines for transit and CDN services can be explained as resulting from decreases in equipment costs (increased performance of new equipment and significant economies of scale).

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147 See WIK-Consult (2011), Ch. 2.3.2.
148 Analysys, quoted from WIK-Consult (2011, Ch. 2.3.2).
149 http://www.analysysmason.com/About-Us/News/Insight/Mobile-data-growth-Sept2012/
150 ARCEP (2012, p. 22/23), high-level estimates.
151 Plum (2011), Ch. 2.2, p. 18/19; Kenny (2011), p. 6,7; WIK-Consult (2011).
152 WIK-Consult (2011), p. 59, likewise Plum Consulting (2011), p. 19, concluding that overall costs are likely to fall for fixed networks.
153 WIK-Consult (2011), p. 60.

### 4.2.2 Pricing trends

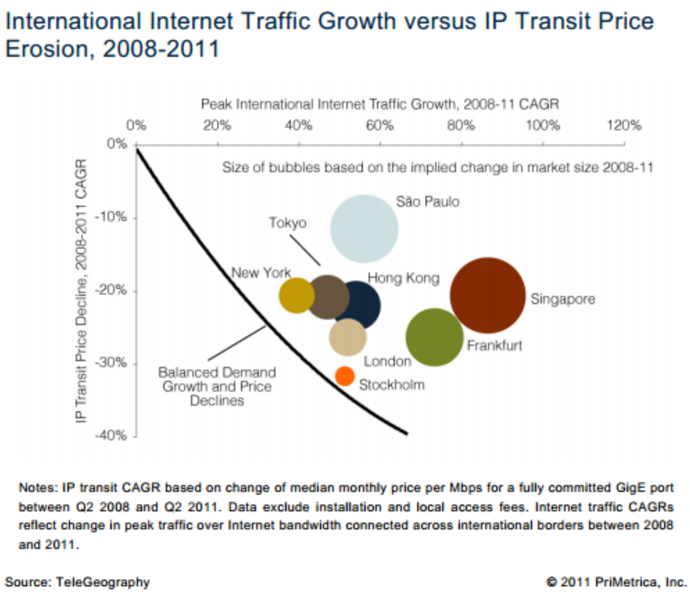
- **Decreasing transit prices**

Over the last few years transit prices decreased significantly because of cost decreases in components used and competition between transit providers.

WIK-Consult concludes that prices (per Mbps) for transit sold to large ISPs and large enterprises declined at a CAGR of -27 % over the period 2008-2010.[154]

These results are also backed by the following figure which shows that the average price decline (expressed in CAGR) in the period 2008 – 2011 differs depending on the location. Average price decline was highest in Stockholm. Very broadly, price declines are higher where traffic growth rates are larger (this is illustrated by the line "Balanced Demand Growth and Price Declines".

*Figure 13: International Internet Traffic Growth versus IP Transit Price*




- **Decreasing prices for CDN services**

For CDN services as well, a significant price decrease can be observed. In the fourth quarter of 2011, CDN prices declined by 20 % (vs. Q4 2010). The corresponding price decline figure for 2010 and 2009 were 25 % and 45 %, respectively.[155] Thus, the price decline still continues, but it is slowing down.

Generally, the trend towards decreasing CDN prices can be interpreted as a result of the competitiveness of the CDN market. At the same time, price developments for transit services are likely to have an impact on the price trend for CDN services. Similarly, price developments for CDN services will probably also impact on transit prices.

154 WIK-Consult (2011), Chapter 2.6.
155 http://blog.streamingmedia.com/the_business_of_online_vi/2011/11/cdn-pricing-stable-in-q4-down-about-20-for-the-year.html.

Price example:

*Figure 14: Video Delivery Pricing (Q4 2011)*[156]

Volume 250TB: High $0.10 per GB, Low $0.05 per GB
Volume 500TB: High $0.06 per GB, Low $0.02 per GB
Volume 750TB: High $0.05 per GB, Low $0.02 per GB
Volume 1PB: High $0.025 per GB, Low $0.015 per GB
Volume 3PB: High $0.02 per GB, Low $0.01 per GB
Volume 5PB: High $0.015 per GB, Low $0.0075 per GB

-This is per GB delivered pricing, not per Mbps sustained
- Volume commits vary from monthly, quarterly and yearly
- Cheaper prices can be found for customers who have smaller volume
- Customers have different needs and requirements which determines the final price
- Pricing is from major CDNs (Akamai, Limelight, Level 3, Amazon, EdgeCast, AT&T, Highwinds)

Source: http://blog.streamingmedia.com/the_business_of_online_vi/2011/11/cdn-pricing-stable-in-q4-down-about-20-for-the-year.html

## 4.3 Revenue flows

Today, CAUs typically have subscribed to an Internet access service which is paid for on a flat-rate basis. In this case, the CAU's eyeball ISP generates a fixed revenue per subscriber per month (average revenue per user – ARPU), independent of the CAU's online time and the volume of traffic he either down- or uploads. In absolute terms, this ARPU has remained relatively constant over recent while (in particular) the speed of the Internet connection increased.

However, this does not imply that an increase in Internet usage – either more time spent online or greater volumes of download and/or upload traffic generated by the CAU – has led to greater costs per CAU for the ISP.[157] This can be explained as follows:

- The marginal costs of conveying additional traffic over the CAU's access line are (at least) very low.[158]
- Providers of Internet access lines typically have to buy transit from other ISPs. Such transit payments cover both down- and upstream traffic.[159]
- Prices for transit have been subject to a significant decrease over recent years.[160] From an economic perspective it is crucial that the unit costs of conveying traffic have even decreased.[161]

As indicated, an increase in traffic does not increase revenues for ISPs. However, customers upgrade their connections. Furthermore, an increase in penetration leads to an increase in revenue from new CAUs.[162]

Next to the volume of traffic generated by a CAU, the number of subscribers also affects an ISPs total revenue. However, these revenues are in line with the increasing number of subscribers.[163]

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[156] It should be noted that in 2009 pricing was mostly done on the basis of "per GB delivered", today, a Mbps basis is more common.
[157] WIK-Consult (2011, p. 10) concludes: *"Price per user is stable because cost per user is stable"*.
[158] See, for example, ARCEP (2012, p. 91) stating that the costs for the fixed access line "are virtually unaffected by traffic volume".
[159] See ERG (2008), Ch. B.2.2 illustrating payment and data flows in IP-based networks. Note that the irrelevance of traffic flow direction holds for transit as well as peering
[160] See Ch. 4.2.2 on the development of transit prices.
[161] See Ch. 4.2.1.
[162] Kenny (2011), p. 8; WIK-Consult (2011), Ch. 2.7, p. 47 ff.
[163] WIK-Consults (2011, p. 10) summarises "*Traffic growth driven by an increase in the number of subscribers should raise no concerns."*

Given the degree of competition between Internet access service providers, it seems plausible to assume that revenues generated by ISPs reflect their costs for providing the service.[164]

## 4.4 Changing players along the value chain

### 4.4.1 Market consolidation under way

By 2007, the hierarchical structure of the Internet still prevailed. The top contributors in term of volume of traffic shifted were traditional operators. At that time Level 3, Global Crossing, AT&T, Sprint and NTT were the *top 5* tier 1 providers. In 2010, operators still accounted for significant traffic volumes, but Google and two CDNs entered the *top 10*.[165] Whereas the *top 10* providers accounted for approximately 30 % of all traffic in 2007, their share increased to 40 % in 2009/2010. Google's share of all Internet traffic increased from approximately 5 % in 2008 to 7 % in 2011.[166]

The ongoing consolidation process becomes evident from some other empirical observations: *"The top 1% of source ASes accounted for close to 90% of incoming traffic; the top 10% of source ASes accounted for more than 99%."*[167] Whereas in 2007, thousands of Autonomous System Number (ASNs)[168] accounted for half of all Internet traffic, in 2009, 150 ASNs contributed the same percentage.[169]

### 4.4.2 (Relative) decrease in the role of Global Backbones

Nowadays, more Internet traffic is conveyed without moving across tier 1 backbones contributing to a decreasing role for global backbones. This is owing to a number of factors:

- More traffic than in the past is routed using peering rather than transit agreements.[170]
- The practice of donut peering[171] whereby ISPs directly exchange traffic regionally also contributes to the bypassing of tier 1 backbones.
- New players have emerged that either did not exist or were less relevant in the past (e.g. CDNs).
- A larger portion of traffic is directly exchanged between large CAPs, CDNs or sometimes even CAUs.
- Using transit may (ceteris paribus) imply higher latency than peering. This characteristic of transit implies a relative competitive disadvantage for the transit model if – as can be observed today – more traffic is quality sensitive.
- In some instances CAPs or CDNs may even vertically integrate performing functions that – in the past – had been provided by pure transit providers.
- If larger CAPs (e.g. Google) increasingly invest in their own network infrastructure and deploy their own national or even international backbones, this will also increase put further pressure on the backbone providers.

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[164] See also WIK-Consult (2011), p. 10.
[165] Labovitz.(2011).
[166] Labovitz (2011).
[167] www.caida.org.
[168] See Footnote 4
[169] Labovitz et al (2009).
[170] See, for example, Weller/Woodcock (2012) pointing out that 99.5 % of interconnection agreements are concluded without a written contract.
[171] See Section 3.2.2.

Generally, there is a certain consolidation process among backbone providers (as well as among CDNs). For example:

- In 2012 Zayo has completed its $2.2 billion acquisition of AboveNet.[172]
- In 2011 Level 3 acquired Global Crossing.
- In 2010 CenturyLink has acquired backbone provider Qwest and in 2011 Savvis, a global provider of cloud infrastructure and hosted IT solutions.
- Furthermore some backbone providers such as Level 3 or AT&T have started to set up a CDN of their own and continue to invest in this field.

It is not yet clear whether this consolidation process of backbone providers (as well as CDNs) may "stop" the relative decrease of backbones.

Transit involves significant economies of scale (big pipes). However, transit comes at the expense of lower quality (higher latency) as factor such as distance and (to some extent) traversing AS boundaries impacts on quality.

Transit providers attribute the competitive challenges they are confronted with to an alleged increase of eyeballs' market power while incumbents refer to an increase in market power of the content providers. The arguments mentioned above illustrate that backbone providers are increasingly exposed to competitive pressure.[173] Given this development it is noteworthy that about a decade ago there was a debate on whether backbone providers might have SMP.[174]

### 4.4.3 CAP developments

When a large CAP such as Google operates its own networks and also peers this can be interpreted as a means of economizing expenditures for upstream capacity. It also contributes to enhance user-experience by reducing latency as content is exchanged directly with another network instead of traversing one or more transit networks.

Furthermore, there are more local CAPs that provide particularly language based content and thus serve specific countries.

CAPs activities such as content creation and aggregation, messaging applications, search engines on cause a large part of Internet traffic. Content providers need to get their content hosted. In practice, this is often done by CDNs.

Creation of content has become more regionalised because part of content is produced at the edges of the network e.g. by CAUs (blogs, P2P, etc).

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[172] http://thenextweb.com/insider/2012/07/02/zayo-has-completed-its-2-2b-acquisition-of-abovenet-creating-an-international-fiber-powerhouse/

[173] Concerning the relative decrease in the role of transit Analysys Mason (2011, p. 3) concluded *"From the backbone provider's point of view, these changes led to a reduction in demand for transit services, and an increase in competition from former customers who now have a number of choices for delivering and exchanging traffic. Further, backbones must compete vigorously on the price of transit in order to generate the traffic volume to continue to peer with one another. This has resulted in an increase in the level of competition for Internet transit services, as evidenced for example in the fall in transit prices over the past five years, with no sign of respite."*

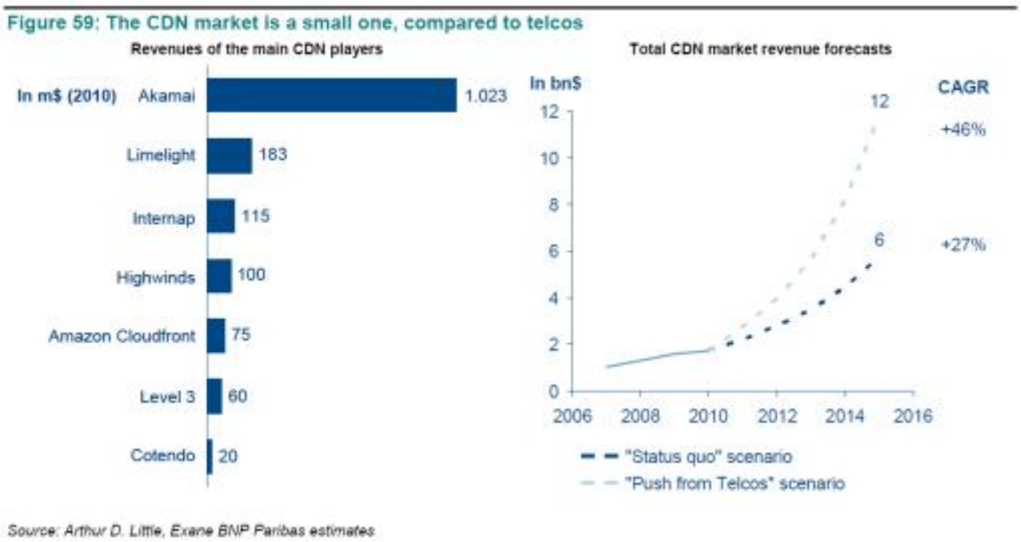
[174] In 2000 more than a third of US traffic was carried by UUNET.

### 4.4.4 Increasing role of CDNs

First generation CDNs were designed primarily to ease network congestion with regards to static web pages. As the content that users consume has evolved and become more technically sophisticated, so have CDNs.

Using services provided by CDNs has various properties which may account for the increasing relevance of the CDN business model:

*Figure 15: Revenues in the CDN market*




- By storing content closer to the CAU, latency can be reduced and quality enhanced. This leads to an acceleration of content/applications thereby improving the CAU QoE (e.g fast download speeds or response times).
- CDNs reduce distance and the number of AS boundaries between server and user. For the content providers using CDNs this ultimately implies (ceteris.paribus) an enhanced competitiveness (in relation to other content providers).
- CDNs also allow for a reduction in transit costs/ peering volumes. Storing content closer to the CAU means that this content needs to be delivered only once from the content providers to the CDNs' caching servers. Otherwise every single content request from a CAU would induce a delivery of content (all the way from the content providers to the CAU). By using CDNs' services each individual content request only induces a "shorter" delivery from the cache server to the CAU implying minimised transmission routes.
- By caching content locally, less international transit is needed to be delivered to the terminating network thereby reducing traffic congestion and avoiding flash crowds whereby a sudden interest in a particular website, (ie during the attacks on 9/11 the CNN web servers got overloaded), can be load-balanced over several CDN servers in that region
- CDNs allow a reduction in transaction costs and exploit economies of scale and scope. By using CDNs, transit costs can be avoided and peering volumes be reduced.
- Assuming a world without CDNs, then each content provider has to interact with several ASs. With CDNs, a single content provider interacts with a single CDN network that then interacts with multiple ASs. Given this, the CDN internalizes the transaction costs (provisioning, monitoring and enforcing) of bargaining with ASs while benefiting from economies of scale and scope.[175]

[175] Faratin et al (2008), p. 66.

- In order to get their content delivered to the terminating ISP, content providers may either buy transit services or ‚use the services provided by CDNs. The latter option is a rational strategy if it is not economically viable for the content owners to provide their own local storage solutions.
- CDNs lower traffic on a networks own backbone. It is cheaper to serve a bit (for instance) in Berlin for a user in Berlin than receiving that bit in Frankfurt.
- Furthermore, CDN typically improve QoE without violating the best effort principles. This holds in particular, where a CDN does not operate its own network, i.e. the CDN is active only on the application layer (see Figure 2).

Next to the differentiation of services provided by CDNs there is also a greater variety of players offering CDN services. In the early days of the CDN business model there were (mainly) "pure" CDNs such as Akamai. Nowadays, increasingly other players vertically integrate and perform CDN functions. This may be network providers or ISP moving up the value chain or CAPs such as Google or also Internet players such as Netflix[176] that provide internal CDN solutions. Other Internet players (e.g. Amazon) offer CDN services for third parties. Furthermore, telcos such as BT, KPN, Level 3, AT&T have also started to provide CDN services, as have equipment and solution vendors such as Alcatel-Lucent, Cisco, and Juniper.[177]

Considering the variety of operators providing CDN functionalities there is no *systematic* trend for CDNs to provide their own networks. As indicated above, it seems that other provides more often integrate forward, i.e. start operating their own CDNs either for their own use or to provide services to others.

From a content providers perspective the CDN make or buy decision depends on the content provider's scale. Whereas it may be economically viable for a global content provider to operate its own CDN smaller content providers may rather use third-party services in order to benefit from their economies of scale and scope.

However a CAP may be more inclined to buy CDN services from a *neutral* CDN (independent of either CAP) rather from a CDN that also provides its own content. Such a neutral CDN may be more trustworthy as it has no incentive to discriminate against its customers.

*Traffic consolidation*

Akamai claims that 20 % of the world's Internet traffic is handled over its platform.[178] Edgecast stated in July 2011 that it carries approximately 4 % of worldwide Internet traffic.[179]

*The role of CDNs in Europe:*

It has to be born in mind that video content in certain European languages is confined to the local market. Therefore there are also examples of national players that provide CDN services (UK: BT Content Connect, TalkTalk)

"*The Internet in Europe is centred around three key public Internet Exchange Points: AMS-IX, DE-CIX, and LINX. This provides Europe with a topological advantage and efficiencies to the European networks that the U.S. doesn't enjoy, a point Robinson makes to illustrate the potentially lower demand in Europe for "global" CDNs, compared to the U.S*"[180]

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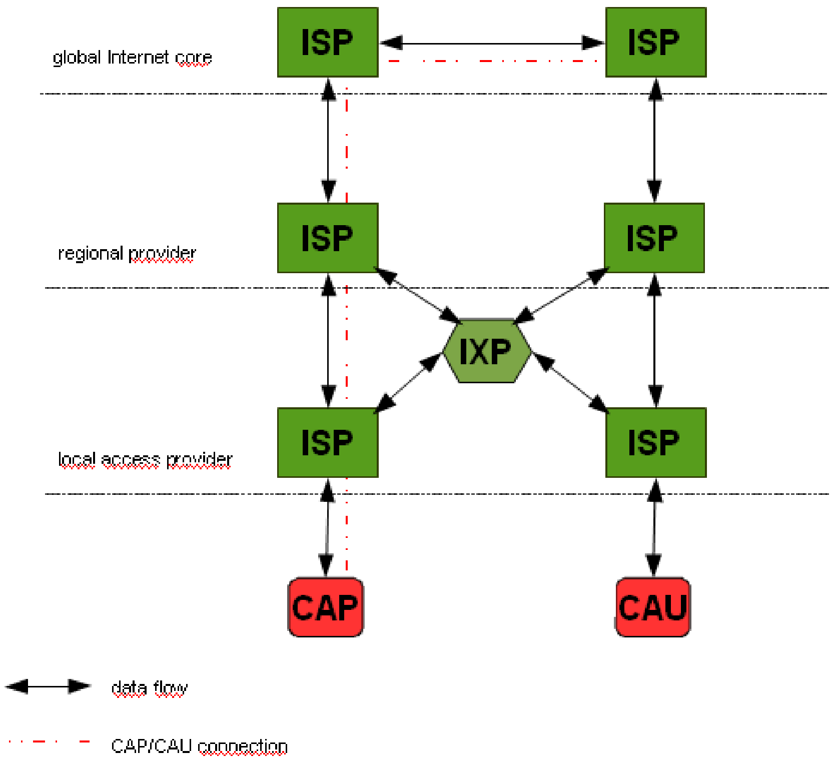
176 http://blog.netflix.com/2012/06/announcing-netflix-open-connect-network.html
177 IDATE (2010), slide 10.
178 http://www.akamai.com/html/technology/visualizing_akamai.html
179 http://www.businesswire.com/news/home/20110726006802/en/EdgeCast-Reports-Continued-Customer-Traffic-Growth
180 http://www.nigelregan.com/2010/04/network-status-2009-the-european-cdn-market/ (April 16, 2012).

European IXPs allow to keep traffic regional and avoid tromboning via the US.

### 4.5 Flattening of network hierarchies

In the past the Internet had a hierarchical structure. In the following figure, the black lines show the data flows, with arrowheads in both directions indicating that the data flows both up- and downstream. Most of the traffic had to be routed via the tier 1 backbone providers as there have not been (substantial) interconnection links on lower levels of the Internet.[181] This is indicated by the dashed red line (CAP/CAU connection).

*Figure 16: The "old" Internet*




Source: BEREC

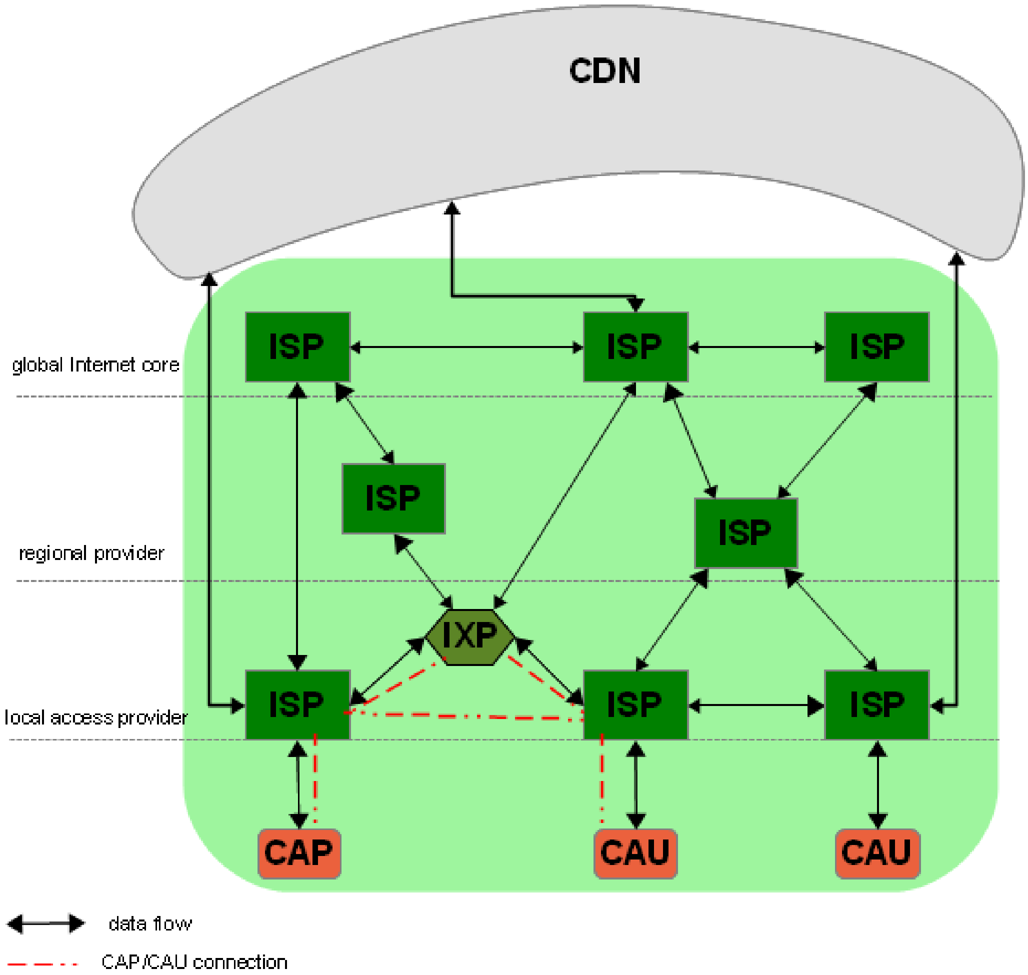
A number of aspects are characteristic of the Internet of today:

- A greater portion of traffic is no longer routed via global tier 1 backbone providers because data is exchanged either directly between local access providers in peering contracts (for example) or via the IXP. In the following figure, this "flattening" is illustrated by the dashed red line.
- Several large eyeball ISPs providing connectivity to a large number of CAUs have acquired tier 1 status and therefore no longer need transit.[182]
- Some CAPs bring their content closer to the CAU either by
  - vertically integrating forward into operating networks of their own or
  - using CDNs or
  - operating their own CDN

These trends lead to a flattening of network hierarchies and a more "meshed" architecture.

[181] See also ERG (2008). Chapter B.2.2 generically describing the data and payment flows.
[182] Wikipedia mentions 17 transit-free networks (http://en.wikipedia.org/wiki/Tier_1_network).

*Figure 17: The "new" Internet*




Source: BEREC

The flattening of network hierarchies reflects the (relative) decrease in the role of transit providers.

The flattening of network hierarchies can be derived from different empirical observations:

a) Generally, there is a trend towards a decrease in the average number of hops on tier 1 networks.

b) Similar, there is an increase in percentage of paths that involve no tier 1 networks. Thus, the bulk of Internet traffic no longer moves across tier-1 transit providers.[183]

### 4.6 Predominance of informal peering arrangements

A voluntary survey of 142 000 peering agreements encompassing 86 % of ISPs led to the following results:[184]

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183 See, for example, Gupta/Goel, slide 19.
184 Weller/Woodcock (2012), p. 9.

- 99.5 % of all peering agreements are ‘handshake’ agreements concluded without a written contract, whereas 0,49% are based on written, formal contracts;
- 99.3% of all peering agreements are based on symmetric terms, whereas 0,27 % are based on asymmetric terms (e.g. paid peering).

The predominance of handshake agreements shows that network operators aim at minimizing transaction costs. Such an informal setting also seems advantageous as it allows the market players to adapt flexibly to changing conditions.

Although there is a lot of talk about paid peering the empirical evidence rather shows that is still of a very limited importance.

### 4.7 The future of the Internet interconnection paradigm

In the past there was a “simple” dichotomy, interconnection was based on either peering or transit agreements. Over the years a variety of types of interconnection has emerged.[185] Nowadays there are variants of peering or transit that did not exist in the early days of the Internet such as partial transit or paid peering (see Ch. 3.2.2). Furthermore, some ISPs try to induce payments from CAPs. However, such paid arrangements exist in practice either not at all or only in rare cases.

The increase in diversity in interconnection arrangements may be explained by the increasing diversity and heterogeneity of the Internet and the players along the value chain. Standardised agreements were appropriate in the early days of the Internet when there was not such a variety of business models as can be observed today.

BEREC’s discussion on IP interconnection in the context of net neutrality takes places in the wider context of ongoing debates between stakeholders on charging mechanisms used for IP-interconnection, including around the revision of the International Telecommunication Regulations (ITRs).[186] While the BEREC and ITU processes are completely independent from each other, they both deal with the common themes of charging principles for IP interconnection and the implications of introducing end-to-end QoS into the Internet. A number of proposals made to WCIT-12 show. [187] More specifically charging proposals such as sending party networks pays are suggested.[188] A number of observations made in this report may contribute to an evaluation of these suggested concepts.

[185] See Faratin et al (2008), p. 51: *“… the challenges of recovering the fixed and usage-sensitive costs of network transport give rise to more complex settlements mechanisms than the simple bifurcated (transit and peering) model …”.*

[186] The ITRs were agreed upon in 1988 when telecommunication services were provided by government-owned monopolies and telecommunications liberalisation was in its infancy. Their focus was on voice telephony. Accordingly, the ITRs encompassed rules for charges, accounting, and payment for international telecommunications. Unlike network operators that provided international voice services, ISPs were not subject to these provisions. The fact that “the Internet” was out of the scope of the ITRs is often considered to be an important factor that contributed to the success of the Internet as it could develop largely driven by market forces and without complex institutional arrangements. The International Telecommunications Union (ITU) discussed a revision of the ITRs at WCIT-12 in Dubai in December 2012. For more detail see WIK 2012, Analysys Mason (2012), Kennard (2912), Huston (2012).

[187] Furthermore, the proposals made cover a variety of issues such as (e.g.) cyber security, misuse and fraud or the role of the ITU etc. See https://fileshare.tools.isoc.org/wentworth/public/WCIT%20issues%20matrix/WCIT-ISSUES-MATRIX- 15June2012.pdf.

[188] ETNO made a proposal suggesting that: “3.1 Member States shall facilitate the development of international IP interconnections providing both best effort delivery and end to end quality of service delivery.” And “3.2…to ensure an adequate return on investment in high bandwidth infrastructures, operating agencies shall negotiate commercial agreements to achieve a sustainable system of fair compensation for telecommunications services and, where appropriate, respecting the principle of sending party network pays. The reasoning given by has been summarized by them: This proposal argues that QoS is needed

As pointed out at the beginning of Chapter 3, circuit-switched networks like the PSTN and connection-less IP networks display very different technical characteristics. More specifically the absence of end-to-end awareness in IP-networks has implications for both, possibility and reasonableness of introducing end-to-end QoS as well as end-to-end charging in IP networks.

With regard to QoS in section 3.3 the problems regarding the implementation of end-to-end quality were spelled out in detail and is was concluded that over the Internet a guaranteed end-to-end QoS offer is neither commercially nor technically realistic. In best effort networks however other mechanisms developed to improve the user's experience of an application's quality applied at end-points rather than within the network. The introduction of end-to-end QoS classes is posing a number of complex problems related to the fact that the packet switched IP-networks do not have an end-to-end awareness, which contributed to the simplicity and success of the IP protocol. Introduction would be costly and it is unclear whether the "Internet" would survive. Although QoS differentiation may be an appropriate tool to deal with scarcity of bandwidth in access networks by prioritising, for example, voice services the situation is different in IP-backbones, where capacity is relatively cheap.

Interconnection on the Internet has operated on the basis of transit/peering arrangements at the higher level as described in Sections 3.1 and 3.2 , and a "bill & keep" approach where the terminating access network operator does not receive payments at the wholesale level for terminating the traffic, but recovers its costs at the retail level from the end-user. If "bill & keep" were to be replaced by SPNP then the ISP providing access could exploit the physical bottleneck for traffic exchange and derive monopoly profits, requiring regulatory intervention[189].

Furthermore, if other practices (e.g. paid peering) became widespread where Internet Access Provider connecting end-users were able to set abusive charges for interconnection out of a monopoly position, this outcome might not be considered desirable.

Introducing such a SPNP-style mechanism would add significant complexity to the Internet, both technically and economically. This would ultimately increase the transaction of all parties involved across the whole value chain. Technically, a system with extensive measuring and analysing of traffic flows would be required. Economically – and closely related to the technical argument – charging for Internet traffic would have to reflect the direction of traffic flows and would have to span the whole value chain. In particular, the transaction cost saving peering would be put at stake.

Also in reference to charging Interconnection of packet switched networks cannot rely on service based end-to-end information or service instances (like a "call") owing to to the sepa-

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- o to deliver services requiring a guaranteed minimum bit rate, latency and error rate (video traffic);
- o to increase the customer base;
- o to guarantee that the Internet is able to provide the services requiring strict network performance;
- o to generate incremental revenues across all Internet eco-system;
- o to enable incremental revenues by end-to-end QoS pricing and content value pricing.

And "Sending Party Network Pays" is advocated

- o because it is well tested;
- o because has delivered efficient results;
- o to promote, where appropriate, a charging principle realigning costs and revenues by assuring that agents are accountable for the costs incurred by their routing decisions.

[189] In its "Common Statement on Future Charging Mechanisms" (BoR (10) 24 rev 1), BEREC considered that (based on its economic analysis), "bill & keep" was more promising in the long run than "calling party network pays" as a regulatory regime for termination, At the same time, BEREC recognised that NRAs' final decisions on the appropriate charging mechanism for voice telephony should reflect the specific circumstances of each country/market

ration of the application layer and the network layer that is inherent to IP-networks. Unlike voice traffic on old PSTN networks, data does not travel over an exclusive, dedicated network connection, and it is not possible to ascertain the nature or volume of a particular data flow end-to-end (and so not possible to charge for it that way either). The origination point of a file may not easily be identified as it may be stored in different locations (and countries). Individual packets belonging to the same flow may take different routes across over separate networks since the Internet is a meshed topology. Therefore, charging for IP-interconnection usually takes place on the basis of the capacity provided at the interconnection point. It is not based on where the traffic originated or terminates. End-to-end SPNP approach to data transmission is totally antagonist to the decentralised efficient routing approach to data transmission of the Internet.

The request for the data flow usually stems not from the CAP who sends the data but from the retail Internet access provider's own customer (who "pulls" content provided by the CAPs, and from whom the ISP is already deriving revenues). Ultimately, it is the success of the CAPs (from whom IAPs wish to extract additional revenues) which lies at the heart of the recent increases in demand for broadband access (i.e. for the ISPs' very own access services).

The incentives created through a sending party pays system, aimed at charging the CAPs may contribute to increasing the digital divide as forego having their content sent to places where delivery cost are too high undermining the principle of protecting the free flow of information.

Summing up such proposals are fundamentally at odds with the principles of connection-less packet switched networks underlying the success of the Internet to date, based decentralisation and simplicity. BEREC believes that the benefits of a connection-less network risk being unravelled by the widespread adoption of connection-based practices on the global Internet. It is in all our interests to protect the continued development of the open, dynamic and global platform that the Internet provides, which has evolved over time without regulatory intervention and helped enable so much innovation at the network endpoints.

# 5 What is the regulatory context for IP interconnection?

As of today, interconnection agreements have developed with little regulatory intervention by Member States. However, under certain circumstances conflicts may arise when one party denies a plea for interconnection and thus would be able to take customers hostage.

In these cases NRAs may have to take action in order to promote and defend fair competition, investment, innovation and consumer welfare in the sense of Art 8 FD and may decide to impose obligations to interconnect. Such obligations may be imposed either under Arts. 8 and 12 (1) lit i AD as a result of finding SMP or under Arts. 4 and 5 AD (compare 5.1 and 5.2).

Furthermore, some NRAs expect having to deal with interconnection disputes under their dispute settlement regulations (compare 5.3)

## 5.1 Obligations to interconnect as a possible result of finding SMP

According to Art. 12 (1) lit i AD NRAs may, in accordance with the provisions of Art. 8 AD, impose obligations on operators that are designated as having significant market power on a specific market to interconnect their networks or network facilities.

Art. 12 (1) lit i AD primarily applies to markets of the Commission's *Relevant Market Recommendation*.[190] In this sense, obligations under Art. 12 (1) lit i AD may be particularly imposed with regard to the markets 2, 3 and 7 of the Commission's *Relevant Market Recommendation.* The Commission did not identify a market for wholesale Internet connectivity (or delivery of incoming/outgoing packets) for the purposes of its *Relevant Market Recommendation,* however. Consequently, there is no *a priori* presumption that the three-criterion test is fulfilled and therefore ex ante market analysis was required in any event.

While this non-inclusion of a market for wholesale Internet connectivity in the Relevant Market Recommendation does not hinder NRAs from identifying such a market as appropriate to national circumstances according to Art. 15 (3) FD, such identification entails a high burden of proof and the procedure is bound to be lengthy. NRAs must first of all be able to collect the comprehensive set of required information before deciding to undertake this process. If this direction is followed, the Framework provides a comprehensive approach to identify the 'relevant market' in which such conduct is taking place, to identify the firm or firms which have SMP within that market, and to target appropriate remedies.[191]

Furthermore, in those cases where the three-criterion test is not deemed to be fulfilled and thus ex-ante regulation is not considered appropriate, it remains always possible to rely on ex-post competition law in the case of a finding of dominance, and in particular the prohibition on abuse of market power contained in Article 102 of the Treaty on the Functioning of the EU.

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[190] *Commission Staff Working Document: Explanatory Note to Commission Recommendation on Relevant Product and Service Markets.*

[191] Only once has an NRA tried to establish such a case notifying separate national markets for transit and peering (PL/2009/1019-1020) claiming SMP for the incumbent and considering the 3-criteria test to be fulfilled. implying ex-ante regulation of these markets. The Commission has entered a phase 2 investigation leading to a veto with regard to this decision. An ERG expert team submitted an opinion largely supporting the Commission's decision. After an appeal of UKE to the ECJ the case is now pending before the ECJ (see ECJ- Case T-226/10).

## 5.2 Obligations to interconnect under Art. 5 AD

Art. 5 AD foresees that NRAs shall" *encourage and where appropriate ensure … adequate access and interconnection, and the interoperability of services … in way that promotes efficiency, sustainable competition, efficient investments and innovation, and gives the maximum benefit to end-users".*

This interconnection regime exists independently of interconnection obligations that are imposed as a result of finding SMP on a market. The regime protects the integrity of the overall communications sector, by giving the possibility to intervene when end-to-end connectivity is at stake.

### 5.2.1 Players that may be subject to interconnection obligations under Art 5 AD

under Art. 5 AD NRAs may only impose obligations on undertakings that control access to end-users reflecting the bottleneck.[192] Whether this bottleneck can be exploited is related to the charging mechanism and the degree of competition at the retail level.

A denial of interconnection or unreasonable differentiation would not constitute a problem as long as there is a choice of supplier and end-to-end connectivity is not at stake.

- Such a situation is generally held to apply at the backbone level where as of now markets are considered to be highly competitive.
- Also large CAPs will face a very competitive choice in their demand for hosting and connectivity and may be able to switch suppliers easily.
- Broadband access and connectivity markets for CAUs are considered to be competitive retail markets but to a lesser degree. A denial of interconnection of an (Eyeball) ISP could reflect taking advantage of the bottleneck to ensure end-to-end connectivity towards CAUs. However if retail competition and the threat of CAUs to change broadband access supplier is strong enough this need not necessarily be the case.

In these cases NRAs may have to take action in order to promote and defend fair competition, investment, innovation and consumer welfare in the sense of Art. 8 FD and may decide to impose obligations to interconnect.

ISPs as described in Section 2 above would clearly constitute undertakings that control access to end-users (in the legal sense), whether these are CAPs or CAUs.

Furthermore the question may arise whether NRAs may also oblige CDNs under this provision. Since the AD focuses on interconnection as "*the physical and logical linking of public communications networks* (Art. 2 lit b AD)", this raises the question whether a CDN operates a telecommunications networks in the sense of the FD and whether it controls access to end-users.

As described at 2.4 there is a reasoning that CDNs conceptually do not operate networks in the sense of the FD with regard to their core functionality but operate virtual networks on top of the network layers of the physical networks. In the case of an *infrastructure* based model one might come to the conclusion that a player performs core functionalities of both a CDN and a network operator. In such cases an obligation to interconnect according to Art. 5 AD would further require that the player also controls access to its end-users.

However, it seems unlikely that infrastructure-based "CDNs" could exercise such a *control* over access to end users, since they do not offer end-to-end connectivity.

[192] This is not the case for over-the-top providers, for example. Furthermore, an assessment of interoperability of services is beyond the scope of this report.

According to Recital (8) AD, *“network operators who control access to their own customers do so on the basis of unique numbers or addresses from a published numbering or addressing range. Other network operators need to be able to deliver traffic to those customers, and so need to be able to interconnect directly or indirectly to each other.“*

This does not apply to CDNs: while content that is not available through a CDN would not be able to take advantage of fast access via nearby CDN servers, the content might however still be accessible for CAUs from the origin server using the network layer of the Internet if the CAP has a separate connectivity provider.

### 5.2.2 Requirements for interconnection agreements under Art. 5 AD

Should NRAs impose have to obligations and conditions under Art. 5 (1) AD they shall be objective, transparent, proportionate and non-discriminatory, and shall be implemented in accordance with the procedures referred to in Articles 6, 7 and 7a FD.

Current interconnection arrangements arise in forms of peering, transit and related variants such as the IXP model. However, it may be questionable whether Art. 5 AD would justify the imposition of any specific form of interconnection obligations.

Considering that current IP-interconnection arrangements developed without regulatory intervention[193] and that ISPs may always have the opportunity to buy transit services instead of peering (if they do not wish to peer or do not meet the requirements for peering) there is no legal basis to oblige operators to provide mandatory any-to-any peering.[194] Moreover, peering is a barter exchange. Generally, two operators will agree to peer with each other only if peering is beneficial for both parties involved. This may depend on many different aspects that have been dealt with in Section 3.

In this sense Art. 5 AD would justify obligations to interconnect on a non-discriminatory basis. However, it would not necessarily provide a legal basis for obligations to interconnect at specific price, e.g. a price of zero via peering.

This question was dealt with in a number of disputes between Cogent and several ISPs such as France Telecom and TeliaSonera:

- At the beginning of 2008, Cogent depeered TeliaSonera, on the grounds of an ongoing dispute related to the capacity and the location of the interconnection points between both parties. TeliaSonera found alternative routes to interconnect with Cogent, in transit via Verizon, Level 3 and AT&T. Those alternative routes were shut down after a couple of hours, since those transit services were not paid for (indeed both Cogent and TeliaSonera were peers of those transit providers). (Direct) interconnection was resumed between Cogent and Teliasonera after 15 days of negotiation, after a new contract was set up between them.

Altogether NRAs so far have hardly based obligations on Art. 5 AD.

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[193] BoR (10) 42, p.2

[194] In its study for the European Commission WIK-Consult (2008, p. XIII) comes to the same conclusion.

### 5.3 Possible treatment of disputes related to interconnection obligations

The FD empowers the NRA to issue a binding decision to resolve any dispute under the Regulatory Framework*, at the request of either party.* Following the recent revision of the Regulatory Framework, Art 20 (1) FD now explicitly addresses disputes *between undertakings providing electronic communications networks or services as well as "disputes between such undertakings and other undertakings in the Member State benefiting from obligations of access and/or interconnection arising under this Directive or the Specific Directives.*" Against this background, some NRAs expect to have to act under their dispute settlement regulations.

# 6 Conclusions

***Developments in the types of interconnections***

a) Generally, peering and transit present two different options for reaching another network. In most instances, operators will employ both transit and peering arrangements. The peering market is generally taken to function more or less competitively as long as ISPs have a choice of transit providers. ISPs that fulfil the requirements for peering can choose between peering and buying transit and therefore are able to substitute between these two forms of interconnection. The decision whether to peer or to buy transit is a matter of network planning and cost optimisation. In most instances, operators will employ both transit and peering arrangements, i.e. they can also be used as complements. ISPs that do not fulfil requirements for peering must buy transit. Transit can be viewed as a default option.

b) The Internet ecosystem has managed to adapt IP interconnection arrangements to reflect (inter alia) changes in technology, changes in (relative) market power of players, demand patterns and business models. This happened without a need for regulation.

c) In the Internet ecosystem speed and flexibility to adapt interconnection arrangements outweigh formal codification of interconnection rules (99 % of interconnection arrangements are concluded on a handshake basis).

d) QoS traffic classes across interconnected networks are not established.

***Trends along the value chain***

e) BEREC considers that the expected volume increase will not require a significant CAPEX increase in fixed network. There is no evidence that cost are skyrocketing due to traffic increases[195]. In fixed networks usage-based costs – accounting for 10-15 % of total costs for fixed broadband networks – are roughly stable.[196] Thus, if technological progress leads to cost improvements (on a per unit basis) which outweigh the increase in traffic volumes then there would be no negative effect (ceteris paribus) on the overall cost position of a network operator.

f) The emergence of large CAPs and CDNs (Google, Akamai, Amazon…) as well as new kinds of peering arrangements (e.g. regional peering) significantly contributed to the flattening of the Internet topology. Boundaries between players in the value chain are becoming more blurred as players increasingly perform different and/or new functionalities and integrate along the value chain.

g) The (relative) decrease of the role of IP-transit providers can be mainly attributed to two trends:
   - It happens in parallel with the emergence of CDNs. The increase in traffic which is rather sensitive to latency as well as the competitive pressure on transit providers caused by CDNs (and the price declines for CDN services as well as for transit services).
   - Regional peering is increasingly used implying a circumvention of transit provided by tier 1 Backbones.

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[195] Plum (2011), Ch. 2.2, p. 18/19; Kenny (2011), p. 6,7; WIK-Consult (2011).
[196] WIK-Consult (2011), p. 59, similar Plum Consulting (2011), p. 19, concluding that overall costs are likely to fall for fixed networks.

h) CAPs make substantial payments for hosting and connectivity. Furthermore they pay for CDN services that bring content closer to the user. Therefore, unlike from what is sometimes alleged by some telcos in the Net Neutrality debate there seems to be no free-riding problem. This holds even for those CAPs that stick to their core activity which is the provision of content and/or applications without further vertically integrating along the value chain. There is no evidence that operators' network costs are not fully covered and paid for in the Internet value chain already (from CAPs at one end, to the end users, at the other).

i) CDNs have contributed to better quality being provided to the users. This may decrease the likelihood that traffic classes will assure that QoS is implemented in interconnection agreements across network boundaries. Also, there is no free-riding by CDNs as they pay for the services they use (see 2.4.e).

j) As long as QoS is not assured across networks, CDNs have a competitive edge over transit networks as they can contribute to the delivery of content with better quality across their own network.

k) Several large Eyeball ISPs providing connectivity to users on a large scale acquire tier 1 status, in that they solely rely on peering and no longer need to buy transit. There are few independent transit providers left.

***Quality of Service versus best-Effort***

l) Although not implying a guaranteed delivery of data the best-effort approach of the Internet does not imply low performance. Best-effort Internet results, in most cases, results in a high quality of experience for users, even for delay-sensitive applications such as VoIP.

m) The best-effort principle is reflected in today's interconnection agreements across IP-networks taking the form of transit and peering agreements generally causing no disruptions of net neutrality in IP interconnection.

n) Nowadays, QoS differentiation potentially leading to deviations from net neutrality typically occurs only within the ISP's network providing connectivity to the user and therefore is not reflected in interconnection agreements across networks at the network layer.

o) Over the internet a guaranteed end-to-end QoS offer is neither commercially nor technically realistic. Differentiated services, which fall just short of guaranteed end-to-end QoS, exist but continue to be exceptional, for the reasons listed in Section 3.3 and not because they are anywhere prohibited)

p) Up to now, interconnection with QoS assured across network boundaries does not / hardly exist in practice. Adding capacity has so far shown to be the strategy of choice.

q) Although QoS differentiation may be an appropriate tool to deal with scarcity of bandwidth in access networks by prioritising e.g. voice services the situation is different in IP-backbones, where capacity is relatively cheap.

r) Potential violations of net neutrality such as blocking and throttling of traffic typically occur in the Eyeball ISP's network and therefore are not reflected in IP interconnection.

s) Specialised services are provided using the Internet Protocol but are operated within closed IP networks. These IP networks rely on strict admission control and they are often optimized for specific applications based on extensive use of traffic management in order to ensure adequate service characteristics. Therefore specialised services can provide guaranteed QoS. The provision of specialised services such as IP-TV does not necessarily require traffic classes across interconnected networks if the service is provide within an operators network.

t) This holds in particular, when considering the cost decreases in core and backhaul networks. Thus, the question whether implementing end-to-end QoS across networks is economically a viable strategy in the future is largely affected by the costs of simply adding more bandwidth.

u) The introduction of traffic classes using prioritisation introduces an incentive to degrade the best effort class in an anti-competitive manner, in order to induce customers to pay the higher price for the managed traffic class.

v) In best-effort networks alternative mechanisms - compared with the strategies followed in networks offering enhanced quality - for improving end-to-end network performance have been developed. Examples are endpoint based congestion control for reduction of the traffic load, Internet Exchange Points and increased use of peering. Also CDNs are used to improve the user's perception of an application's quality (QoE).

***Charging principles***

w) Interconnection on the Internet has operated on the basis of transit/peering arrangements at the higher level as described in Sections 3.1 and 3.2 , and a "bill & keep" approach where the terminating access network operator does not receive payments at the wholesale level for terminating the traffic, but recovers its costs at the retail level from the end-user. "Bill & keep"[197] at the access level leading to an absence of termination charges is one of the major reasons making an exploitation of the termination bottleneck difficult.

x) Both sides of the market, namely CAPs and CAUs contribute to pay for connectivity to the Internet. Whether an ISP can exploit the physical bottleneck for traffic exchange depends on:
   - whether the charging mechanism entitles that ISP to a payment at the wholesale level out of its monopoly position *and*
   - the degree of competition at the retail level for users.

   This rationale applies not only for voice but also for data traffic as the latter is conveyed across the same physical bottleneck.

y) Unlike voice traffic on old PSTN networks, data does not travel over an exclusive, dedicated network connection, and it is not possible to ascertain the nature or volume of a particular data flow end-to-end (and so not possible to charge for it that way either). The origination point of a file may not easily be identified as it may be stored in different locations (and countries). Individual packets belonging to the same flow may take different routes across over separate networks since the Internet is a meshed topology.

z) Therefore, charging for IP-interconnection usually takes place on the basis of the capacity provided at the interconnection point. It is not based on where the traffic originated or terminates. End-to-end SPNP approach to data transmission is totally antagonist to the decentralised efficient routing approach to data transmission of the Internet.

aa) The request for the data flow usually stems not from the CAP who sends the data but from the retail Internet access provider's own customer (who "pulls" content provided by

[197] For an analysis of the efficiency properties of bill and keep see BoR (10)

the CAPs, and from whom the ISP is already deriving revenues). Ultimately, it is the success of the CAPs (from whom IAPs wish to extract additional revenues) which lies at the heart of the recent increases in demand for broadband access (i.e. for the ISPs' very own access services).

***Separation of network and application layers***

bb) The separation of network and application layers is a characteristic feature of the best-effort Internet. It is only thanks to this feature that commercial relationships between CAPs and users are possible without the network operator being involved (provision of over the top services). They gave rise to a level of competition and innovation at the application level in today's Internet unprecedented before.

***Regulatory issues***

cc) The current Regulatory Framework foresees that NRAs can impose an obligation to interconnect on a non-discriminatory basis (Art. 5 AD). However it does not necessarily provide a legal basis for mandating free peering.

dd) The market has developed very well so far without any significant regulatory intervention.

ee) Disruptions in IP-interconnection due to disputes between ISPs potentially lead to a situation where not all destination of the Internet may be reached. However such instances have been few and have to date been solved in a relatively short time without regulatory intervention – also due to the competitive pressure of end-users at the retail level.

ff) Since the early days of the Internet there have been constant changes in the respective markets along the value chain - involving new types of players as well as new types of interconnection arrangements. NRAs need to understand these markets better.

gg) Depending on Member States' respective situations, NRAs may take different approaches: Some countries may consider data-gathering exercises useful whereas most others do not consider them appropriate unless concrete problems or requests occur.

hh) Any measure could potentially be harmful, so it should be carefully considered.

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