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Body of European Regulators
for Electronic Communications
BEREC

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

Draft report for public consultation

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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 in particular take place 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 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 who 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 efforts 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"; Draft for consultation BoR (12)32; BEREC (2012b) Draft BEREC report on differentiation practices and related competition issues in the scope of Net Neutrality"* , BoR (12) 31.

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 thus 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 where 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 due 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 sevices 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*

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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 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 ensure end-to-end connectivity across several AS. Having an AS number implies using BGP and applying peering/transit. Having an AS number 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 AS-numbers 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 3-criteria 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).While 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 vs. 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

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[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]

Quality of Service

- "Quality of service (QoS) is potentially gaining importance in the interconnection of IP / NGN.

- If a guaranteed (end-to-end) network performance over IP-based networks is desired one has to use the IP packet transfer *technology* allowing for implementation of traffic classes. This could lead to different qualities for electronic communication services. Operators are free to develop this as competitive markets are often built on quality differentiation, which can generally be considered to be welfare-enhancing.

- Nevertheless 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."

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 *"**(Draft)** Guidelines for Quality of Service in the scope of Net Neutrality"*

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

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 as well as quality of service 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 while 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.[11] 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 Distribution 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 as well as new types of interconnection agreements
- Chapter 5 looks at the regulatory context
- Chapter 6 concludes with some hypotheses.

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 it is referred to BEREC (2012a).

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

2 Players and business models in the Internet ecosystem

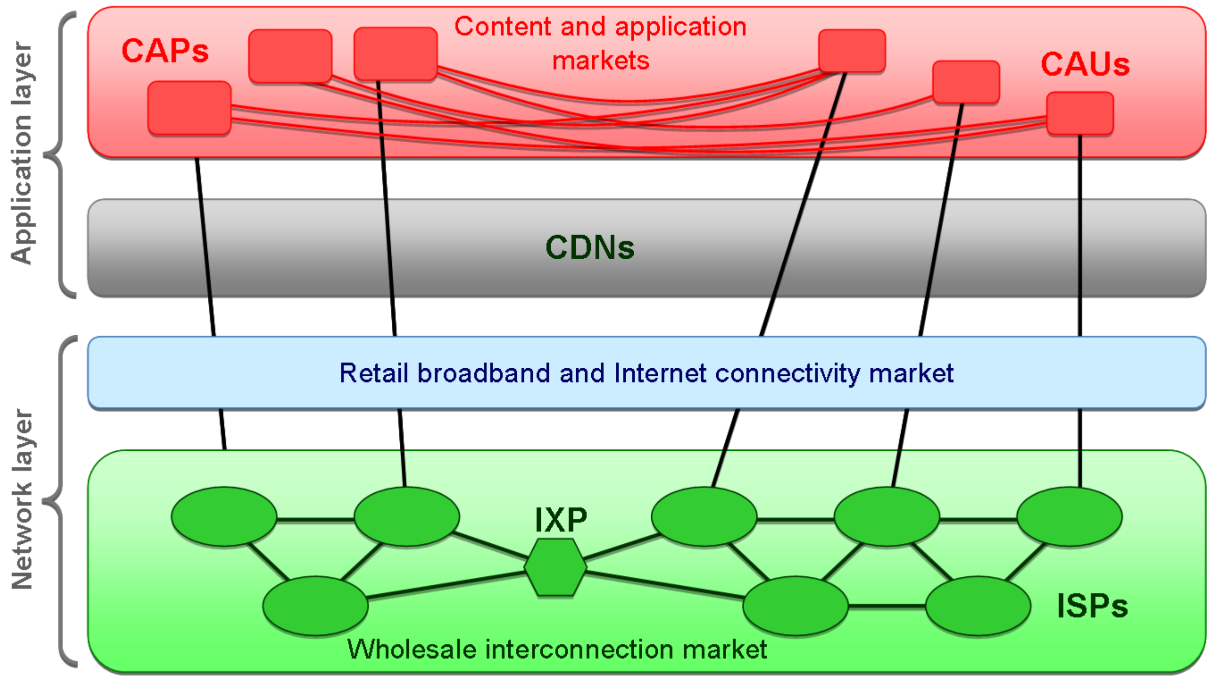
We will look at the whole value chain including retail markets to put interconnection and changes in the interconnection pattern into context.

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 stylized fashion concentrating on specific functionalities such as Content and Application Providers (CAPs) and Content and Applications Users (CAUs), different types of Internet Service Providers (ISPs) as well as Content Distribution Networks (CDNs).[12]

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



Source: BEREC (Note that this figure is an adapted version of Figure 5 in BEREC (2012b)

The figure above 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 black lines illustrating an exchange of traffic on the transport layer

- Both CAPs and CAUs 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 CAUs (indicated by the black lines) through "retail broadband and Internet connectivity markets" (blue area)
- ISPs interact with each other on "wholesale interconnection markets" (green area, black lines);

[12] See also BEREC (2012b),

- CDNs sell their services to CAPs (red line) and usually buy wholesale services from ISPs (black lines). Figure 2 (Ch. 2.4) further specifies the interaction of CDNs 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[13] as *"a user not providing public communications networks or publicly available electronic communications services"*. This definition encompasses different types of end-users, namely those that produce content and applications (CAPs) and those that use content and applications (CAU).[14] While sometimes only the latter are called end-users[15], we will use the term CAU to avoid overlap with the definition according to 2 (n) FD.

The way CAPs and CAUs 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 CAUs mostly *receive* traffic, unless they also provide peer-to-peer applications. Also some ISPs focus on CAPs as customers (also offering services like hosting), while other focus on CAUs (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 CAUs. 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 CAUs 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 lead 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 outgoing packets are treated equally, the direction of data flows is of no importance. Consequently, there is no need to differentiate between termination and origination on the network layer. Such a distinction would only be relevant in those cases where the interconnection of applications is considered.

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.[16]

Question 1 (Chapter 2): Are any other important players and/or relationships missing?

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

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

[15] See *"(**Draft**) BEREC report on competition issues related to Net Neutrality"*.

[16] CAUs and CAPs both constituting end-users in the sense of are intrinsically defined as neither provinding ECS nor operating networks.

2.1 Content and Application Providers

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

In order to make the content accessible for the CAUs they need to buy connectivity. They may also want to use hosting services[17].

a) Service: core functionalities

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

b) Further functionalities (resp. vertical integration)

CAPs may vertically integrate along the value chain as they get bigger. They may establish (e.g) 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 expensed 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 CAU. A payment from CAU to CAP for the provision of content can occur independently of the network (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 – at through 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 minimize their expenses.[18] CAPs buy upstream capacity and hosting services from ISPs and/or CDNs. They do not currently make any direct payments to the ISPs providing connectivity to CAUs.

e) Examples

CAPs encompass a wide array of different players: This may be players like (illustrative):
- Platforms enabling transactions: e.g. Amazon, eBay
- Social platforms: e.g. Facebook

[17] The core functionality of a hosting service consists in the the provison of server capacity.
[18] 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.

- 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
- Entertainment services: e.g. Youtube, Dailymotion, myvideo
- Application providers: e.g. Skype
- Video on demand: e.g. Netflix
- Non commercially driven provision of content via blogs and other Web 2.0 applications (such content may be provided by players that act predominantly as CAUs as described below).

Question 2 (Chapter 2): Do you agree with the classifications of CAPs as outlined above?

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.

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.[19] 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 services/applications such as Peer-to-Peer[20] applications, Youtube videos, Internet blogs etc. This may dramatically change (c.p.) the relation between traffic downloaded respectively 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 that everyone connected to the Internet may be an actor on numerous markets, without direct involvement of the network itself.

c) Revenues

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

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

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

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

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 different, 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.

Question 3 (Chapter 2): Do you agree with the classifications of CAUs as outlined above?

2.3 ISP (network providers)

Generically, the term ISP relates to operators who sell broadband access (network access) and connectivity to the Internet at the retail level 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.

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" 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 as of July 2011.
    - Further functionalities
        - Often, ISPs provide services over the user's broadband connection bundled with the Internet access that compete with e.g. over the top providers. Those facilities-based services are called specialised services[21]. They are electronic communications services that are provided using the Internet Protocol and op-

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

erated within closed electronic communications networks.[22] 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 CAP's
  - Costs
    - To provide connectivity eyeball ISPs need to buy upstream capacity via 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 up-stream 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[23], 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 via transit and/or peering so that the content of their customers can be accessed from CAU's. This is similar to the case of "eyeball" ISPs.

  Examples: Cogent, 1&1, Strato

- Backbone ISPs provide transit service for other ISPs. 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.

Question 4 (Chapter 2): Do you agree with the classifications of ISPs as outlined above?

2.4 Content Delivery Networks

CDNs serve as aggregators of content usually on behalf of content and application providers. 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.

a) Service: core functionalities

Generically, a Content Delivery Network (CDN) is a system of servers, deployed at the edge (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 operates 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).

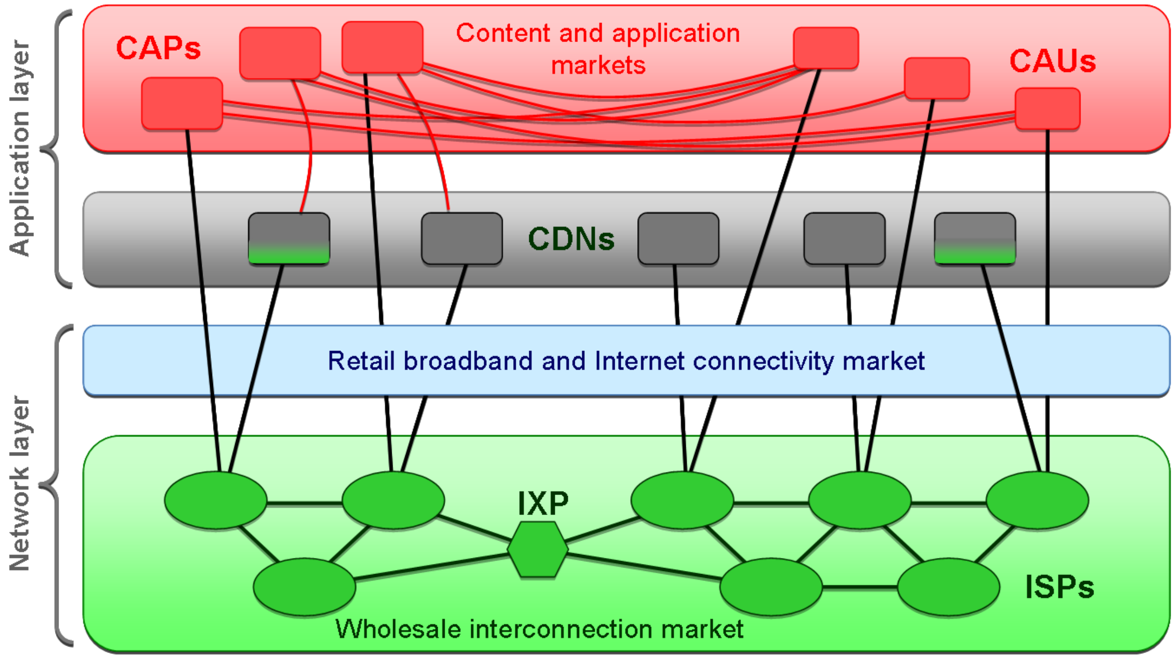
[22] For details see BEREC (2012a)

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

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 from an ISP. This is indicated with 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 unauthorized modification.

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 user (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 e.g. web browsing[24] watch videos.

b) Further functionalities (resp. vertical integration)

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

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

own characteristics (amount of data, up- and/or downstream, peak traffic, hard- and software to speed up programs) where different CDNs can provide added value.

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

c) Legal classification of CDNs

Since CDNs have evolved only recently and the contractual situation is often unclear there is 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[25] ARCEP[26], and NPT[27]. 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)[28] ?
- Do CDNs operate a telecommunications network (ECN)[29] 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 transport of signals on electronic communications networks. The studies from PTS, ARCEP and NPT have construed this latter criterion as to contain 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 CDN’s service is publicly provided and normally paid for, but would not consist wholly or mainly in the transmission of signals. The CDNs 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 himself and thus may not be held responsible for it. Therefore – following the criteria developed in

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[25] 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/

[26] 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.

[27] See NPT report "Content Delivery Networks - regulatorisk vurdering", http://www.npt.no/ikbViewer/Content/137120/Content Delivery Networks - regulatorisk vurdering april 2012.pdf

[28] 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).

[29] 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 broadcastin, 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).

the survey of 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 his servers and offers in addition to his core functionality to transport 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 as an ECS, since this additional offer consisted wholly or mainly in the transport of signals.

According to the studies by ARCEP and NPT, such an infrastructure based model a player could not only qualify 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 transport services provided over the network were available to the public. In this case the player would execute both a core functionality of 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[30] or per Mb consumed but other approaches like 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 CDN's revenues.[31]

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:[32]

- *pure* CDNs: e.g. Akamai (servers only)
- *also* operating a network: e.g. Limelight,
- network providers and ISPs: e.g. Level 3, AT&T
- CAPs: Google, Amazon (Cloudfront)
- equipment and solution vendors are also positioning:[33] e.g. Cisco, Juniper, Alcatel Lucent

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

Question 5* (Chapter 2): *Do you agree with the classifications of CDNs as outlined above?

[30] 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 assessed that 60 % of contracts for video are based on a Mbps basis.
[31] Cisco, Global CDN market forecast
[32] See also Ch. 4.4.4.
[33] 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[34]. 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 efforts principle. A final section looks at the status of interconnection arrangements involving some form of QoS assurance.

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 following multiple forms (peering, transit, paid peering, partial transit etc.).

3.1 Transit

Transit is typically a bilateral agreement where an ISP provides full connectivity**[35]** 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.[36] It sells access to all destinations in its routing table.[37] Transit is a wholesale product against a payment.

Typically, the rationale of transit agreements is “bill your customer & 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.[38] 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.”[39]

Whereas transit typically provides *full* connectivity, in other cases “partial transit” is applied which is a more limited form of transit where 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

Transit is usually 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.[40] In transit agreements, the Internet/broadband access provider pays for connectivity to the upstream network for upstream and downstream transmission of traffic.”[41]* Payments for transit cover both, outgoing and incoming traffic.[42] Typically, the maximum of both directions determines the price for the transit service provided.

[34] For details see e.g. ERG (08) 26final, Ch. B.2.2 “Interconnection in existing IP-based networks”.
[35] 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 connectivity to the “whole” Internet.
[36] See ERG (2008).
[37] 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.
[38] ERG (2008), p. 6.
[39] ERG (2008), p. 6, note: this also holds for peering (see next section).
[40] Note: Since there is generically no distinction between origination and termination of data flows in IP networks (see above at p.) this also holds for peering, see next section.
[41] ERG (2008), p. 5, 6.
[42] ERG (2008), p. 48.

Often, a 95th percentile measurement is applied to determine the volume of traffic exchanged for billing transit services.[43] With this scheme, traffic samples are taken at intervals of (e.g.) 5 minutes. At the end of the billing period (typically a month), the samples are ranked by sized 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 optimization 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).

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 others customer's customer etc). Thus, different from 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 only gets access to the customers of B but not the customers of C.[44]

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":[45]

- 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:[46]

- Specification of a ratio between outgoing and incoming traffic
- Traffic volume and/or capacity: peering policies may require a certain traffic volume, which often is 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.

[43] WIK-Consult (2008, p. 71) points out that the 95th percentile approach was often used in the mid-nineties.
[44] See e.g. Laffont, Marcus, Rey, Tirole (2001), Internet Interconnection and the Off-Net-Cost Pricing Principle, 23 .April 2001, p. 3.
[45] www.drpeering.net.
[46] See Faratin et al (2008), p. 56; Analysys (2011), Annex A.2.3; WIK-Consult (2008), p. 74.

When two peers exchange traffic the principle of hot-potato routing applies. The network where the traffic originates from will hand off this traffic as early as possible to the other network (and vice versa). Thus if a “small” network X hands off its traffic to a “big” network Y, the latter would 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 (c.p.) have to make bigger investments than the smaller network. This would imply that the small networks free-rides on the big networks infrastructure. This is also the reason why typically a larger network is not inclined to peer with a smaller network or require from their 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.[47] 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). 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.[48]

- Marketing considerations: an 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.[49]

- Other aspects: factors like 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 in order to warrant the transaction costs incurred.[50]

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.

[47] WIK-Consult (2008), p. 74.
[48] Faratin et al (2008), p. 56: “*Consistent announcements allow a peer to hot potato traffic, inconsistent announcements force a peer to cold potato traffic.*”
[49] WIK-Consult (2008), p. 74.
[50] WIK-Consult (2008), p. 74, Footnote 140.

Costs of peering

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

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

Besides these transaction costs of building and supervising a peering relationship occur. Given the CAPEX incurred for these cost positions and the transaction costs involved it is 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 saving 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 who is willing to peer avoids the costs of having to buy transit otherwise.

But peering may also be the preferred option as 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 of 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.[51]

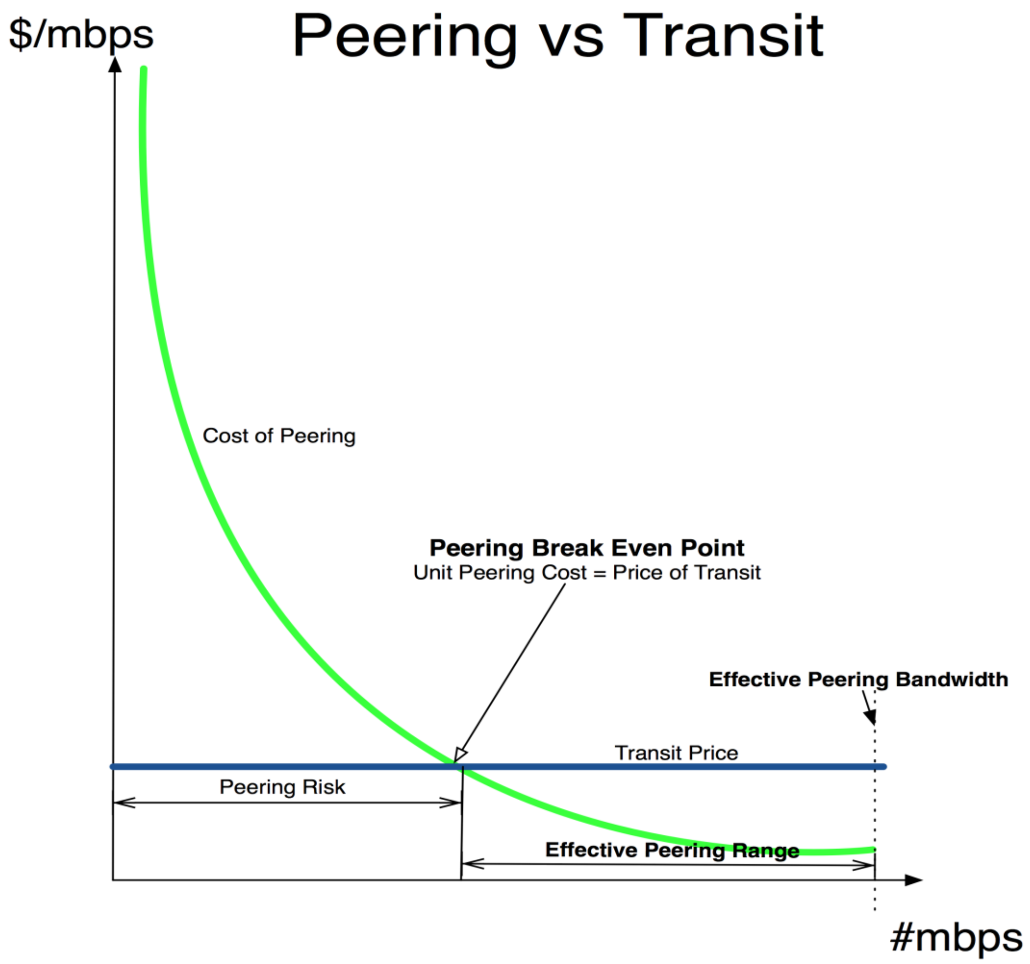
Whereas transit is a provider/customer relationship peering rather is of a symmetrical nature. Two parties will typically only agree to peer with each other if both expect to be better off than without peering. In this respect, an agreement to peer implies a Pareto improvement for the involved parties. Peering ultimately is 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 own network infrastructure and hence saves operating costs while simultaneously assuring an appropriate performance level (see Figure 3 below).

[51] Norton (2003).

Figure 3: Peering vs. Transit



Source: Dr. Peering

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.[52]

ISPs that do not fulfill 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.[53]

Question 6* (Chapter 3): *To what extent are requirements regarding traffic ratios still important in free peering arrangements?
Question 7* (Chapter 3*): To what extent does the functioning of the peering market hinge on the competitiveness of the transit market?

[52] ERG (2008), p. 49., see also WIK-Consult (2008), p. 72.
[53] ERG (2008), p. 6.

3.2.2 Further Types of Peering Arrangements

Secondary / Donut / Regional Peering

In the early days of the Internet peering applied (almost) only between Tier 1 backbone providers. With secondary peering two lower tier ISPs (who are no Tier 1 providers) directly exchange traffic[54]. 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 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

Different from settlement free peering with paid 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.

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.[55] This was the case with the rise of video content in the Internet. It is estimated that a 3-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.[56] However, it should be noted, that as of 2011 only 0,27% of peering contracts are paid for (*Examples seems to be Akamai and Limelight having paid peering contracts with Comcast.*

Question 8* (Chapter 3)*: Does an imbalance of traffic flows justify paid peering?
Question 9* (Chapter 3)*: Does paid peering increase (number of contracts and volume handled under such contracts)?
Question 10* (Chapter 3)*: To what extent does regional peering increase in relevance and affect transit services?

3.2.3 Internet Exchange Points (IXPs)

An Internet Exchange point Point (IXP) is a place where multiple ISPs interconnect their respective networks.[57]

[54] Analysys (2011, p. 32) uses secondary peering and direct interconnection as synonyms.
[55] Faratin (2008), p. 60; Analysys Mason (2011) p. 24.
[56] Analysys Mason (2011) p. 24.
[57] Norton (2012).

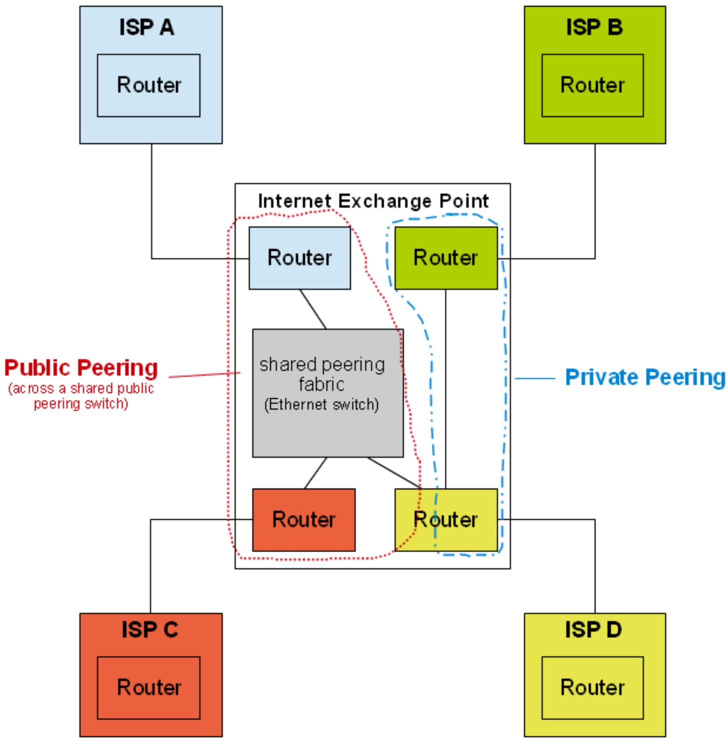
Internet Exchange Points (IXPs), or as they were used to be called Network Access Points (NAP), constitute another institutional setting for the exchange of traffic, where ISPs can voluntarily participate and where they agree to interconnect at a multilateral peering point to exchange their traffic without needing to buy transit from an upstream provider and thus reducing costs as there are, usually no payments for the exchange of traffic [58]. The Internet players have long adopted this interconnection model where many ISPs meet to exchange their traffic with other providers, each bearing the cost of transmitting the IP traffic to the IXP/NAP.[59] 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:[60]

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 who peer. This form is most common at an IXP.

Internet Exchanges often allow a multilateral form of peering arrangements.

58 Costs may be covered by annual or monthly fees, depending e.g. on transmission speeds used.
59 ERG (08) 26, p. 49/59.
60 Norton (2012).

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 also peer at that IXPs.

***Private peering**:*

With private peering two operators exchange traffic at the IXPs across a dedicated cross-connect between them. In practice, IXPoften support both, public and private[61] peering.

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:[62]

- 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 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 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. [63]

Question 11*(Chapter 3)*: Are any important services missing from the list of services provided by IXPs?

Question 12* (Chapter 3)*: Are there any further developments regarding IXPs to be considered?

Question 13* (Chapter 3)*: Should in future Europe evolve to have more decentralised IXps closer to CAUs?

[61] 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.

[62] Norton (2012).

[63] 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).

3.3 QoS interconnection

QoS traffic classes on the Internet?

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 SLA (Service Level Agreements) includes rules on availability, throughput capacity and resilience of the of the edge/border routers, i.e. the interconnection connection at the interconnection interface. Any arrangements on the quality conditions of the exchanged traffic across interconnected networks are not part of the peering and transit agreement. Each ISP manages the traffic transfer within his network autonomously[64]. The default traffic transfer strategy is the best-effort principle.

Therefore, QoS assured interconnection did not play a role within that context. Despite this, there has been a discussion about QoS Interconnection with guaranteed traffic classes across networks for some years now. The following explanations provide some further insights into these issues:[65]

With the migration from legacy circuit-switched networks towards 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 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 rather has 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[66], 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 opposed to the Internet access service he 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 only concerned 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[67]. When interconnecting several IP networks the performances of the single networks are summed up to an end-to-end network performance form UNI (user network interface) to UNI[68]. The end-to-end network performance (UNI-to-UNI) is referred to as end-to-end IP service or traffic class.

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64 BEREC (2011), See chapter 4.1

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

66 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).

67 See BEREC (2012a)

68 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

Therefore, IP interconnection within the Internet ecosystem only relates to the interconnection 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 layer traffic classes.

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). There are several traffic management mechanisms[69] and protocols (e.g. DiffServ, IntServ, MPLS) available to support traffic classes within IP networks.

Traffic classes constitute the building block of specialised services (e.g. for closed business services), but may also be applied on the Internet in the future (which would then also offer higher priority levels than best-effort). IP-based networks have been able to offer such traffic classes at different levels of quality for perhaps a decade.

Internet services however are at present more limited in their use of quality techniques. However, the standardization by IETF of quality architectures could also enable guaranteed QoS for the Internet in the future[24]. The most challenging aspect regarding implementation of these architectures is the IP interconnection between providers[70].[71]

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[72]. It requires agreement on harmonized traffic classes and end-to-end implementation of protocols for e.g. allocation of performance budgets and “QoS signalling” (e.g. priority marking) of IP packet streams. The challenges of providing QoS across interconnected networks have been described in some detail in 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 as of now:[73]

- 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 of what constitutes a “premium” quality 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 costly to implement.

- Network externalities 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 his network.

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69 Traffic management issues of QoS issues are dealt with in BEREC (2011) Chapter 4.4) and BEREC 2012a

70 Several RFCs are standardized by IETF specifying quality architectures like Differentiated Services (RFC 2475 and others) and Multiprotocol Label Switching (RFC 3031 and others) that are used extensively inside individual providers’ networks, but that also are applicable to inter-provider solutions.

71 See BEREC (2011) *“A framework for Quality of Service in the scope of Net Neutrality”,* Chapter 4.5.

72 See e.g. 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).

73 Marcus (2006), Ch. 3.2.2.

- Given the high cost of implementation possibly lower cost “best-effort” capacity up to now has shown to be the strategy of choice.

- While not implying a guaranteed delivery of data, 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. Best-effort Internet in most cases results in a (relatively) high quality of experience for users, even for delay-sensitive applications such as VoIP;

- Other mechanisms for improving end-to-end network performance have developed:
    - Endpoint based congestion control for reduction of the traffic load in order to limit the congestion and avoid overloading the network[74].
    - 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).

- Consequent lack of customer willingness to pay much of a premium for better service.

While QoS traffic classes can be welfare enhancing as long as CAUs can transparently choose there are also concerns associated with the introduction of them:

- 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. Therefore it creates the need for more regulatory control including the potential need for a minimum quality of service introducing additional monitoring requirements.

QoS interconnection for specialised services

Specialised services are electronic communications services that are provided using the Internet Protocol[75] and operated within closed electronic communications networks. These networks rely on admission control and they are often optimised for specific applications based on extensive use of traffic management in order to ensure adequate service characteristics.

- Specialised services do not directly interfere with the best effort Internet or other IP networks. These closed IP networks rely on admission control and they are often optimized for specific applications based on extensive use of traffic management in order to ensure adequate service characteristics.[76]

- For the offer of specialised services (like business VPNs and IPTV offers) integration of QoS traffic classes within the network layer is inevitable.

- 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 wholesale bitstream product will need to allow for QoS features.

[74] See BEREC (2011) Chapter 4.4.
[75] Specialised services may also comprise non-IP based services like cable television or circuit switched telephony, but the focus in these guidelines is on IP based service provisioning.
[76] For details see BEREC (2012a)

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

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.

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.

QoS interconnection and deviations from Net Neutrality

- If traffic classes were implemented 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 of the CAU compared to applications not employing such techniques. Even a CDN operating his 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.

Question 14 **(Chapter 3)*****: Will traffic classes ever become available in practice on a wide scale?***
Question 15 **(Chapter 3)*****: Will interconnection for specialised services be provided across networks?***
Question 16 **(Chapter 3)*****: Will other solutions for improving QoE like CDNs become more successful rather than traffic classes?***

4 Recent Changes

4.1 Traffic evolution:

Generally, two factors impact on the increase in traffic:

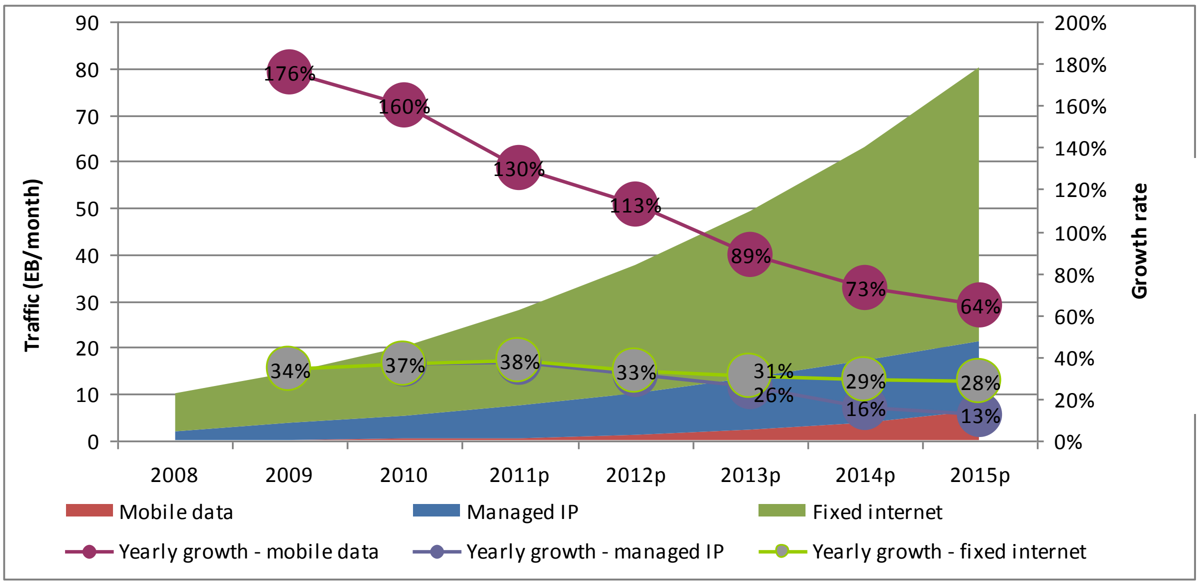
- the increase in the number subscribers and
- the increase in traffic per subscriber.

While the absolute number of fixed broadband subscribers still increases, the rate of growth shows a slight decline.[77]

It can be shown that the growth of total IP traffic is particularly driven by the traffic growth per subscriber while the subscriber rate of growth plays a smaller role.[78] 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.[79]

Figure 5: 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 due to the fact that the increase in mobile traffic starts from a significantly lower level. In 2011 mobile had a share of approximately 2 % of total IP traffic. While the growth rate for global mobile data traffic was about 130 % in 2011 it is expected to decline to 64 % in 2015.[80]

- **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 con-

77 WIK-Consult (2011), Ch. 2.5, similar Telegeography.
78 For details see WIK-Consult (2011), p. 35/36.
79 Telegeography (2011).
80 WIK-Consult (2011, p. 31/32) based on Cisco and WIK calculations.

tent is stored closer to the consumer, using CDNs allows to reduce the need for transit.

- In 2010 P2P traffic represented the largest share of Consumer Internet traffic in 2010 (approx. one third). However, its share is declining. Cisco estimates a share of P2P traffic of 22 % for 2012.[81]

- Increase in streaming and direct download: While the share of P2P traffic is likely to decline, it is forecasted that Internet video streaming and direct download will grow to nearly 60 % of all consumer Internet traffic in 2014 and Cisco had projected that by the end of 2010 global Internet video traffic would surpass P2P traffic. [82]

  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.[83]

- **Regionalisation** of traffic

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

  - A large part of content is provided nationally (language based)[84]
  - 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 (c.p.) more traffic is conveyed circumventing the networks of global backbone providers.

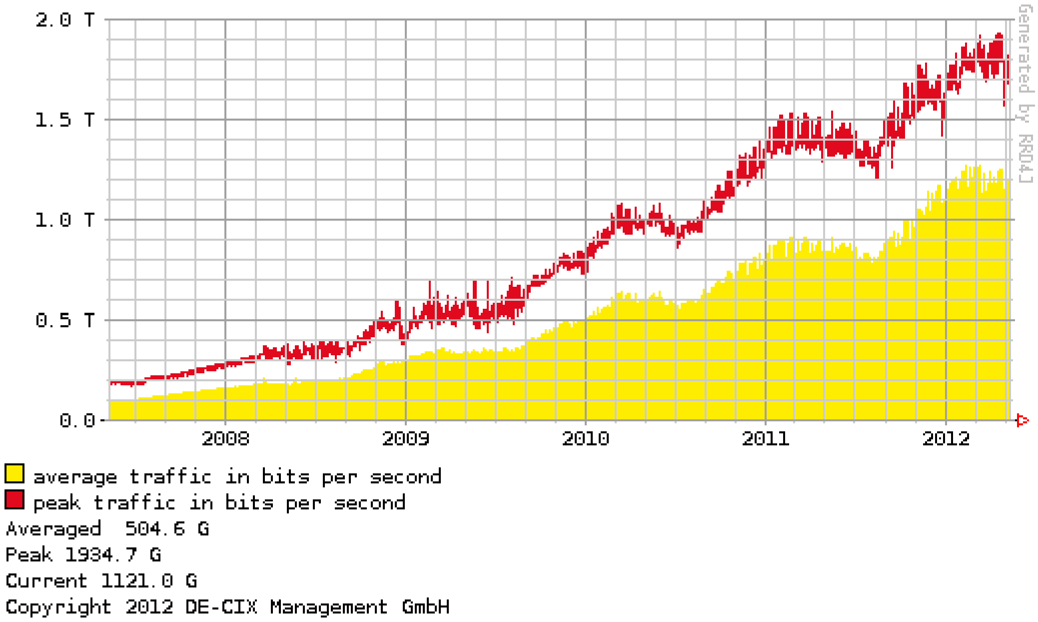
- **Development of IXP**

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

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

[81] Cisco (2010) p. 11.
[82] Ibid, p. 9, see also Labovitz et al (2009) also predicting that P2P will be eclipsed by streaming and direct download.
[83] http://de.nachrichten.yahoo.com/spotify-beauftragt-carpathia-hosting-mit-einf%C3%BChrung-den-usa-000000992.html.
[84] See Boston Consulting Group (2012).

Figure 6: 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)[85] while it was about 750 Gbit/s end of 2011. And for the LINX the corresponding figures are 745 Gbit/s[86] (March 18 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 (Nov. 18, 2011). [87] Equinix, who ranks 3rd among the largest IXPs is also a US corporation, however, it does not only operate IXP facilites in the US but also in Europe.

Question 17* (Chapter 4)*: Which of the factors impacting on the regionalisation of traffic is most important: language, CDNs, direct peering?
Question 18* (Chapter 4)*: Are any further issues missing?

4.2 Pricing and costing developments:

4.2.1 Decreasing costs

The overall cost position of network operators is affected in particular by two aspects: the increase in overall traffic volumes and technological improvements. 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. However, per unit costs may even fall depending on the economies of scale.

Technological progress is the second factor impacting both, on overall and particular per-unit costs of a network operator. 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

[85] http://en.wikipedia.org/wiki/List_of_Internet_exchange_points_by_size.
[86] http://en.wikipedia.org/wiki/List_of_Internet_exchange_points_by_size.
[87] http://en.wikipedia.org/wiki/List_of_Internet_exchange_points_by_size.

effect (c.p.) on the overall cost position of a network operator. Of course, in practice, a comprehensive assessment would require to also take into account the revenues generated by this operator.

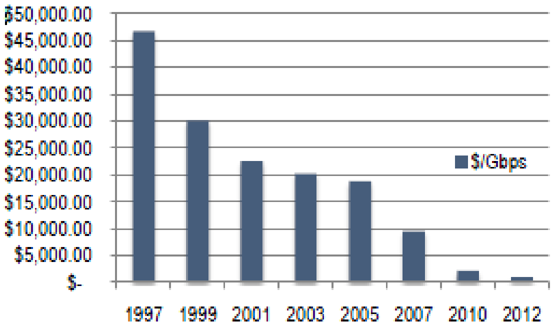
Moore's law provides an interesting illustration that technological progress leads to significant performance improvements. In 1965 Gordon Moore stated that the number of integrated circuits on a computer chip was doubling every 18-24 month.[88]

In order to assess the relevance of Moore's law on cost positions of network operators it is necessary to separately look at unit costs in the core network and in mobile networks.[89]

Core networks:

- 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 their routers decreased at an annual rate of 23 %: (1997-2012).[90]

Figure 7: Router costs $ per Gbps



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

And the costs per gigabyte for DWDM optoelectronic equipment was also subject to a continuous price decline while the total DWDM capacity is expected to rise significantly in the near future (2012-2014) (see Figure 8 below).[91] Costs for routers and DWDM optics are major cost drivers affecting the usage-based costs of fixed core networks. Other cost items such as labour costs are much less usage-sensitive.

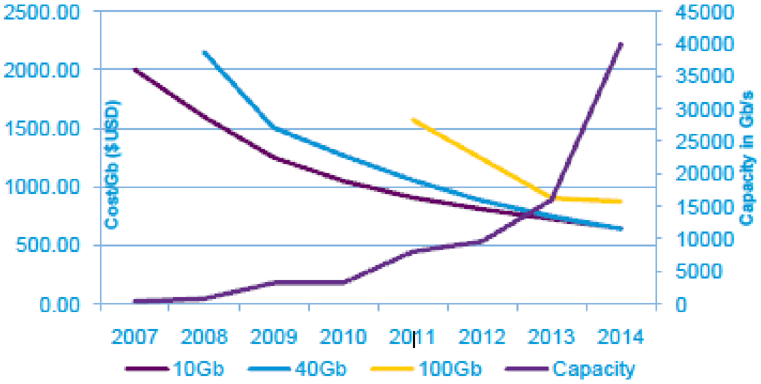
[88] Originally, Moore had assumed a doubling every 12 months.

[89] See WIK-Consult (2010, Ch. 2.3) for a deeper analysis looking at unit costs in the core networks, mobile networks and the last mile.

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

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

Figure 8: DWDM optic cost and DWDM capacity



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

Overall. 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.[92]

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 technologies imply significant decreases in costs for a given capacity compared to current mobile technologies.[93] This is due to spectrum efficiency improvements as well as lower costs of carrying traffic. For example, compared to basis W-CDMA technology, LTE leads to a cost decline of 94 %.[94]

  Traffic volumes in mobile networks increase at a higher rate – however, from a significantly lower level in absolute terms – than in fixed networks. However, mobile operators respond to these traffic developments and to their relative capacity disadvantage compared to fixed networks by typically offering capped flat rates for mobile Internet usage while fixed operators (typically) offer unlimited flat rates.

Last mile:

- Unit costs declines are mainly relevant in core/aggregation networks and in mobile networks. Generally, costs in the last mile are mainly driven by the number of users and not by traffic volumes. As pointed out by WIK-Consult Moore's Law is much less relevant at the edge of the fixed network. [95]

Summing up, the assumptions of many opertors that costs are exploding due to traffic increases[96] lose much of their seeming persuasiveness if cost developments on a per unit basis are looked at. In fixed networks usage-based costs - accounting for 10-15 % of total costs for fixed broadband networks – are roughly stable.[97] These usage-based costs basically follow the growth in the number of fixed network subscribers.[98] And this subscriber growth comes implies corresponding revenues per subscriber. Acknowledging technological differences between fixed and mobile networks, also the latter is subject to significant cost de-

92 WIK-Consult (2011), Ch. 2.3.
93 See WIK-Consult (2011), Ch. 2.3.2.
94 Analysys, quoted from WIK-Consult (2011, Ch. 2.3.2).
95 WIK-Consult (2011), Ch. 2.3.3.
96 Plum (2011), Ch. 2.2, p. 18/19; Kenny (2011), p. 6,7; WIK-Consult (2011).
97 WIK-Consult (2011), p. 59, similar Plum Consulting (2011), p. 19, concluding that overall costs are likely to fall for fixed networks.
98 WIK-Consult (2011), p. 60.

clines and mobile operators reacting by offering tariff plans to assure 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).

4.2.2 Pricing trends

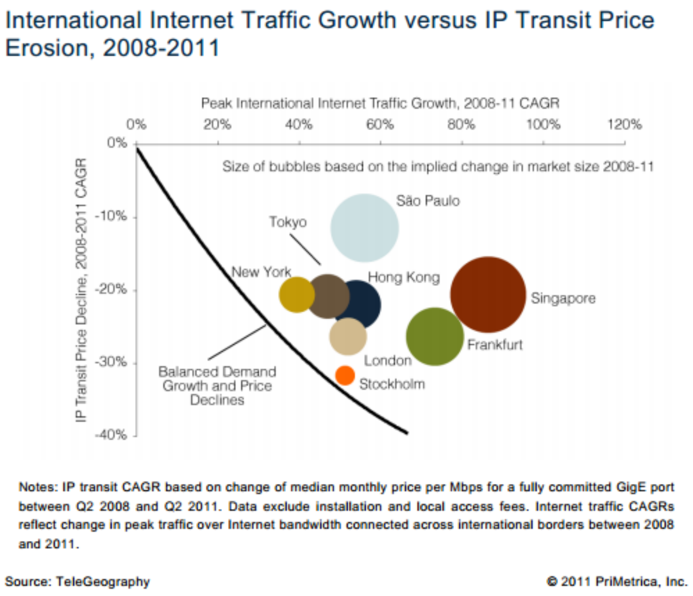
- **Decreasing transit prices**

  Over the last few years transit prices decreased significantly due to 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.[99]

  These results are also backed by the following figure depicting that the averaged 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 9: International Internet Traffic Growth versus IP Transit Price



- **Decreasing prices for CDN services**

  Also for CDN services there a significant price decrease can be observed. In Q4 2011 CDN prices declined by 20 % (vs. Q4 2010). The corresponding price decline figure for

[99] WIK-Consult (2011), Chapter 2.6.

2010 and 2009 were 25 % resp. 45 %.[100] Thus, the price decline still continues, however, 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 will likely have an impact on the price trend for CDN services. Similarly, price developments for CDN services will probably also impact on transit prices.

Price example:

Figure 10: Video Delivery Pricing (Q4 2011)[101]

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 figure ARPU has remained relatively constant over the last years 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 resp. upload traffic generated by the CAU – has led to greater costs per CAU for the ISP.[102] This can be explained as follows:

- The marginal costs of conveying additional traffic over the CAU's access line are (at least) very low.
- Providers of Internet access lines typically have to buy transit from other ISPs. Such transit payments cover both down- and upstream traffic.[103] Prices for transit have been subject to a significant decrease over the last years.[104] From an economic perspective it is crucial that the unit costs of conveying traffic even have decreased.[105]

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 by new CAUs.[106]

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

[101] It should be noted, that in 2009 pricing was mostly done on the basis of "per GB delivered", today, an Mbps basis is more common.

[102] WIK-Consult (2011, p. 10) concludes: *"Price per user is stable because cost per user is stable"*.

[103] See ERG (2008), Ch. B.2.2 illustrating payment and data flows in IP-based networks.

[104] See Ch. 4.2.2 on the development of transit prices.

[105] See Ch. 4.2.1.

[106] Kenny (2011), p. 8; WIK-Consult (2011), Ch. 2.7, p. 47 ff.

Next to the volume of traffic generated by a CAU also the number of subscribers affects an ISPs total revenue. However, these revenues are in line with the increasing number of subscribers.[107]

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.[108]

Question 19* (Chapter 4)*: Given the cost reductions and the economies of scale and scope observable in practice, why do network operators call for compensation

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, however, Google and 2 CDNs entered the *top 10*.[109] While the *top 10* providers accounted for approximately 30 % of all traffic in 2007, their share increased to 40 % in 2009/2010. Google share of all Internet traffic increased from approximately 5 % in 2008 to 7 % in 2011.[110]

The ongoing consolidation process becomes evident by 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%."*[111] Whereas in 2007, thousands of Autonomous System Number (ASNs)[112] accounted for half of all Internet traffic, in 2009, 150 ASNs contributed the same percentage.[113]

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 of global backbones. This is due to a number of factors:

- More traffic than in the past is routed using peering rather than transit agreements.[114]
- The practice of donut peering[115] where 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).

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[107] WIK-Consults (2011, p. 10) summarizes „*Traffic growth driven by an increase in the number of subscribers should raise no concerns.".*

[108] See also WIK-Consult (2011), p. 10.

[109] Labovitz.

[110] Labovitz (2011).

[111] www.caida.org.

[112] See Footnote 4

[113] Labovitz et al (2009).

[114] See e.g. OECD (2011) pointing out that 99.5 % of interconnection agreements are concluded without a written contract.

[115] See Section 3.2.2.

- A larger portion of traffic is directly exchanged between large CAPs, CDNs or sometimes even CAUs
- Using transit may (c.p.) 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 own network infrastructure and deploy their own national or even international backbone this would also increase put further pressure on the backbone providers.

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

- In 2011 Level 3 has 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 traffic is (often) transmitted across large distance with several router hops.

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.[116] Given this development it is noteworthy that about a decade ago there has been a debate on whether backbone providers might have SMP.[117]

4.4.3 CAP developments

When a large CAP like 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 increase 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 who provide particularly language based content and thus serve specific countries.

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

[116] Concerning the relative decrease in the role of transit Analysys (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.”*

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

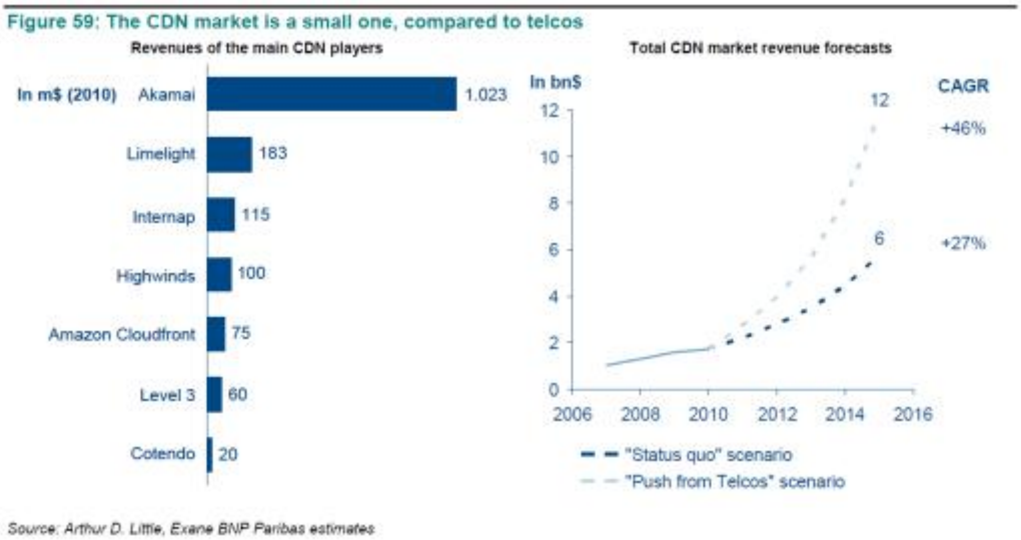
Creation of content has become more regionalized because part of content is produced at the edges of the network e.g. by CAUs (blogs, p2p etc).

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 11: 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).
- By delivering content from servers closer to the CAU router hops can be avoided as content does not have to traverse various transit networks. For the content providers using CDNs this ultimately implies (c.p.) an enhanced competitiveness (in relation to other content providers).
- CDNs also allow for a reduction in transit costs/reduce peering volumes. By storing content closer to the CAU this content only needs to be delivered 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 minimized 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 for a particular website, (ie during the attacks during 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 ASes. With CDNs, a single content provider interacts with a single CDN network who then interacts with multiple ASes. Given this, the CDN internalizes the transaction costs (provisioning, monitoring and enforcing) of bargaining with ASes while benefiting from economies of scale and scope.[118]
- In order to get their content delivered to the terminating ISP content providers may either buy transit services or they may use the services provided by CDNs. The latter option is a rational strategy if it is not economically viable for the content owner to provide their own local storage solutions.

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 like Akamai or Limelight. Nowadays, increasingly other players vertically integrate and perform CDN functions. This may be network providers or ISP moving up the value chain, CAPs like Google or also Internet players like Apple who provide internal CDN solutions. Other Internet player (e.g. Amazon) offer CDN services for third parties. Furthermore, also telcos such as BT, KPN, Level 3, AT&T have started to provide CDN services as well as equipment and solution vendors such as Alcatel-Lucent, Cisco or Juniper.[119]

From a content providers perspective the CDN make or buy decision depends on the content providers' 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 who also provides its own content. Such a neutral CDN may be more trustworthy as it has no incentive to discriminate against between its customers.

Traffic consolidation

Akamai claims that 20 % of the world's Internet traffic is handled over its platform.[120] And Edgecast stated in July 2011 that it carries approximately 4 % of worldwide Internet traffic.[121]

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 who 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*"[122]

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

Question 20* (Chapter 4)*: Do you subscibe to the view that CDNs lead to improvement of QoS without violating the best effort principle?

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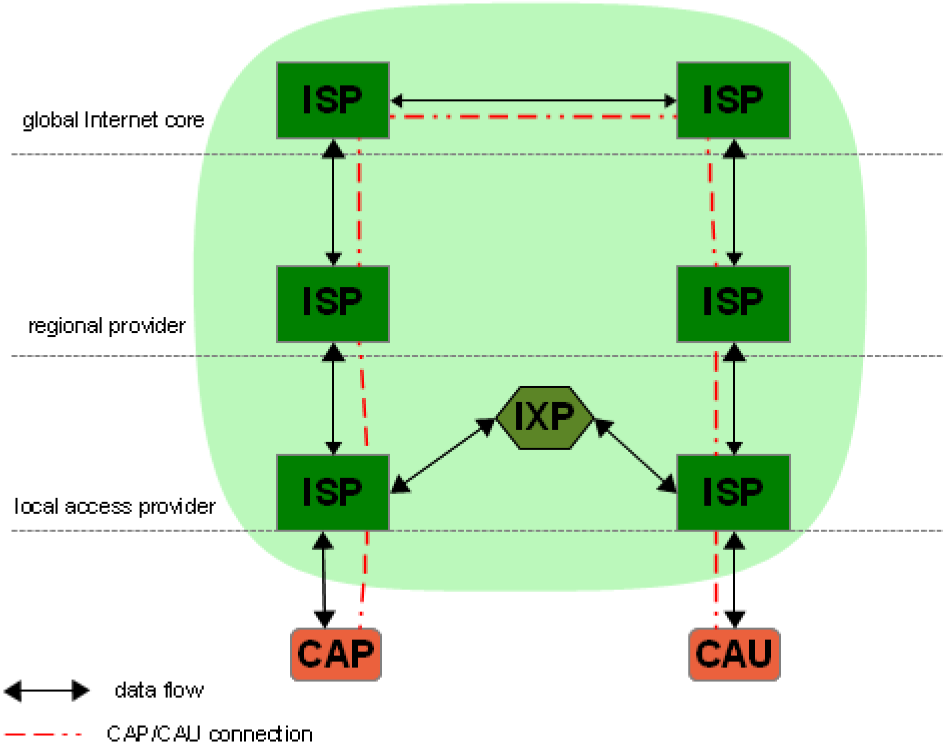
[118] Faratin et al (2008), p. 66.
[119] IDATE (2010), slide 10.
[120] http://www.akamai.com/html/technology/visualizing_akamai.html
[121] http://www.businesswire.com/news/home/20110726006802/en/EdgeCast-Reports-Continued-Customer-Traffic-Growth
[122] http://www.nigelregan.com/2010/04/network-status-2009-the-european-cdn-market/ (April 16, 2012).

Question 21 **(Chapter 4)*****: Is there a trend for CDNs to provide their own networks (i.e. integrating backwards)?***

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.[123] This is indicated by the dashed red line (CAP/CAU connection).

Figure 12: The "old" Internet



Source: BEREC

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

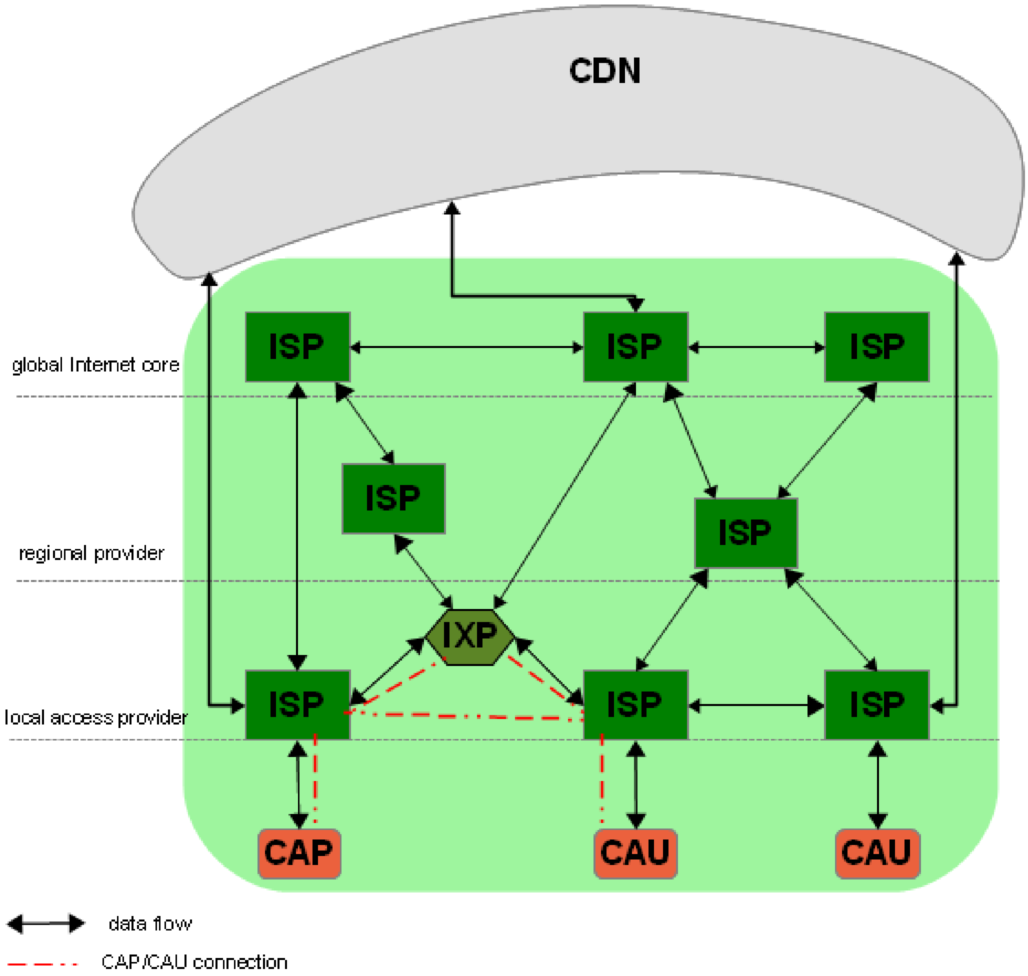
- A greater portion of traffic is no longer routed via global Tier 1 backbone providers because data is either exchanged (e.g.) directly between local access providers in peering contracts or via the IXP. In the following figure 13, this "flattening" is illustrated by the dashed red line.
- An increasing number of ISP's providing connectivity to a large number of CAU's have acquired Tier 1 status and therefore no longer need transit.
- 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

[123] See also ERG (2008). Chapter B.2.2 generically describing the data and payment flows.

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

> ***Question 22*** **(Chapter 4)*****: Is there a general tendency for eyeball (CAU) ISPs to deploy their own transit capacities and long distance networks or even to become Tier-1 backbones?***
> ***Question 23*** **(Chapter 4)*****: If an eyeball ISP becomes Tier-1 provider, does this increase the eyeball's market power on the interconnection market because there are no alternative Tier-1 providers to reach the customers of this eyeball ISP?***

Figure 13: The "new" Internet



Source: BEREC

The flattening of network hierarchies reflects the (relative) decrease in the role of transit providers.[124]

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.

[124] OECD, Annex 1, Recital 5.

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.125

4.6 Predominance of informal peering arrangements

A voluntary survey of 142,000 peering agreements encompassing 86% of ISPs (Woodcock/Adhikari, Packet Clearinghouse for the OECD, May 2011) lead to the following results:

- 99.5 % all peering agreements are 'handshake' agreements concluded without a written contract, while 0,49% are based on written, formal contracts
- 99,3% of all peering agreements are based on symmetric terms, while 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 flexibly adapt to changing conditions.

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

4.7 New types of interconnection agreements emerged over the years:

In the past there was a "simple" dichotomy, interconnection was based either on peering or transit agreements. Over the years a variety of types of interconnection has emerged.[126] 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, either such paid arrangements do not exist in practice 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. Standardized agreements were appropriate in the early days of the Internet when there has not been such a variety of business models as can be observed today.

[125] OECD, Annex 1, Recital 5; see also Gupta/Goel, slide 19.

[126] See Faratin (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 …".*

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*.[127] 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,* though. Consequently, there is no *a priori* presumption that the 3-criteria 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 to identify 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.[128]

Furthermore, in those cases where the three criteria 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.

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

[128] 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

NRAs may only impose obligations under Art 5 AD on undertakings that control access to end-users reflecting the bottleneck. 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 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 begs the question whether a CDN operates a telecommunications networks in the sense of the FD and whether he 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.

According to rec. (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

Obligations and conditions imposed under Art 5 (1) AD 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[129] and that ISP 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.[130] Moreover, peering is a barter exchange. Generally, two operators will only agree to peer with each other 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 provide a legal basis for obligations to interconnect at specific price, namely 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, due to 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.

Question 24* (Chapter 5)*: Will Art. 5 become more relevant as some large Eyeballs have equally qualified as Tier 1 providers not having to rely on transit any more?

[129] BoR (10) 42, p.2
[130] 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 having to act under their dispute settlement regulations.

6 Hypotheses / 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 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. In most instances, operators will employ both transit and peering arrangements, i.e. they can also be used as complements. ISPs that do not fulfill 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) The emergence of hyper giants (Google, Akamai, Amazon…) as well 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 becoming more blurred as players increasingly perform different and/or new functionalities and integrate along the value chain.

f) 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.

g) CAPs make substantial payments for hosting and connectivity. Furthermore they pay for CDN services that bring content closer to the CAU. Therefore different 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. Therefore BEREC conjectures that everything is covered and paid for in the Internet value chain (from content providers to the CAUs).

h) CDNs have contributed to better quality being provided to the CAUs. This may decrease the likelihood for traffic classes assuring QoS being implemented in interconnection agreements across network boundaries. And there is no free-riding by CDNs as they pay for the services they use (see 2.4.e).

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

j) Increasingly large Eyeball ISPs providing connectivity to CAUs on a large scale acquire Tier 1 status, in that they solely rely on peering no longer needing to buy transit. There are few independent transit providers left.

Quality of Service vs. best-Effort

k) While 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.

l) 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.

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

n) Potential violations of Net Neutrality such as blocking and throttling of traffic typically occur in the Eyeball ISP's network and therefore not reflected in IP interconnection.

o) Specialised services are provided using the Internet Protocol but are operated within closed IP networks. These IP networks rely on 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 speczialized services such as IP-TV does not necessarily require traffic classes across interconnected networks if the service is provide within an operators network.

p) Generally, QoS classes at the network layer can be welfare enhancing as long as CAUs can make an informed decision. This requires transparency.

q) On the other hand, 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.

r) Up to now, interconnection with QoS assured across network boundaries does not / hardly exist in practice.

s) In best effort networks alternative mechanisms - compared to 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 CAU's perception of an application's quality (QoE).

Charging principles

t) 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 CAUs.

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

Separation of network and application layers

u) 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 CAUs 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

v) The current Regulatory Framework foresees an obligation to negotiate interconnection on a non-discriminatory basis (Art. 5 AD). However it does not provide a legal basis for mandating free peering.

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

x) 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 competitive pressure of end-users at the retail level.

y) 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 better understand these markets.

z) Depending on MSs’ 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.

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

Questions

Question 1 (Chapter 2): Are any other important players and/or relationships missing?

Question 2 (Chapter 2): Do you agree with the classifications of CAPs as outlined above?

Question 3 (Chapter 2): Do you agree with the classifications of CAUs as outlined above?

Question 4 **(*Chapter 2): Do you agree with the classifications of ISPs as outlined above?***

Question 5 **(Chapter 2):** ***Do you agree with the classifications of CDNs as outlined above?***

Question 6 **(Chapter 3):** ***To what extent are requirements regarding traffic ratios still important in free peering arrangements?***

Question 7 **(Chapter 3*): To what extent does the functioning of the peering market hinge on the competitiveness of the transit market?***

Question 8 **(Chapter 3)*: Does an imbalance of traffic flows justify paid peering?***

Question 9 **(Chapter 3)*: Does paid peering increase (number of contracts and volume handled under such contracts)?***

Question 10 **(Chapter 3)*: To what extent does regional peering increase in relevance and affect transit services?***

Question 11**(Chapter 3)*: Are any important services missing from the list of services provided by IXPs?***

Question 12 **(Chapter 3)*: Are there any further developments regarding IXPs to be considered?***

Question 13 **(Chapter 3)*: Should in future Europe evolve to have more decentralised IXps closer to CAUs?***

Question 14 **(Chapter 3)*: Will traffic classes ever become available in practice on a wide scale?***

Question 15 **(Chapter 3)*: Will interconnection for specialised services be provided across networks?***

Question 16 **(Chapter 3)*: Will other solutions for improving QoE like CDNs become more successful rather than traffic classes?***

Question 17 **(Chapter 4)*: Which of the factors impacting on the regionalisation of traffic is most important: language, CDNs, direct peering?***

Question 18 **(Chapter 4)*: Are any further issues missing?***

Question 19 **(Chapter 4)*: Given the cost reductions and the economies of scale and scope observable in practice, why do network operators call for compensation***

Question 20 **(Chapter 4)*: Do you subscibe to the view that CDNs lead to improvement of QoS without violating the best effort principle?***

Question 21 **(Chapter 4)*: Is there a trend for CDNs to provide their own networks (i.e. integrating backwards)?***

Question 22 **(Chapter 4)*: Is there a general tendency for eyeball (CAU) ISPs to deploy their own transit capacities and long distance networks or even to become Tier-1 backbones?***

Question 23 **(Chapter 4)*: If an eyeball ISP becomes Tier-1 provider, does this increase the eyeball's market power on the interconnection market***

because there are no alternative Tier-1 providers to reach the customers of this eyeball ISP?

Question 24* (Chapter 5)*: Will Art. 5 become more relevant as some large Eyeballs have equally qualified as Tier 1 providers not having to rely on transit any more?

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