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BEREC Report on
IP-Interconnection practices in the Context of
Net Neutrality

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Executive Summary

In 2012 BEREC published the report "An assessment of IP interconnection in the context of Net Neutrality" which had concluded that the Internet ecosystem managed to adapt IP interconnection arrangement to reflect changes in technology, in the (relative) market power of players, in demand patterns and in business models, all this happening without a need for regulatory intervention.

In November 2016 BEREC held the 3rd expert workshop in IP-interconnection in co-operation with the OECD – bringing together members of academia, market experts and participants as well as public authorities including European NRAs, the FCC, the Mexican Regulator as well as DG Competition.[1] The insights gained at the workshop have informed the current project.

The report is now updated and puts these findings to the test considering the developments having occurred since 2012. Empirical evidence shows that many developments observed in 2012 are still ongoing:

- Internet traffic volumes continue to increase - mainly driven by video streaming services.
- Prices for transit or CDN services are still declining. BEREC considers that the price decline for transit services indicates that the market is highly competitive but at the same time put under pressure, both from peering services as well as CDN services.
- Costs of delivering data packets (on a per unit basis) continue to decline.

Furthermore, this report displays recent developments with regard to business models (e.g. CDNs), changes in traffic delivery and institutional arrangements (e.g. peering). Internal servers such as on-net CDNs or cache servers are becoming more prevalent within the market reducing the need for interconnection capacity. The increasing importance of CDNs as a means of traffic delivery coincides with the general growth in traffic, in particular video, as well as the gaining relevance of large CAPs with huge volumes of content.

Some large CAPs also participate in different network infrastructure projects. It can be generally observed, that the Internet becomes more densely interconnected than in the past. Informal "handshake" agreements concluded without a written contract continue to make up for than 99% of all peering agreement. However, the evidence suggests that paid peering is not uncommon involving some larger European Internet access service providers. Also, traffic volumes exchanged at the biggest European IXPs – DE-CIX, AMS-IX, LINX continue to grow.

This report also gives a generic outline of typical IP interconnection disputes in recent years. Traffic asymmetries are a major factor in those instances where disputes emerged in practice. Often, these disputes are characterized by mutual recriminations between the parties involved.

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[1] BEREC (2016b).

Furthermore, BEREC sets out the challenges of identifying the exact location of congestion as well as the party responsible for this. While congested Internet links may exist in practice, this does not seem to be a general phenomenon as empirical findings show.

A country case section displays how different European NRAs / NCAs have engaged in IP interconnection issues since 2012. This includes France, the Netherlands, Spain and Switzerland as well as the European Commission and the US.

Based on the evidence provided in this report BEREC draws in particular the following conclusions:

- While aggregate Internet traffic volumes continue to grow, prices for transit and CDN services also continue to decline. BEREC considers that the **Internet ecosystem's ability to cope with increasing traffic volumes is still given**.
- Where disputes have emerged in practice these seem to involve **complex relationships** as well as **economic/strategic considerations** of the providers.
- They were typically solved in the market **without regulatory intervention**. However, NRAs should carefully monitor whether this continues to be the case.
- **Competition and transparency for consumers remain key factors** ensuring that market forces work efficiently
- NRAs should continue to apply a **careful approach** when considering whether regulation is actually warranted.

1 Introduction

BEREC published a first report “An assessment of IP interconnection in the context of Net Neutrality” in 2012.[2] In that report BEREC described how the Internet ecosystem had managed to adapt IP interconnection arrangements to reflect changes in technology, in the (relative) market power of players, in demand patterns and in business models. This had happened without the need for regulatory intervention.

Now, five years later, BEREC provides an update reflecting developments that have occurred since 2012. In order to inform this update BEREC – in co-operation with the OECD – held a workshop on IP-interconnection on November 2016.[3] During that workshop the topic of IP interconnection was addressed from different perspectives, covering latest empirical trends on internet interconnection, measurement performance, industry viewpoints on Internet traffic exchange as well as public authorities approach to IP interconnection.

A condensed look at the legal basis for IP interconnection also considering the Regulation 2015/2120 as well as BEREC’s Guidelines on Net Neutrality serves as a starting point (chapter 2). The following chapter 3 encompasses an updated description of various developments allowing to juxtapose them to the developments described in 2012. This includes a description of recent traffic (3.1) as well as pricing and costing developments (3.2) allowing to verify the hypothesis that – broadly speaking – the Internet is able to cope with increasing traffic volumes particularly resulting from the growing popularity of video streaming services. Chapter 3.3. then displays recent developments with regard to business models (e.g. CDNs), changes in traffic delivery and institutional arrangements (e.g. peering). Chapter 4 describes in a generic way the nature of IP-interconnection disputes that have occurred since BEREC’s previous report. As such disputes typically involve claims of congestion, Chapter 5 assess whether this has become more prevalent, but also the challenges of identifying location as well as causation of congestion. This is followed (Chapter 6) by some country cases of European NRAs / NCAs having engaged in IP interconnection issues since 2012 as well as a focussed look at the European Commission’s and the FCC. The annex provides a more comprehensive view at various empirical findings.

2 Legal basis

In its 2012 report BEREC displayed the regulatory context for IP interconnection. According to this obligations to interconnect may be imposed under Art. 8 and Ar. 12 (1) lit I AD as a result of SMP. The current Commission’s Relevant Market Recommendation[4] does not

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[2] BEREC (2012a).

[3] BEREC (2016b).

[4] *“Commission Recommendation of 9 October 2014 on relevant product and service markets within the electronic communications sector susceptible to ex ante regulation in accordance with Directive 2002/21/EC of*

identify a market for wholesale Internet connectivity susceptible to ex ante regulation. Where end-to-end connectivity is at stake, an obligation to interconnect could also be imposed (independent of SMP) under Arts. 4 and 5 AD. The regulatory context set out by BEREC is **still applicable**.[5]

The focus of the Regulation 2015/2120 is on internet access services provided to end-users. With regard to IP-interconnection BEREC's Guidelines clarified that the EU-Regulation 2015/2120 in its Art. 3 (3) concerns equal treatment of all traffic "when providing internet access service" and therefore excludes IP interconnection practices from its scope.[6]

The Regulation does not create powers in addition to those existing under the Regulatory Framework. However, BEREC acknowledges in its Guidelines on Net Neutrality that NRAs **may take into account** the interconnection policies and practices of ISPs in so far as they have the effect of **limiting the exercise of end-user rights** under Art.3(1) of the Regulation. This may be relevant e.g. if interconnection is implemented in a way which seeks to circumvent the Regulation.[7]

3 Major developments since BERECs report 2012

3.1 Traffic evolution

In its report from 2012 BEREC showed that IP traffic was increasing although at a declining growth rate. This development is continuing. IP traffic is estimated to grow with a compound annual growth rate (CAGR) of 20 % for Western Europe and 27 % for Central and Eastern Europe respectively (2015-2020).[8] Also, mobile Internet traffic growth rates continue to level off.

Traffic growth is largely driven by video traffic. The share of consumer Internet video traffic of all consumer Internet traffic in Western Europe is expected grow from 66 % (2015) to 83 % (2020).[9] This development is spurred as users increasingly use multiple devices for video streaming. On the other hand, file sharing traffic is declining in relative terms. Given that video is typically consumed at peak hours it seems plausible that Internet traffic is expected to see a more pronounced peak-to-average ratio. Busy hour Internet traffic is

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the European Parliament and of the Council on a common regulatory framework for electronic communications networks and services", http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32014H0710&from=EN

5 For details see BEREC (2012a), Ch. 5.

6 BEREC (2016a), para. 50.

7 BEREC (2016a), para. 6.

8 Further empirial findings on traffic developments as well as other major developments are set out in the annex.

9 Cisco, *VNI Forecast Highlights Tool*.

forecasted to grow at a CAGR of 36 % (2015-2020) while the corresponding figure for average hour Internet traffic is 25 % “only”.[10]

Furthermore, Internet traffic via mobile and Wi-Fi devices is expected to become even more importance. Its share will grow from 62 % (2015) to 78 % (2020) while the share of Internet traffic from wired devices will decline to 22 %.[11] These developments are driven by smartphones and increasingly tablets as well as the growing availability of public Wi-Fi hotspots. While mobile Internet traffic excels fixed Internet traffic in terms of growth rates, absolute volumes of traffic remain higher for fixed traffic.

3.2 Pricing and costing developments

Generally, the pricing developments described in BEREC’s last report from 2012 are continuing. For example, **transit prices** fell by 33 % in 2015.[12] In addition to this general trend, transit markets exhibit geographic differences. Less mature markets display steeper price decline while transit prices in more mature markets have already reached a lower level in particular due to competitive pressures.

Similarly, also the prices for **CDN** services continue to decline. They fell by 25 % in 2014 and 20 % in 2015.[13] However, it should be noted that this only provides a broad picture, while in practice CDN prices vary between providers and also depending on the size of the customers. Economies of scale largely impact on the actual prices for CDN services.

As shown by BEREC in its 2012 report that the costs of delivering traffic on a per unit basis were subject to continuous declines which was due to competitive pressure as well as technological progress. BEREC sees no indications that this general trend has either stopped or even reversed. This seems plausible as prices for certain services (see above) continue to decline. In general, investment in networks is more or less stable as costs of delivering traffic on a per unit basis decreases and traffic volume is increasing.

3.3 Changing players along the value chain and changes in traffic delivery

3.3.1 CDNs

The economic relevance of CDNs continues to grow as CDNs account for an increasing share of total traffic. On a global scale, CDN traffic is expected to grow with a CAGR of 34%

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[10] Cisco (2016), section „*Trend 10: Traffic-Pattern Analysis (Peak Compared to Average and CDN Uptake*“.

[11] Cisco (2016), section „*Trend 9: Mobility (Wi-Fi) Continues to Gain Momentum*“,These figures relate to the *type of device* used and not whether the *connection* is fixed or mobile..

[12] DrPeering.

[13] Rayburn (2016).

increasing its share of all Internet traffic to 64 % by 2020 (45 % in 2015). This is largely driven by the increasing quantitative relevance of video streaming traffic.

In the recent past many CAPs seem to increasingly rely on a multi-CDN strategy as this may enhance resilience. Self-delivery of CDN services is a viable option, but only for very large CAPs (like Facebook, Amazon, Google, Microsoft, Netflix etc.).[14]

Besides this, internal servers such as **on-net CDNs or cache servers are becoming more prevalent** within the market. These platforms located within the network of an ISP are used to locally store copies of certain contents available on the Internet. They aim to bring content closer to users, with the intention of optimizing costs and performance. The need for interconnection capacity is reduced as content that is requested by a large number of customers needs to be sent only once through the interconnection link to feed these servers which subsequently serve users as often as the content is requested.

According to the information collected by ARCEP in its report on the state of the art of Internet in France[15] published in May 2017, the internal CDNs/cache provide around 11 % of the traffic for main ISPs in France - with great variability from one ISP to another. Besides, a standard ratio between incoming and outgoing traffic for a cache server or a CDN can vary between 1:8 and 1:25. In other words, each content stored is accessed 8 to 25 times on average, reducing the need to use interconnection capacity for these contents.

3.3.2 Infrastructure deployment of CAPs

In recent years, large CAPs such as Google or Facebook participated in different network infrastructure projects. With projects such as deployment of sea-cables these players not only reduce their dependence from third party transit providers' services but also gain flexibility when it becomes necessary to further upgrade capacities. In addition, CAPs tend to set up internal CDNs within ISPs networks.

3.3.3 Regionalisation of traffic

A recent study provides some insights to what extent network operators in a given country are interconnected with other domestic networks in comparison to foreign networks. For example, while in 2011 29 % of US networks interconnection partners were US networks, this figure declined to 23 % in 2016.[16] Similar developments can be observed for the UK (declining from 41 % in 2011 to 33 %) and Germany (declining from 32 % to 17 %).

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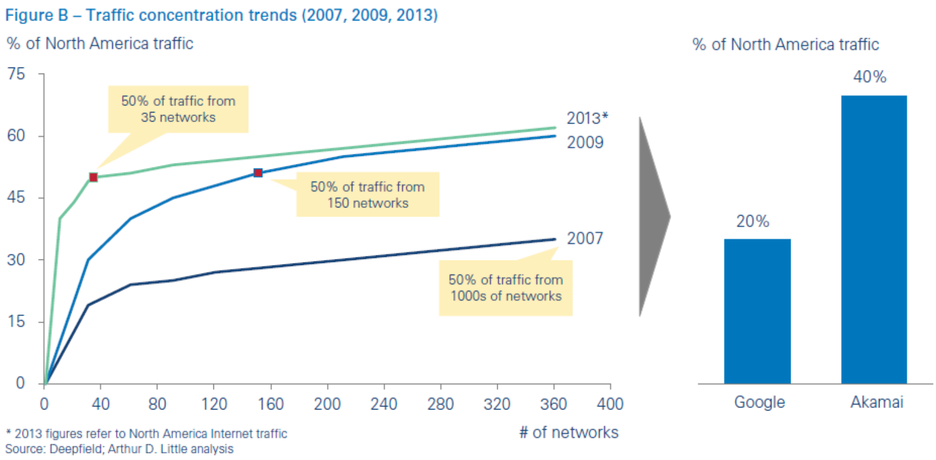
[14] More specifically, see Rayburn (2016b).
[15] See ARCEP (2017), L'état de l'internet en France, May 2017.
[16] Woodcock/Frigino (2016), p.6.

But at the same time the number of interconnected networks is increasing another trend is traffic concentration as the following figure shows:

Figure 3-1: Traffic concentration trends (2007, 2009, 2013)[17]



3.3.4 IXP traffic developments

BEREC's report from 2012 showed that the traffic volumes exchanged at the biggest European IXPs (DE-CIX, AMS-IX, LINX) were constantly growing. Peak capacities as well as average throughput continue to rise since the time of BEREC's last report. This supports the assumption that the non-profit IXP model turned out to be an efficient way for traffic exchange in Europe.

3.3.5 Peering developments

A recent study shows that **99.93%** of peering agreements are **informal "handshake" agreements** concluded without a written contract.[18] In the previous study this figure was 99.51 %.[19] Furthermore, **99.98%** of peering agreements are now based on **symmetric terms**, which is up from 99.73 % in 2011. However, these figures may look very different in terms of traffic volumes. However, these figures reflect the situation at a global (rather than European) level and do not distinguish between large and small IAPs. The evidence we discuss in chapters 4 and 6 suggests that paid peering is not uncommon involving some larger European Internet access service providers. At least in some cases paid peering seems to have been a result of disputes on congested peering links.

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17 Arthur D. Little (2014), p. 7.
18 Woodcock/Frigino (2016), p. 3.
19 Weller/Woodcock (2013), p. 9.

As pointed out already video streaming amounts to a substantial percentage of all Internet traffic. To the extent that interconnection disputes would end with paid peering agreements – as between Netflix and Comcast e.g. – this would obviously, imply that the percentage of paid peering in terms of traffic volumes is at least significantly greater as in terms of number of peering agreements.

Generally, the Internet is becoming more densely interconnected. One indication for this is that across all networks the **average number of interconnections per network rose from 77 to now 292**.

The study also emphasizes the **prevalence of multilateral peering** where more than two parties exchange traffic, which is the case at IXPs. According to this study, multilateral peering became the dominant practice in 2011 as it accounts for more AS-adjacencies than bilateral peering.[20] However, some large eyeballs ISPs do not follow this trend and peer with only a few other networks, prefer to have paid peering agreements on a bilateral basis rather than joining multilateral peerings at IXPs.[21]

Given these properties and benefits it seems plausible to assume **that usage of IXPs will rather gain more importance in the next yea**rs, particularly considering a **catch-up effect in developing countries** displaying higher growth rates.[22]

Besides, between 2012 and 2016 in France, transit has decreased at the expense of peering and more specifically private peering with CAPs.[23] These interconnections are in most cases paid ones. Thus, this explains the increase of the paid peering during the same period.

4 A generic outline of typical IP interconnection disputes

In its 2012 report, BEREC concluded that the market had developed well so far without any regulatory intervention. Nevertheless, this did not preclude that disruptions in IP interconnection due to disputes between ISPs may occur. BEREC pointed out that such instances had been few and had to date been solved in a relatively short time without regulatory intervention.[24]

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20 However, Woodcock/Frigino (2016) point out as a caveat that there are uncertainties whether this relates to corresponding volumes of traffic (p. 11).

21 Woodcock/Frigino [(2016), p.12/13] interpret this as a rent seeking strategy where dominant carriers try to extract rents from third parties using paid peering agreements rather than joining multilateral peerings at IXPs.

22 See also Internet Society (2016a).

23 ARCEP (2017)

24 According to Arthur D. Little (2014, p. 38), disputes concern less than 1 % of all IP interconnection agreements, and are solved by commercial agreements in more than 50 % of cases.

The dispute on IP-interconnection between Netflix and eyeballs ISPs such as Comcast or Verizon that popped up during 2013/2014 may be used as a generic example for such instances that have occurred since BEREC's previous report was published.

In the past, Netflix has used different options to get its content delivered to the consumer: third party CDNs, own CDN, transit services and direct interconnection with eyeball ISPs. Originally, Netflix had agreements with different CDN providers. Netflix has pointed out that Comcast had tried to impose terminating fees on various CDNs.[25] Then, during 2012, Netflix increasingly had relied on different transit providers who had settlement free peerings with Comcast. Between mid 2013 and early 2014 Comcast users had experienced high latency during peak hours when streaming video.[26]

The parties involved debated heavily about which side had caused the decline in video streaming quality: [27]

The CAP's perspective:

- Netflix pointed out that it has already paid their transit providers. Thus it was in the responsibility of the eyeball ISP and the transit providers to ensure that interconnection links were properly dimensioned. Ultimately, Netflix reasoned that Comcast let the interconnection links congest in order to extract termination payments.[28]

- It asserted that Comcast did not upgrade interconnection capacities thereby causing congestion in order to extract payments from the CAPs.

The eyeball ISP's perspective:

- Eyeball ISPs on the other hand referred to significanct increases in traffic volumes due to streaming services thus exceeding traffic ratios of typical settlement-free peering arrangements.[29] It was even argued that Netflix was causing congestion by sending traffic via certain transit path that could not handle these traffic volumes in order to force the eyeball ISPs to increase capacities.[30]

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25 Netflix (2014).

26 Verizon customers made similar experience in 2014 (see e.g. http://www.theverge.com/2014/7/10/5888239/verizon-netflix-congestion).

27 It should be emphasized that BEREC does not judge upon this case. It is only intended here to illustrate the respective arguments and perspectives of the parties involved.

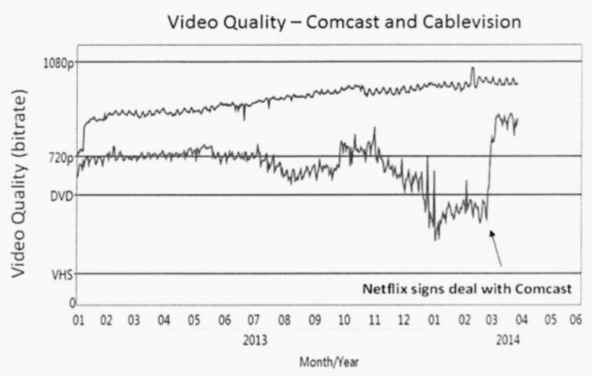
28 Netflix (2014).https://ecfsapi.fcc.gov/file/7521825167.pdf

29 http://www.theverge.com/2014/7/14/5897743/google-netflix-facebook-fcc-interconnection-fees-net-neutrality

30 Feamster (2015a); see also http://www.theverge.com/2014/7/10/5888239/verizon-netflix-congestion.

In February 2014 Netflix finally entered into a paid peering arrangement for direct interconnection with Comcast.[31] Quite soon after this agreement the quality of Netflix streaming improved for customers of that eyeball ISPs. Nevertheless, it would be too simple to infer from this improvement of quality which party had caused the problem previously. For example, Rayburn argues that "t*he return to normal in March 2014 was caused by a decision that Netflix and Comcast made, but that was Netflix's decision to pay Comcast for a direct connection, rather than continuing to use congested paths through the transit providers*."[32]

Figure 4-1: Netflix Video quality[33]



What can be derived from this dispute? While it may be tempting to infer from a certain result (e.g. low streaming quality) which parties have caused the problem, a closer look may be necessary. Ultimately, this boils down to the question whether CAPs depend more on eyeball ISPs or vice versa or in other words, who derives higher benefits from a peering relation.

5 Measuring congestion at IP-interconnection links

The previous sections showed that congestion issues may occur in practice. However, it seems necessary to adress some related questions:

- is congestion rather *short-lived* or is becoming more *prevalent*;
- *where* across the whole value chain (from the CAP to the consumer) does congestion occur;
- how can congestion be *identified* and measured;
- is it possible to clearly identify *who causes* congestion?

[31] https://gigaom.com/2014/02/21/comcast-netflix-peering/

[32] Feamster (2015a); see also https://www.engadget.com/2014/03/10/netflix-reportedly-reaches-another-comcast-style-agreement-with/.

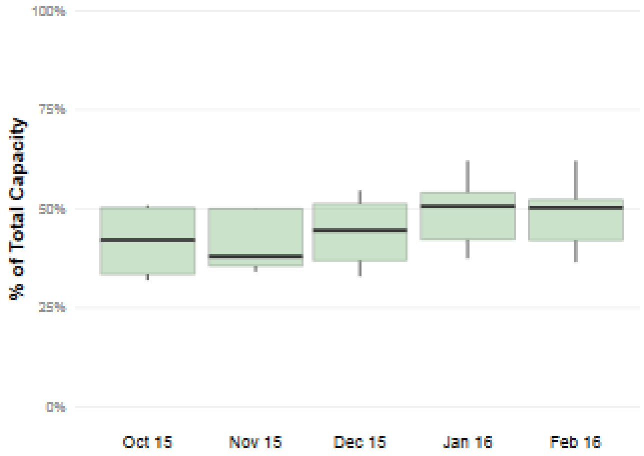
[33] https://qz.com/256586/the-inside-story-of-how-netflix-came-to-pay-comcast-for-internet-traffic/

ARCEP takes the following approach to have an overview of interconnection links. It consists in collecting periodically and on ad-hoc basis information about links capacities as well as inbound and outbound traffic.[34] Comparing the amount of traffic going through a link with this link's capacity may give some hints about potential congestion and helps to locate the problem as soon as it occurs. ARCEP has noticed a regular increase in interconnection links' capacities. This increase in capacity explains why congestion is not a prevalent problem even though traffic volume is increasing tremendously.

A recent paper[35] points out that typically **information on whether interconnection links are congested was very opaque**. This paper presents the findings of a study including data from seven US-ISPs. Each of them has installed a measurement system from DeepField Networks allowing for an *aggregated* look at the utilization at internet interconnection points but not at *specific* interconnection points.[36] The participating ISP cover roughly every second broadband subscriber in the US.

The paper concludes: "*From October 2015 through February 2016, aggregate interconnect capacity has been roughly 50% utilized at peak, and capacity has grown consistently by about 3% monthly, or about 19% over the five-month period*."

Figure 5-1: Distribution of 95th percentile peak ingress utilization across all ISPs, with all ISPs equally weighted



For the sake of completeness, it should be clarified that due to the aggregated dataset it is not possible to derive whether a "particular ISP experiences congestion in a particular region, to a particular partner network, or across a set of links." However, at a more

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34 ARCEP collects other information (finacial terms, location,etc.). This will be explained in more details in 6.1.1.

35 Feamster (2016).

36 Note that the data provided by ISPs were "aggregated sampled flow statistics across link groups in each region", thus did not look at individual interconnections.

aggregated level it turned out that "less than 10% of all links experience a 95th percentile peak utilization that exceeds 90%".

Despite these limitations, the figure sheds some interesting light on the question whether – in simple terms - the increasing traffic volume lets the Internet runs at full capacity utilization.

Furthermore, the findings from this study seem to be backed by anecdotal evidence from providers. Cogent points out that peering partners typically upgrade port capacity when utilization reaches about 50 %.[37] And Level3 explained in a blog-post that the average utilization across all its interconnected ports is 36 % percent.[38]

Similarly, another study from the **MIT** also assesses **whether congestion** of interconnection transit and peering links **is a widespread phenomenon**.[39] It argues that long-lived/recurring congestion would be a signal of mismatch between capacity and demand. Where such a mismatch occurs the underlying cause is rather considered economic as disputes, such as between Netflix and eyeball ISPs, are mainly about which party should provide (and pay for) an increase of interconnection capacities.[40] The study has measured interconnection links of major broadband providers. It turned out that even congestion of peering links carrying Netflix traffic that were congested for 18 hours a day "***vanishes essentially overnight***" when the involved parties concluded a new business agreement. It is also emphasized that congestion "*can come and go essentially overnight as a result of network reconfiguration and decisions by content providers as how to route content*".[41,42]

The study concludes that congestion at interconnection links among US broadband providers does **not** appear to be a **widespread** issue. Instead, congestion occurs rather occasionally.[43] Congestion rather results from business disputes. Once these are settled, congestion vanishes. **These findings generally support BEREC's 2012 reasoning** that in those few instances where disputes occurred these were typically settled by the market mechanism.[44] It remains to be seen, whether these general findings will also apply in the

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37 http://arstechnica.com/information-technology/2014/02/netflix-packets-being-dropped-every-day-because-verizon-wants-more-money/

38 Level3 (2014).

39 MIT (2014).

40 Aside from this, eyeballs have tried to promote a change of the interconnection charging mechanism (from Bill and Keep towards Sending Party Network Pays), often referring to large traffic volumes "caused" by CAPs. See BEREC's (2012b) on these proposals.

41 Dyn Research provides an "*Outages Bulletin*" (http://b2b.renesys.com/eventsbulletin/) which displays when and how often such issues occur.

42 Nevertheless, it might also be the case that the CAP is "forced" to reroute the traffic due to the ISP's practice.

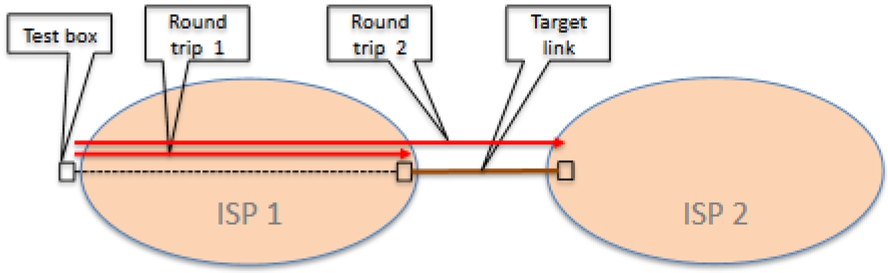
43 "*We typically see two or three links congested for a given ISP, perhaps for one or two hours a day which is not surprising in even a well-engineered network, since traffic growth continues in general, and new capacity must be added from time to time as paths become overloaded. We see some congestion on costly links, such as trans-oceanic links*."

44 The relative market power between the parties involved as well as the opportunity costs of not finding an agreement may be factors impacting on the outcome of such disputes.

future, given that peak hour Internet traffic – driven by video streaming – is the major source of traffic growing at a faster pace than average hour traffic.

A study from MIT and CAIDA researchers aims at localizing and quantifying inter-domain congestion in the Internet.[45] For this purpose time-sequence latency probes are used. This approach applies frequently repeated round trip time measurements from a vantage point to the near and far routers of an interdomain link (figure X below). "The measured round trip times are a function of the queue lengths of the routers on the forward and reverse paths: as queue lengths increase, so does round trip time." When round trip times increase to the far router but not to the near router, it is inferred that a queue between these two routers induced the delay. The study concludes that no evidence of widespread persistent congestion was found.

Figure 5-2: Round-trip time measurement to identify congestion[46]



Another paper specifically addresses the question *where* Internet congestion is occurring.[47] Figure 5-2 displays that congestion **may occur at two different locations**:

- **at interconnection points**: Disputes in practices that occurred since BEREC's 2012 report reflect this possible location of congestion "at the entry" to the eyeball's network (see above).

- **in transit providers' networks**: the author[48] refers to the dispute between Netflix and Comcast. He argues that Netflix's shift from using Akamai as a CDN to Level 3 and Limelight coincided with extreme congestion starting in the middle of 2011. While this shift may cut Netflix's costs of delivering its content significantly, its new wholesale providers delivering content to the user may have not had sufficient capacities to cope with these traffic volumes.

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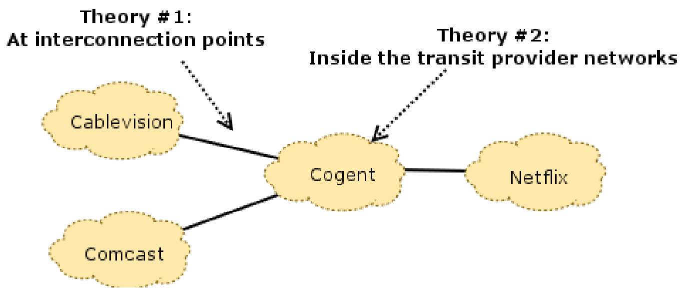
[45] Clark et al (2014).
[46] Clark et al (2014).
[47] Feamster (2015b).
[48] Feamster (2015b).

Thus, the main challenge may not be to find evidence of congestion as such but to associate congestion with a particular link.[49]

Figure 5-3: Possible locations of congestion[50]



Feamster points out that congestion seems to have occurred in both locations, at interconnections points and in transit providers' networks.

The challenges of exactly localizing congestion let the FCC conclude: "*We decline at this time to require disclosure of the source, location, timing, or duration of network congestion, noting that congestion may originate beyond the broadband provider's network and the limitations of a broadband provider's knowledge of some of these performance characteristics…While we have more than a decade's worth of experience with last-mile practices, we lack a similar depth of background in the Internet traffic exchange context.*"[51]

It can be concluded that while it is possible to identify *whether* there is congestion, it poses a much greater challenge to unambiguously identify the *location* of that congestion, particularly when considering that the details of interconnection agreements are typically subject to non-disclosure agreements. But even if it is clearly identified that congestion occurs at the interconnection links only, this does not provide an answer to the question which of the involved parties has *caused* this congestion either by not upgrading port capacities according to the traffic requirements or for example by routing traffic via certain routes to let interconnection links congest. As pointed out above disputes in practice typically involved mutual recriminations of the parties involved.

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49 See also Feamster (2015b) who elaborates on the limitations of using the approach applied by MIT/CAIDA. He concludes that the study suggests that congestion occurs at interconnection points but is inconclusive as to whether congestion *also* occurs within a transit provider's network.

50 Feamster (2015b).

51 FCC (2015), para 168.

6 Activities of authorities

6.1 National Regulatory Authorities in Europe

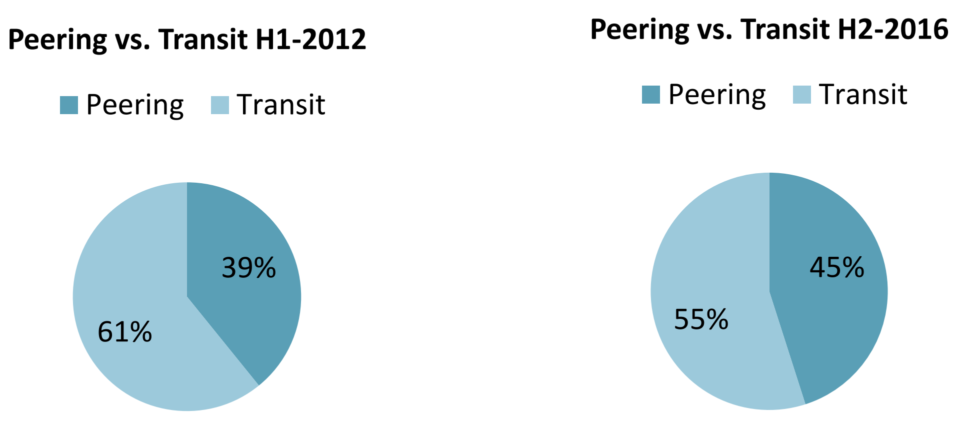
6.1.1 France

Since 2012, ARCEP has collected, every 6 months, information about interconnection conditions of autonomous systems in France: peers, providers and clients, locations and capacities, inbound and outbound volumes and financial information. Thanks to this data collection campaigns, ARCEP has become closer to technical experts and has acquired high knowledge about interconnection issues. This knowledge is shared regularly with the whole community during national and international conferences.

In France, the overall interconnection traffic exchanged by the four main ISPs increased by around 27%, between the end 2015 and the end 2016, to reach a total inbound traffic of 8.4 Tbps. Traffic is mainly carried through transit, but ISPs in France are increasingly using peering. A strong growth in traffic generated by major content and application providers (sometimes up to 150%) is noted in French interconnection market. It is explained by a more intensive use of direct interconnection between CAPs and ISPs.

Furthermore, in May 2017, ARCEP presented a report on the state of the market in France.[52] This report includes aggregated data about the interconnection market in France between 2012 and 2016. This information consists of the evolution of interconnection capacity, inbound traffic, peering vs transit ratio, paid peering and free peering ratio, etc.

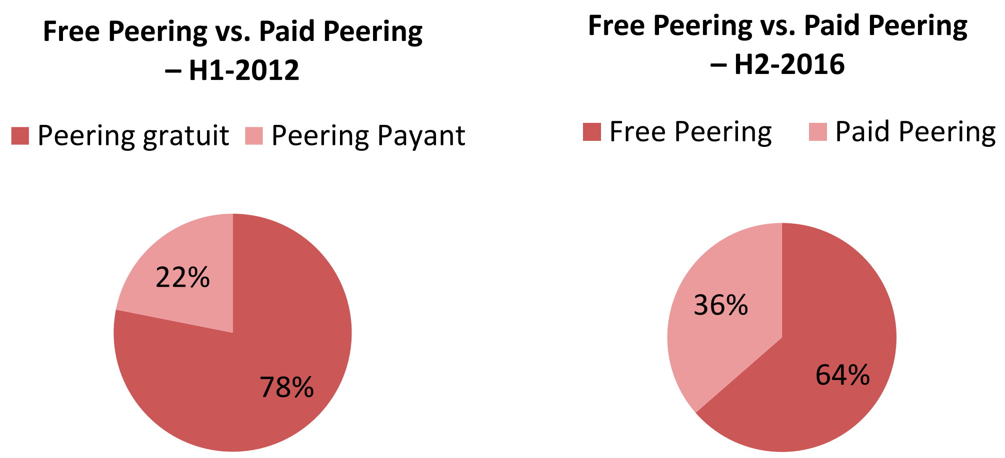
Figure 6-1: Peering vs. Transit in France*



**Weighted by inbound traffic volume*

52 Arcep (2017)

Figure 6-2: Free Peering vs. Paid Peering in France*



**Weighted by inbound traffic volume*

Besides, two IP interconnection cases were reported. First, in 2011 a Cogent vs Orange dispute was taken to the competition authority by Cogent over the opacity of Orange's interconnection offers and the financial terms asked. Cogent considered that Orange was abusing its dominant position by asking to be paid for extra bandwidth capacity. Cogent and Open Transit International (Orange transit operator) had a peering agreement where the exchange of traffic between the operators was free, based on an asymmetry ratio threshold set at 2.5 to 1. ARCEP provided an expert opinion to the competition authority that held the view that requiring compensation for the provision of extra bandwidth capacity in peering agreements in case of a significant traffic imbalance was not to be considered as anti-competitive behavior. The authority validated Orange's behavior after the latter committed to some transparency measures. This case was an incentive for ARCEP to start gathering interconnection data gathered data both on a periodical and an ad hoc basis. Second, in 2012 ARCEP investigated Free's interconnection practices after numerous consumers' complaints when accessing Internet services such as YouTube. In this case, Free's transit ports proved congested but it was affecting similarly all services. It resulted mainly from the sizing of Free's interconnection links with IP transit operators and IP peering partners. Both when the investigation was publicly opened then closed, Free reacted swiftly by increasing its transit capacity limits.

ARCEP intends to continue monitoring the interconnection market but will not regulate, only reacting in case of necessity. Further areas of expansion are QoS and information to consumers; ARCEP is also investigating new market developments such as internal CDNs. Starting from the second semester of 2017, ARCEP is likely to consider extending the interconnection data gathering campaign to include information about internal CDNs.

6.1.2 Netherlands

The IP interconnection study carried out by ACM in 2015 was triggered by the Netflix/Comcast dispute in the US and aimed at answering the following questions: is there any restrictive IP interconnection behaviour in the Netherlands? Does ACM have sufficient power/tools to regulate if necessary? The report methodology included the analysis of existing cases, theories of harm, interviews with stakeholders, evaluate market circumstances and input from interviews to assess the likelihood of competition problems. ACM concluded that the likelihood of competition problems resulting in consumer harm is currently[53] very low in the Netherlands. Problems that do occur, can be dealt with by ACM using Section 24 (1) of the DCA regarding the abuse of dominance. In addition and depending on the classification of the actor in terms of the Dutch Telecommunications Act, this act provides ACM with relevant norms to address problems regarding willingness to negotiate in the field of IP interconnection. Based on these conclusions, ACM considers its current set of instruments sufficient to guarantee a competitive IP interconnection market in the Netherlands. However, the regulatory analysis showed that it’s unclear whether or not various actors in the field of IP interconnection are subject to the Dutch Telecommunications Act. As the classification of an actor as a provider of Public Electronic Communications Network and Public Electronic Communications Service can imply a variety of norms to which the actor can be subjected, ACM recommends legislators to provide clarity on this matter and resolve ambiguities in this regard.

6.1.3 Spain

In Spain, in the context of the acquisition of DTS (main pay TV player in Spain) by Telefónica, the final remedies offered by the notifying party that the CNMC considered sufficient to ensure that the problems posed by the merger would be adequately addressed enabling it to give the authorisation, included terms applying to the Telefónica's Internet interconnection.

In relation to the access to its network, Telefónica could have the incentives (it can block or restrict access to its network and to its customers) to substantially reduce competition from third-party Internet-based pay television operators. In that regard, the remedies approved allow those Internet-based pay television providers to access Telefónica's broadband customers on terms which allow them to compete effectively.

In order to provide access to its network in Spain with sufficient capacity and quality assurances for third-party operators and content providers, Telefónica will ensure that its interconnection with, at least, three relevant operators providing transit services will not suffer congestion exceeding 80%. Telefónica also undertakes to negotiate interconnection

[53] October 2015.

agreements, for the delivery of audiovisual content to its fixed or mobile broadband end users, on equitable, reasonable, transparent, objective and non-discriminatory terms.

Finally, in this context, Telefónica also undertakes not to employ network and traffic management techniques in Spain which could, in a discriminatory manner, degrade the flow of third-party video or similar data over its Internet network.

On the other hand current figures published by Netflix[54] about rate by ISP in Spain from February 2016 to February 2017 show that Telefónica is the ISP with the worse results from all ISPs included in the panel. Anyway, as this information is provided by one of the parties involved, a further analysis would be required if a formal complaint is received.

6.1.4 Switzerland

Init7, a rather small transit provider in Switzerland, submitted in 2013 a request to regulate (ex post sector-specific regulation) the peering conditions of the incumbent in Switzerland, Swisscom. The trigger for this request was the introduction of a maximum traffic exchange ratio of 2:1 (inbound:outbound) as a peering condition by Swisscom. Init7, which greatly exceeded this maximum traffic exchange ratio, refused to sign a paid-peering agreement. Swisscom therefore throttled Init7's peering connection. As a result, Init7 lost one of its main transit costumers, a TV streaming provider, to Swisscom. The Swiss NRA (ComCom) provisionally obliged Swisscom to re-establish the peering connection with Init7 according to the peering conditions applicable before 2012 (settlement-free peering). In accordance with procedural rules, ComCom initiated a market investigation into IP interconnection markets in cooperation with the Swiss competition authority (ComCo). During this market investigation, the Swiss competition authority found indications of an unlawful IP interconnection agreement affecting competition between Swisscom and its main transit provider Deutsche Telekom AG and opened a new, additional competition law case targeting the relation between Deutsche Telekom and Swisscom. The assessment of the contract in question indicated that the agreement between Swisscom and Deutsche Telekom might have restricted competition through collusion on prices, volumes and geographic markets. However, since the involved parties agreed to adjust the contract and avoided the problematic clauses, in addition to the fact that the involved revenues are modest, the competition authority closed in 2017 the competition law case against Deutsche Telekom and Swisscom prematurely and without imposing sanctions.

The Swiss NRA ComCom suspended its ongoing sector-specific regulatory procedure Init7 against Swisscom during the investigation by the competition authority. The NRA will now assess, on the basis of the survey and analysis conducted in collaboration with the

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[54] https://ispspeedindex.netflix.com/

competition authority[55], whether Swisscom has a dominant position in the market, which could justify a sector specific regulation. The definitive decision of the NRA is still outstanding, thus the preventative provision relating to settlement-free peering for Init7 is still in place.

The (so far published) main findings of the Swiss competition authority in the context of its investigation into IP interconnection markets and the commercial relationship between Swisscom and Deutsche Telekom AG are as follows:

The authority identified a "technical monopoly" in relation to direct IP access to Swisscom customers. However, due to the architecture of the internet, it is in general possible to access Swisscom's customers indirectly via other providers with a direct Swisscom interconnection. The test of a small but significant and non-transitory increase in price (SSNIP) showed that Swisscom could not increase prices for direct interconnection in a profitable way, since more traffic would be routed indirectly and without payment to Swisscom. The authority therefore concluded that there exists (a limited number of) substitutes to direct interconnection with Swisscom, particularly the transit and paid-peering services of Swisscom's transit providers. Hence, Swisscom's transit providers belong to the same relevant market for IP access to Swisscom's customers. Furthermore, large peering partners of Swisscom could possibly belong to this market, though the market boundaries are not very clear. In terms of the geographic scope of the relevant market, the authority defined these as (at least) all interexchange points in Europe where Swisscom and Deutsche Telekom offer interconnection services.

According to the Swiss competition authority, the contract between the Tier 1 operator Deutsche Telekom AG and the Tier 2 operator Swisscom entailed elements of a transit agreement as well as of a peering agreement ("a hybrid agreement"). The contract obliged Swisscom as well as promoted incentives for Swisscom to route as much data traffic as possible via the transit service of Deutsche Telekom. Since Swisscom in fact did not have to pay for the transit services of Deutsche Telekom (due to revenue and cost sharing), Swisscom's incentives to agree on settlement-free peering with other AS were significantly reduced, affecting the market power of Swisscom in the whole relevant market. Since transit providers of Swisscom were deemed as competitors of Swisscom in the relevant market, the competition authority qualified the contract as a possibly unlawful horizontal agreement, which potentially restricts competition in the market for IP access to Swisscom's customers. The authority found indications of an unlawful agreement on minimum prices for Deutsche Telekom's transit services (into the Swisscom network), of an unlawful agreement on volumes as well as on geographic markets and customers.

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55 As a result of the market survey, the Competition Authority provided a broader analysis of the IP Interconnection markets for the attention of the NRA (confidential).

However, the competition authority closed the preliminary investigation and did not open a formal investigation, which would be a precondition for imposing sanctions. To open a formal investigation had been seen as disproportionate, after the adaption of the contract in question and the deletion of the problematic clauses, which resolved the competition authority's concerns. Opening an investigation in order to be (potentially) able to impose sanctions was not deemed as justified due to the high complexity and the expected associated administrative costs, in addition to the relatively modest revenues involved. Furthermore, the outcome of the investigation would have been uncertain, since the authority identified only indications of unlawful behaviour, though no concrete evidence of this.

6.2 European Commission

The European Commission conducted an investigation on competition law during 2011 to 2014. The investigation looked at whether telecommunication operators such as Deutsche Telecom, Telefonica and Orange, were behaving in an anticompetitive way, thus violating the prohibition to abuse a dominant market position.[56]

The European Commission announced in October 2014 to close the investigations but to continue monitoring the sector.[57] Since the above operators had very limited content themselves, it was concluded there was no incentive to favour their own content because of vertical integration. Furthermore, it was at stake who can ask for money. In cases without a commercial agreement, the effect was that traffic from certain routes was congested at the point of entry of the domestic network. If Telcos do not want to pay to mitigate that, then that is a fact. The European Commission found no evidence of behaviour aimed at foreclosing transit services from the market.

It was considered better to let the commercial negotiations go on without interference of a competition authority. However, consumers may not know where the issue is when their experience is unsatisfactory. Therefore transparency was considered important to identify the problem.

6.3 FCC

The Open Internet Order of February 2015 concluded that it would be premature to apply prescriptive rules to interconnection agreements. The FCC monitors IP interconnection and considers claims involving IP interconnection agreements on a case-by-case basis under section 201 and 201 of the Communications Act, which prohibit unjust and unreasonable conduct by common carriers, including broadband service providers. A number of cases for disputes were identified. The claim on one side was that artificial congestion took place

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[56] Article 102 of the Treaty on the Functioning of the European Union – TFEU.
[57] http://europa.eu/rapid/press-release_IP-14-1089_en.htm

because capacity upgrade was not taking place, to trigger paid peering. The other party rather argued that it was edge providers sending extremely large traffic volumes imposing a cost, by constantly requiring an upgrade. Therefore, paid peering was required to allocate such cost. In 2015 however no application of bright line rules to IP-interconnection took place, which is traditionally governed by commercial regulation. With regard to two merger cases requirements were imposed to file all interconnection agreements the FCC. In addition, in one case a request was imposed to provide interconnection performance metrics to the FCC (latency packet loss and utilisation). In the other case mandatory interconnection requirements were imposed for 7 years.

7 Conclusions

a. Generally, it is expected that aggregate Internet traffic volumes **continue to grow significantly**. This seems to be largely driven by the increasing popularity of video streaming services. In order to avoid congestions, Interconnection links capacity should continue to increase also to handle this volume increase.

b. This implies a more **accentuated peak to off-peak traffic ratio** as video services are typically consumed at peak times.

c. The development of traffic volumes is further reinforced as users increasingly tend to have multiple devices for accessing the Internet. Usage of mobile and Wi-Fi devices gains importance.

d. **Prices** for transit or CDN services **continue to decline at a pace corresponding to this traffic increase**. This is due to competitive pressures as well as technological progress. Given these price declines BEREC considers that the Internet ecosystem's ability to cope with increasing traffic volumes is still given.

e. Typically, **traffic asymmetries** are a major factor in those instances where disputes emerged in practice. Often, these disputes are characterized by mutual recriminations between the parties involved.

f. Even where it is possible to identify *that* congestion occurs, it remains a challenge to clearly identify its exact **location** across the value chain and even more **who is responsible** for the problem.

g. This holds in particular because IP interconnection issues seem to involve **complex relationships** as well as **economic/strategic considerations** of the providers. Often providers have **different options to overcome** a problem (e.g. using transit, peering, CDNs, caching services in access networks etc.)

h. So far, such disputes were typically solved in the market **without regulatory intervention**. However, NRAs should carefully monitor whether this continues to be the case.

i. From a NRAs perspective **competition and transparency for consumers remain key factors** ensuring that market forces work efficiently thereby contributing that either disputes do no emerge or are solved in the market.

j. Against the background as well as the empirical findings displayed in this report NRAs should continue to apply a **careful approach** when considering whether regulatory intervention is actually warranted.

Literature

ACM (2015), *IP interconnection in the Netherlands: a regulatory assessment*, The Netherlands Authority for Consumers and Markets, October 2015, https://www.acm.nl/en/publications/publication/14821/Study-into-IP-interconnection-in-the-Netherlands/

ARCEP (2015), *ARCEP: opinion on the structure of the bandwidth use of Internet access networks in France*, July 7, 2015, http://www.arcep.fr/uploads/tx_gsavis/15-0832.pdf (http://www.arcep.fr/uploads/tx_gsavis/15-0832-ENG.pdf (English version)

ARCEP (2017), L'état d'internet en France 2017, May 2017, https://www.arcep.fr/uploads/tx_gspublication/rapport-etat-internet-france-2017-mai2017.pdf

Arthur D. Little (2014), *The Future of the Internet. Innovation and Investment in IP Interconnection*, May 2014, http://www.adlittle.de/uploads/tx_extthoughtleadership/ADL_LibertyGlobal_2014_FutureOfTheInternet_01.pdf

BEREC (2012a), *An assessment of IP interconnection in the context of Net Neutrality*, BoR (12) 130. December 6, 2012, http://berec.europa.eu/eng/document_register/subject_matter/berec/reports/1130-an-assessment-of-ip-interconnection-in-the-context-of-net-neutrality

BEREC (2012b), *BEREC's comments on the ETNO proposal for ITU/WCIT or similar initiatives along these lines*, BoR (12) 120 rev.1, http://berec.europa.eu/eng/document_register/subject_matter/berec/others/1076-berecs-comments-on-the-etno-proposal-for-ituwcit-or-similar-initiatives-along-these-lines

BEREC (2016a), *BEREC Guidelines on the Implementation by National Regulators of European Net Neutrality Rules*, BoR (16) 127, August 30, 2016, http://berec.europa.eu/eng/document_register/subject_matter/berec/regulatory_best_practices/guidelines/6160-berec-guidelines-on-the-implementation-by-national-regulators-of-european-net-neutrality-rules

BEREC (2016b), *BEREC expert workshop on IP-Interconnection in co-operation with the OECD*, Brussels, November 21, 2016, http://berec.europa.eu/eng/events/berec_events_2016/139-berec-expert-workshop-on-ip-interconnection-in-co-operation-with-the-oecd

Cisco (2016), *The Zettabyte Era- Trends and Analysis*, June 2, 2016, *http://www.cisco.com/c/en/us/solutions/collateral/service-provider/visual-networking-index-vni/vni-hyperconnectivity-wp.html*

Cisco, *VNI Forecast Highlights Tool*, http://www.cisco.com/c/m/en_us/solutions/service-provider/vni-forecast-highlights.html

Clark, David; Steven Bauer, William Lehr, kc claffy, Amogh Dhamdhere, Bradley Huffacker, Matthew Luckie (2014), Meas*urement and Analysis of Internet Interconnection and Congestion*, September 9, 2014, https://groups.csail.mit.edu/ana/Measurement-and-Analysis-of-Internet-Interconnection-and-Congestion-September2014.pdf

DrPeering, *An International Peering Model (Part 2 of 2)*, http://drpeering.net/AskDrPeering/blog/articles/Ask_DrPeering/Entries/2013/4/29_An_International_Peering_Model_%28Part_2_of_2%29.html *[retrieved: April 21, 2017]*

Dyn Research, *Outages Bulletin*, http://b2b.renesys.com/eventsbulletin/

FCC (2015), *Report and Order on Remand, Declatory Ruling, and Order*, February 26, 2015, http://transition.fcc.gov/Daily_Releases/Daily_Business/2015/db0312/FCC-15-24A1.pdf

Feamster, Nick (2015a), *Why Your Netflix Traffic is Slow, and Why the Open Internet Order Won't (Necessarily) Make It Faster*, March 25, 2015, https://freedom-to-tinker.com/2015/03/25/why-your-netflix-traffic-is-slow-and-why-the-open-internet-order-wont-necessarily-make-it-faster/

Feamster, Nick (2015b), *Where is Internet Congestion Occurring?*, April 2, 2015, https://freedom-to-tinker.com/2015/04/02/where-is-internet-congestion-occurring/

Feamster, Nick (2016), *Revealing Utilization at Internet Interconnection Points*, 5 Sept. 2016, https://arxiv.org/pdf/1603.03656.pdf

Internet Society (2012), *Assessment of the impact of Internet Exchange Points (IXPs) – empirical study of Kenya and Nigeria*, 2 Apr 2012, http://www.internetsociety.org/ixpimpact

Internet Society (2016a), *IXPs level up in emerging Asia-Pacific*, February 15, 2016, http://www.internetsociety.org/blog/asia-pacific-bureau/2016/02/ixps-level-emerging-asia-pacific

Internet Society (2016b), *Policy Brief Slides: Internet Exchange Points (IXPs)*, November 4, 2016 http://www.internetsociety.org/policybriefs/slides/ixps

ITU (2016), *Recommendation D.52 (10/16) : Establishing and connecting regional Internet exchange points to reduce costs of international Internet connectivity*, October 25, 2016, http://www.itu.int/rec/T-REC-D.52-201610-I

Kovacs, Anna-Maria (2012), *Internet Peering and Transit*, April 4, 2012, http://www.broadbandforamerica.com/sites/default/themes/broadband/images/mail/AMKInternetPeeringandTransit_FINAL.pdf

Labovitz, Craig (2013), *Massive Ongoing Changes in Content Distribution*, Content Delivery Summit, Spring 2013, http://conferences.infotoday.com/documents/172/2013CDNSummit-B102A.pdf

Level3 (2014), *Observations of an Internet Middleman*, May 5, 2014, http://blog.level3.com/open-internet/observations-internet-middleman/ [*not retrievable anymore*]

Massachusetts Institute of Technology (**2014**), *Measuring Internet congestion: A preliminary report*, June 18, 2014, https://www.ncta.com/sites/prod/files/MIT-Congestion-DC.pdf

Netflix (2014), *Petition to deny of Netflix, Inc.*, August 27, 2014, https://ecfsapi.fcc.gov/file/7521825167.pdf

Rayburn, Dan (2014), *Apple Building Out Their Own CDN To Deliver Content To Consumers*, February 3, 2014, http://blog.streamingmedia.com/2014/02/apple-building-cdn-software-video-delivery.html

Rayburn, Dan (2016a), *By My Estimate, Apple's Internal CDN Now Delivers 75% Of Their Own Content*, April 20, 2016, http://blog.streamingmedia.com/2016/04/apple-cdn-traffic-volume.html

Rayburn, Dan (2016b), *Current State Of The CDN Market: DIY, Pricing Trends, Competitive Dynamics*, May 9 2016, http://blog.streamingmedia.com/wp-content/uploads/2016/05/2016CDNSummit-Rayburn-Pricing.pdf

Rayburn, Dan (2017), *Best Practices For Using A Multi-CDN Strategy: How To Balance, Prioritize and Optimize Traffic*, January 25, 2017, http://blog.streamingmedia.com/2017/01/using-multi-cdn-strategy.html

Sandvine (2011), *Sandvine's Take on Netflix's Impact on P2P File Sharing*; May 4t 2011, http://www.internetphenomena.com/2011/05/netflix%E2%80%99s-impact-on-p2p-file-sharing/

Telegeography (2015), *IP transit price and peering trends yield regional revenue divide*, July 9, 2015, https://www.telegeography.com/products/commsupdate/articles/2015/07/09/ip-transit-price-and-peering-trends-yield-regional-revenue-divide/

Telegeography (2015), *IP Transit Prices Continue Falling, Major Discrepancies Remain*, September 09, 2015, https://www.telegeography.com/press/press-releases/2015/09/09/ip-transit-prices-continue-falling-major-discrepancies-remain/index.html

Weller, Dennis; Bill Woodcock (2013), Internet Traffic Exchange: Market Developments and Policy Challenges, OECD Digital Economy Papers, No. 207, OECD Publishing, Paris, http://dx.doi.org/10.1787/5k918gpt130q-en

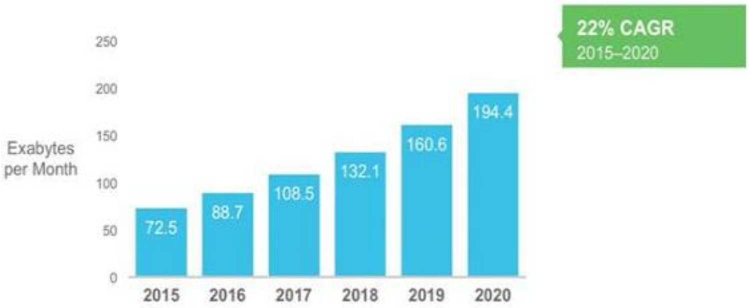
Woodcock, Bill; Marco Frigino (2016), *2016 Survey of Internet Carrier Interconnection Agreements*, Survey presented during BEREC's expert workshop on IP-Interconnection in co-operation with the OECD 21 November 2016, Brussels http://berec.europa.eu/eng/document_register/subject_matter/berec/others/6574-2016-survey-of-internet-carrier-interconnection-agreements

Annex

Traffic developments

It does not come at a surprise that traffic volumes continue to grow. **Global IP traffic** is expected to nearly threefold between 2015 and 2020 which translates into a compound annual growth rate of 22 % from 2015 to 2020.[58] The corresponding growth rate for Western Europe is 20 % and 27 % for Central and Eastern Europe. The amount of global IP traffic reached in 2020 is "*equivalent to 504 billion DVDs per year*".

Figure A 1: Cisco VNI Forecasts 194 EB per Month of IP Traffic by 2020[59]



Fixed Internet traffic which accounts for approx. two thirds of all traffic as of year end 2020[60] is expected to grow at an almost constant pace 21 % from 2015 to 2020.

Per capita bandwidth usage of IP traffic in Western Europe is expected to grow by factor 2.44 from 27 GB (2015) to 66 GB (2020) while the growth rate for Internet traffic alone is even more distinct (x2.71 2015 to 2020) **which may largely be attributed to the increase in video traffic delivered over the Internet.**[61]

Mobile data traffic is still developing at a faster pace (**CAGR of 53 %**) than fixed IP-traffic. This may still be due to the fact that mobile traffic started from a significantly lower level. Nevertheless, while mobile Internet traffic growth rates in Western Europe are still at a high level they are levelling off (down from 64 % growth between 2015 and 2016 to 36 % between 2019 and 2020). The corresponding figures for Eastern Europe resp. the whole world display the same tendency albeit at a higher level. Lower growth rates may indicate that mobile markets are in a more mature state.

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58 Cisco (2016).

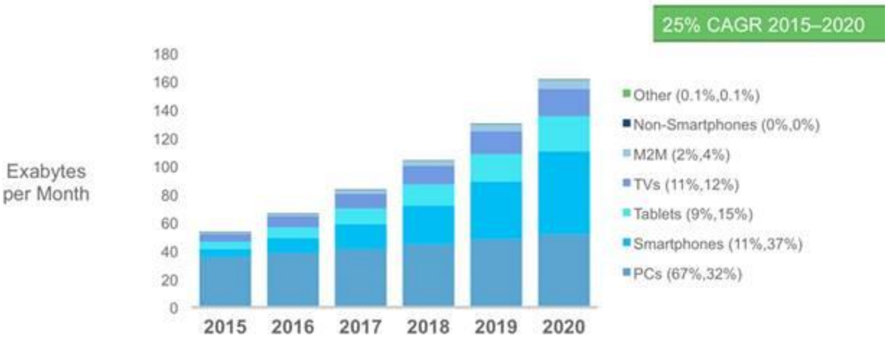
59 Cisco (2016).

60 67 % Internet, 17 % managed IP, 16 % mobile data.

61 Cisco, *VNI Forecast Highlights Tool*.

A closer look displays some drivers for overall traffic growth. On a global scale, **devices and connections**[62] **grow faster** (CAGR of 10 %) **than Internet users** (CAGR of 6.5 %). Simply put, users avail of more devices than ever before. And more devices are used for bandwidth "hungry" purposes like video streaming.

Figure A 2: Global Internet traffic by devices[63]



The previous figure shows that by 2020 only one third of global Internet will originate from PCs (down from 67 % in 2015) while the share of traffic originated via tablets and particular smartphones increases significantly.

Composition of traffic:

Video seems to be a major factor impacting on observable traffic developments. In **Western Europe Internet video traffic** is expected to grow 4-fold (**CAGR of 29%)** which is significantly higher than the 2.8-fold increase of Internet traffic (CAGR of 22 %). It is not only the increase in the number of devices that spur video traffic volumes but also the **tendency towards high-definition (HD) and even ultra-high-definition** (UHD) video streaming. The share of UHD Internet video traffic in Western Europe is expected to rise to 16.1 % (up from 1.6) and the share of HD will reach 71 % (up from 53,2 %). Premium content (sports, films) may also become more important for providers of video services further driving traffic volumes. This may strengthen the growth of streaming platforms at the expense of traditional pay-TV platforms.[64]

For **online gaming** even a 7-fold increase (CAGR 47 %) is expected. Nevertheless, the quantitative relevance in absolute terms is much lower for gaming compared to Internet

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62 Cisco includes here PCs, tablets, TVs, smartphones, non-smartphones, M2M connections.

63 Cisco (2016), section "*Trend 1: Continued Shifts in Mix of Devices and Connections*".

64 E.g., Amazon Prime signed a deal with HBO in 2014 (http://variety.com/2014/digital/news/hbo-cuts-exclusive-licensing-deal-with-amazon-1201161895/) or with Broad Green Pictures in 2016 (http://www.tvbeurope.com/amazon-pens-broad-green-deal/). Netflix signed deal (e.g.) with Disney in 2016 (https://www.forbes.com/sites/alishagrauso/2016/05/24/netflix-to-begin-exclusive-streaming-of-disney-marvel-star-wars-and-pixar-in-september/#66ac6993135d).

video. While gaming amounts to 5 % of consumer Internet traffic (Western Europe) in 2020 (up from 2 % 2015), consumer Internet video traffic will reach 83 % (up from 66 %).

Figure A 3: Consumer Internet Traffic (PB per month) in Western Europe: [65]

	2015	2016	2017	2018	2019	2020	CAGR 2015-2020
Total	6,957	8,618	10,712	13,088	16,180	19,723	23%
Web, Email, and Data Traffic	1,269	1,435	1,593	1,695	1,692	2,021	10%
P2P file transfer	4,798	4,550	4,224	3,840	2,207	2,340	-5%
Consumer Internet Video	4,545	6,047	7,978	10,247	13,334	16,433	29%

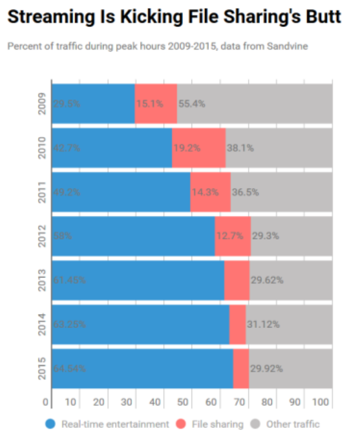
Positive growth rates can be observed for all traffic categories, despite at different growth rates. However, this is **not the case for file sharing**, which actually does not grow in absolute terms in Western Europe. Thus, the relative decline of the share of P2P traffic, which BEREC mentioned in its 2012 report, continues.

This development becomes obvious with a closer look at the **impact of Netflix and other streaming services on File Sharing**.[66] Between 2009 to 2015 the percentage of real-time entertainment services in North America during peak hours more than doubled reaching almost two thirds of all Internet traffic. During the same period the share of file-sharing services dropped from 15.1 % to 5 %.

65 Cisco *VNI Forecast Highlights Tool*.

66 http://www.vocativ.com/196575/netflix-vs-bittorent-streaming-traffic-is-dwarfing-file-sharing-traffic/ (based on Sandvine data).

Figure A 4: Percent of streaming traffic during peak hours 2009-2015[67]



The increasing relevance of video traffic delivered over the Internet implies that **busy hour traffic** grows at a faster rate (global CAGR 36 %) than average traffic (CAGR 24.9).

Figure A 5: Busy-Hour Compared with Average Internet Traffic Growth[68]

This seems obvious considering most people's habits when they typically consume video. Overall this contributes to a more pronounced peak of overall Internet traffic. This is relevant for the ISPs as they dimension their networks according to the busy hour.

67 http://www.vocativ.com/196575/netflix-vs-bittorent-streaming-traffic-is-dwarfing-file-sharing-traffic/; Sandvine (2011).

68 Cisco (2016), section „*Trend 10: Traffic Pattern Analysis (Peak Compared to Average and CDN Uptake*".

Pricing and costing developments

Transit pricing

In its 2012 report BEREC noted that transit prices dropped at an annual rate of approx. 36 % since 1998. Having a look at more recent figures shows that this **decline continues** (see figure X).

Figure A 6: Internet Transit Pricing (1998-2015)[69]

Internet Transit Pricing (1998-2015)
Source: http://DrPeering.net

Year	Internet Transit Price		% decline
1998	$1,200.00	per Mbps	
1999	$800.00	per Mbps	33%
2000	$675.00	per Mbps	16%
2001	$400.00	per Mbps	41%
2002	$200.00	per Mbps	50%
2003	$120.00	per Mbps	40%
2004	$90.00	per Mbps	25%
2005	$75.00	per Mbps	17%
2006	$50.00	per Mbps	33%
2007	$25.00	per Mbps	50%
2008	$12.00	per Mbps	52%
2009	$9.00	per Mbps	25%
2010	$5.00	per Mbps	44%
2011	$3.25	per Mbps	35%
2012	$2.34	per Mbps	28%
2013	$1.57	per Mbps	33%
2014	$0.94	per Mbps	40%
2015	$0.63	per Mbps	33%

It should be noted however that other sources identify a lower decrease of transit prices. Telegeography refers to an average 14 % decrease compounded annually between 2012 and 2015 for median 10 gigabit per second Ethernet (10 GigE) port prices across key *global* transit markets.[70] The figures displayed in the figure above however focus on US transit prices. Besides this, such differences in price decline rates may also be due to methodological differences. [71] BEREC considers that the price decline indicates that the market for transit services is highly competitive but at the same time put under pressure, both from peering services as well as CDN services.

Geographic differences in the transit market:

Besides this general tendency the transit market is characterized by **geographic differences**, with regard to absolute transit prices, price developments (in %) as well as transit revenues.

The following figure illustrates that major transit hubs (London, Los Angeles, Miami) display significantly lower prices and steeper price declines compared to Sao Paulo or Sydney. Telegeography explains that Sao Paulo, which exhibits higher prices and lower price declines exchanges most of its Internet traffic in Miami.[72]

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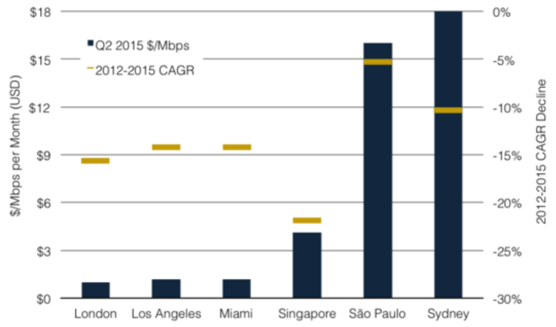
69 DrPeering (2013).

70 https://www.telegeography.com/press/press-releases/2015/09/09/ip-transit-prices-continue-falling-major-discrepancies-remain/index.html

71 Kovacs (2012) reasons "*While the TeleGeography data we cite above is specific to particular cities and port types and sizes, our impression is that Norton's data cuts across those variations*.", http://www.broadbandforamerica.com/sites/default/themes/broadband/images/mail/AMKInternetPeeringandTransit_FINAL.pdf , p. 19.

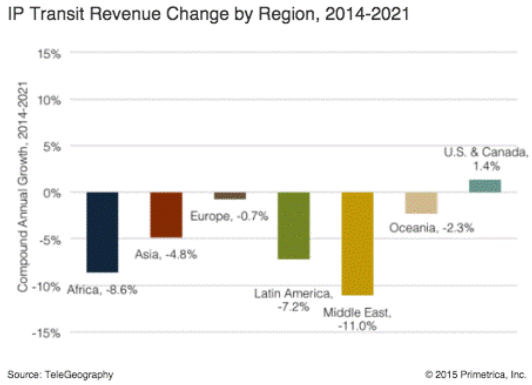
72 Similar, a major part of Sydney's Internet traffic is exchanges in Los Angeles.

Figure A 7: 10 GigE IP Transit Prices & Price Declines[73]



Differences in the rate of price declines and differences in the share of Internet traffic exchanged via transit agreements are the factors driving this regional difference.[74] While emerging market display the highest Internet traffic growth rates, Telegeography points out that ISP in these areas are more quickly switching from transit services to free peering agreements than in more mature market. At the same time transit prices in these **less mature markets display steeper price declines** leading to the results illustrated in figure X below.[75]

Figure A 8: Estimate for transit revenues[76]



CDN pricing

Generally, the **price decline for CDN services seems to continue**, commodity CDN prices dropped 25 % in 2014 and 20 % in 2015.[77] It should be noted however, that these figures

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73 https://www.telegeography.com/press/press-releases/2015/09/09/ip-transit-prices-continue-falling-major-discrepancies-remain/index.html

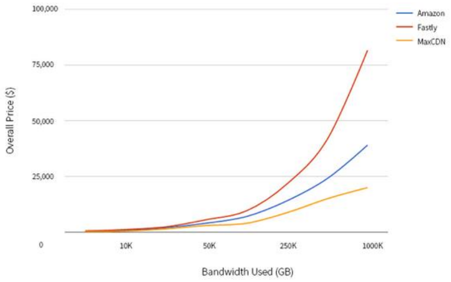
74 https://www.telegeography.com/products/commsupdate/articles/2015/07/09/ip-transit-price-and-peering-trends-yield-regional-revenue-divide/

75 The compounded annual price decline until 2021 (price per Mbps for a 10GigE port) is forecasted to be between 27 % and 29 % in Africa, Latin America and the Middle East and 20 % in North America and Europe (https://www.telegeography.com/products/commsupdate/articles/2015/07/09/ip-transit-price-and-peering-trends-yield-regional-revenue-divide/).

76 https://www.telegeography.com/products/commsupdate/articles/2015/07/09/ip-transit-price-and-peering-trends-yield-regional-revenue-divide/

only provide a "broad picture" considering that CDN prices vary between providers and also depending on the size of the customers. For biggest customers prices dropped even 45 % in 2015. These differences also become evident with the following figure illuatrating that CDN prices are largely driven by economies of scale. Given that both, prices for transit as well CDN services see a constant decline, it seems plausible to assume that the prices of each of these services **impacts on the other (and vice versa)**.

Figure A 9: Prices for CDN services in relation to bandwidth used[78]



Costing developments

In its 2012 report BEREC also had a closer look at cost issues. Overall, it turned out that the costs of delivering traffic were subject to a significant decline (e.g. the router costs $ per Gbps. This development seems to be largely due to competition, technological progress as well economies of scale that become relevant in the light of increasing traffic volumes. The decline in costs has offset increasing traffic volumes. This contributed to the fact the Internet was well able to cope with increasing traffic volumes.

Generally, there are **no indications that this development has stopped**. As illustrated above the prices for various services are still declining. Given that prices in competitive markets reflect underlying costs, it seems plausible to assume that the costs of delivering data packets (on a per unit basis) are also declining.

E.g. it is assumed that it costs about $ 0.008 to deliver one hour of premium over-the-top video via a 3rd party CDN.[79] This would amount to less than $1 for a user consuming 60 hours per month.

Anecdotal evidence also supports these findings. The CEO of Sonic (US-based ISP) pointed out that a few years ago it had spent about 20 % of its revenue on basic infrastructure. Since

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77 Rayburn (2016b).
78 https://stratusly.com/akamai-amazon-cloudflare-fastly-maxcdn-verizon-cdn-comparison/
79 Rayburn, 3 Jan. 2017, https://twitter.com/DanRayburn/status/817498806006796288.

the costs of routers, switching equipment and other related gear declines so much that this ISP's infrastructure costs are now slightly above 1.5 % of its revenue.[80]

Furthermore, in practice disputes between CAPs and eyeball ISPs are often centered on increasing available port capacities, and who should bear these costs. Unsurprisingly, cost estimations of providing additional capacity at interconnection points, differ depending on which party involved in such disputes is asked. Comcast assess that adding a new port "*involves capital costs of about $50,000 and ongoing recurring costs of about $25,000 a year*".[81] On the other hand, Level3 pointed out in a blog-post that the expense is "*not significant"*.[82] And Netflix assesses the marginal costs of adding a port at less than $10.000 with an amortization period of three to five years.[83]

Changing players along the value chain and changes in traffic delivery

CDNs

In its 2012 report BEREC elaborated on the properties and functionalies of content delivery networks (**CDNs**) and also provided a legal classification.[84] These descriptions still hold. The increasing relevance of CDNs was one of the major developments carved out by BEREC in 2012.

This gaining relevance of CDNs is a tendency which is now going on for several years which supports the finding of the **competitiveness of the CDN market**: The following figure illustrates that CDNs account for an increasing share of total consumer traffic in the USA, exceeding a share of 50 % in 2013. There are no indications that this trend is stopped or even reverted.

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80 http://www.cio.com/article/3075975/internet-service-providers/what-big-isps-dont-want-you-to-know-about-data-caps.html (27 May 2016).

81 Letter from Joseph W. Waz, Jr., Senior Vice President, External Affairs and Public Policy Counsel, Comcast Corp., and Lynn R. Charytan, Vice President, Legal Regulatory Affairs, Comcast Corp. to Sharon Gillett, Chief Wireline Competition Bureau, Federal Communications Commission, GN Docket No. 09-191, at 3 n.4 (Nov. 30, 2010). Cited from https://ecfsapi.fcc.gov/file/7521825167.pdf , p. 65.

82 Level3 (2014).

83 Netflix (2014), p. 65.

84 BoR (12) 130, Chapters 2.4 and 4.4.

Figure A 10: CDN growth[85]

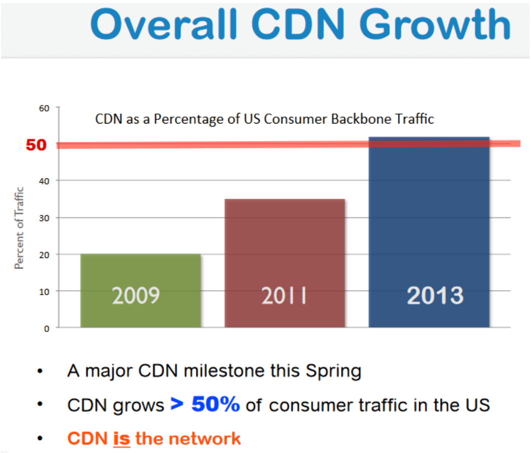
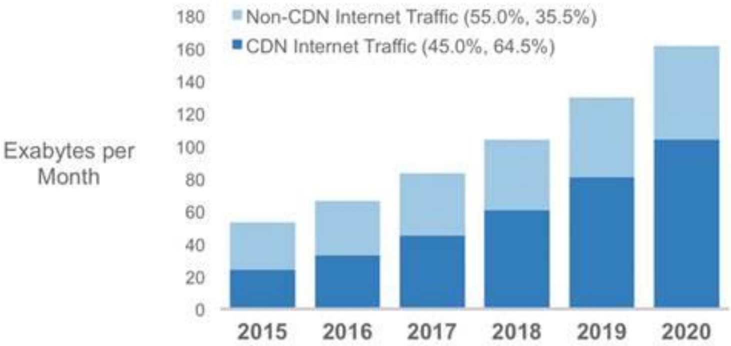


Figure A 11: Global Content Delivery Network Internet Traffic, 2015 and 2020[86]



On a global scale CDN traffic is expected to grow with a **CAGR of 34** % increasing its share of all Internet traffic to 64 % by 2020 (45 % 2015). Total CDN industry's revenue grew approx. 14 % year over year between 2014 and 2016.[87] Given that the development of CDNs coincides in particular with the increase of video streaming over the Internet (e.g. Netflix) it is plausible that the share of all Internet video traffic that is delivered via CDNs is even higher (61 % in 2015 / 73 % in 2020).[88]

The increasing importance of CDNs as a means of traffic delivery **coincides with the general growth in traffic, in particular video**, as well as the gaining relevance of **large CAPs with huge volumes of content**. The impact of video on the development of CDNs is not only due to the traffic volumes. The quality enhancing properties of CDNs will even reinforce this impact.

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85 Labovitz (2013).

86 http://www.cisco.com/c/en/us/solutions/collateral/service-provider/visual-networking-index-vni/vni-hyperconnectivity-wp.html

87 Rayburn (2016b).

88 http://www.cisco.com/c/m/en_us/solutions/service-provider/vni-forecast-highlights.html#

Some voices in the industry are sceptical whether 4K streaming and virtual reality streaming will drive revenue growth for CDNs.[89] They doubt whether 4K will be a mass phenomenon and point out that it not only the cost of traffic delivery (via CDN) is a relevant factor. Other factors such as edit, store, transcode are also relevant for the provision of 4K as well as the availability of 4K-enabled devices among end-users and their willingness to pay for such high-end video services. Furthermore, it is argued that OTT services (e.g. PlayStation Vue[90]) are not the main driver for CDN growth. Correspondingly, the largest growth in OTT is not delivered by third party CDNs but rather by those players who provide CDN services themselves.[91]

In the recent past many CAPs seem to increasingly rely on a **multi-CDN strategy**.[92] This development gained momentum in recent years particularly for companies delivering content to many users on a global scale in many different locations. In **simple** terms, deploying multiple CDNs may improve resilience. Where CAPs use several CDNs they may also use a load balancer to efficiently distribute traffic between them.[93] Based on the location of the users requesting the content either *CDN A* or *CDN B* may be used.[94] There are also aggregators[95] who provide CDN service from several CDNs (which implies one-stop shopping from the CAPs perspective).

Generally, the CDN market continues to consist of a great **variety of players**: pure CDN providers, in-house CDNs, telcos providing CDN services.

For a CAP **self-delivery of CDN** services may be an alternative to buying CDN services from third parties. However, this is **likely only a viable strategy for very large CAPs**. For example, Apple, which originally relied on third-party CDN services to deliver its software updates, videos, apps etc., start (around 2013/2014) to build their own CDN.[96] According to estimations, Apple delivered approx. 75 % of their own content via its internal CDN.[97]

Other companies that also provide their own CDN services are e.g. Google, Amazon or Facebook.[98] Similarly, **Netflix** also relies on an internal-CDN strategy. Netflix launched its CDN ***Open Connect*** in June 2012.[99] While Netflix in the past had relied on various transit

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[89] Rayburn (2016b).

[90] TV service that streams live TV, movies, and sports on a variety of devices without a cable or satellite subscription.

[91] Rayburn (2016b).

[92] Rayburn (2016b; 2017); https://www.maxcdn.com/blog/multi-cdns/.

[93] https://www.maxcdn.com/blog/multi-cdns/

[94] https://www.maxcdn.com/blog/multi-cdns/

[95] E.g. http://www.turbobytes.com/

[96] Rayburn (2014).

[97] Rayburn (2016a).

[98] Note: statement not to be understood as "use *only* their internal CDN"

[99] See https://openconnect.netflix.com/en/ for a description and the requirements for participation.

and third party CDNs it now provides its traffic [all?] using its own CDN. Netflix is said to have invested +100 million dollars in its CDN.[100]

Obviously, the decision to build and deploy an internal CDN is driven by economic considerations. **Relevant factors for this make or buy decision** are: content volumes, economies of scale, opportunity costs of using self-deployed, third-party CDN or using transit services, quality considerations etc.

Infrastructure deployment of CAPs

One of the developments mentioned in BEREC's 2012 report was that large CAPs began to deploy their own networks. For example, late 2016 Google and Facebook teamed up to lay a nearly 8,000-mile cable between Los Angeles and Hong Kong with a bandwidth of 120 terabits per seconds.[101] Google also was part of a consortium that invested in cable infrastructure between the US-westcoast and Japan.[102] In another project, Facebook and Microsoft have built a 6,600 km submarine with a capacity of 160Tbps cable crossing the Atlantic.[103]

All these undersea cable projects link data centers of these large content providers. Telegeography views these projects as a new trend. Traffic volumes are large enough that "make instead of buy" is a rational choice. Furthermore, owning such subsea cables allows them to flexibly upgrade capacity without depending on third parties.[104]

Regionalisation of traffic

A recent study provides some insights to what extent network operators in a given country are interconnected with other domestic networks respectively with foreign networks. For example, while in 2011 29 % of US networks interconnection partners were US networks, this figure declined to 23 % in 2016.[105] Similar developments, can be observed for the UK (declining from 41 % in 2011 to 33 %) and Germany (declining from 32 % to 17 %).

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100 Encompassing deployment costs and R&D, https://qz.com/256586/the-inside-story-of-how-netflix-came-to-pay-comcast-for-internet-traffic/

101 http://www.theverge.com/2016/10/12/13255858/google-facebook-submarine-cable-trans-pacific

102 The consortium includes Google, Global Transit, China Telecom Global, Singtel, China Mobile International, and KDDI (http://www.nec.com/en/press/201606/global_20160629_02.html)

103 https://blogs.technet.microsoft.com/hybridcloud/2016/05/26/microsoft-and-facebook-to-build-subsea-cable-across-atlantic/

104 http://www.wired.co.uk/article/google-facebook-plcn-internet-cable. According to Telegoegraphy, despite these new cable builds, there is a lot of spare capacity in existing subsea systems to last for a long time.

105 Woodcock/Frigino (2016), p.6.

However, these figures require careful interpretation. They may indicate that the Internet becomes **more densely interconnected** than in the past.[106] Assuming that a large percentage of US traffic is domestically produced and consumed, the declining *share* of US networks domestic interconnection partners may presumably reflect such a tendency towards a more interconnected Internet. On the other hand, many developing countries tend to have a relative high percentage of international connectivity which may rather reflect a low degree of domestic production of content.

Peering developments

A recent study provides some insights into the dissemination of peering agreements.[107] A previous version of this study was conducted in 2011[108] analyzing 142,210 Internet carrier interconnection agreements. The updated study now builds upon 1,935,822 interconnection agreements representing 10,794 carrier networks in 148 countries.[109]

It turned out that **99.93%** of peering agreements are **informal "handshake" agreements** concluded without a written contract. In the previous study this figure was 99.51 %. Thus, the percentage of written, formal contracts declined from 0.49 % to now 0.07 %. The report refers to interviewees who even expect the portion of written contracts to decline further over time.

Furthermore, **99.98%** of peering agreements are based on **symmetric terms** now, which is up from 99.73 % in 2011. Thus, only 0.02 % of all peering agreements are currently based on asymmetric terms. However, in terms of traffic volumes these shares may look very different.

Since the previous report the dozen largest networks have **increased the number of peering partners** from a range of 700 – 2.400 in 2011 to 2.200 – 4.500 in 2016. The percentage of networks with ten or fewer peering partners declined from 62 % in 2011 to 35% in 2016. Across all networks the **average number of interconnections per network rose from 77 to now 292**. These developments indicate that network operators regardless of their size are more inclined to peer and tend to increase the number of peering partners. Generally, this results in a more densely interconnected Internet, which also improves quality as more direct paths are established.

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[106] This is in line with the findings presented in Ch. XXX [increasing number of peering partners per network].
[107] Woodcock/Frigino, (2016).
[108] Weller/Woodcock (2013).
[109] These countries include all OECD countries.

The study also emphasizes the **prevalence of multilateral peering** where more than two parties exchange traffic, which is the case at IXPs. According to this study, multilateral peering became the dominant practice in 2011 as it accounts for more AS-adjacencies than bilateral peering.[110] Referring to the focus of Russian, French, Canadian IXPs on multilateral peering it is expected in this study that the predominance of this peering mode will further accelerate.[111]

As pointed out above, traffic volumes in the Internet are still increasing. Growth rates are particularly high in developing countries, which is largely due to the fact that traffic volumes in absolute terms are at a significantly lower level. With such developments ongoing, the question arises what the most efficient way of exchanging traffic across networks is.

A study[112] from 2012 analyses the benefits of using an IXP in developing countries, using Kenya and Nigeria as examples. It depicts that countries in the first phase of their Internet development largely **rely on tromboning** using their international connections for exchanging domestic traffic. Establishing IXPs in these countries helped to eliminate reliance on tromboning, thereyby significantly **reducing costs**[113] and **reducing latency**. Growth of IXPs again makes it increasingly attractive for other ISPs as well as content providers to participate. **Google** has installed a **cache in Kenya in 2011**.[114] This cache led to an immediate and significant spike of traffic volumes exchanged at the IX as users increasingly used Google content (e.g. Youtube).[115]

Using IXPs may thus have several positive effects, saving transit costs, enhancing quality, spurring bandwidth consumption, lower prices for end-users, as well as fueling the emergence of a national Internet ecosystem, both in terms of communications infrastructure as well as the production of local content and applications.[116] All these aspects and effects are to some extent interrelated. Acknowledging these positive effects, the International Telecommunication Union (ITU) recommends promoting local or regional IXP (ITU-T Recommendation D.52[117])

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110 However, Woodcock/Frigino (2016) point out as a caveat that there are uncertainties whether this relates to corresponding volumes of traffic (p. 11)

111 Ibid, p 11.

112 Internet Society (2012).

113 According to this study the Kenya Internet Exchange Point (KIXO) accounts for estimated cost savings on international connectivity of almost $1.5 million per year. And latency reduced significantly from 200-600 ms to 2-10 ms.

114 Originally, the cache was initially provided to one operator in Nairobi, under the condition that the contents would be made available to all members of KIXP.

115 The usage of the IXP also had positive effects for mobile operators in Kenya. Mobile data revenues increased by an estimated $6 million for operators having generated at least an additional traffic of 100Mbit/s per year.

116 Internet Society (2016b).

117 ITU (2016).http://www.itu.int/rec/T-REC-D.52-201610-I

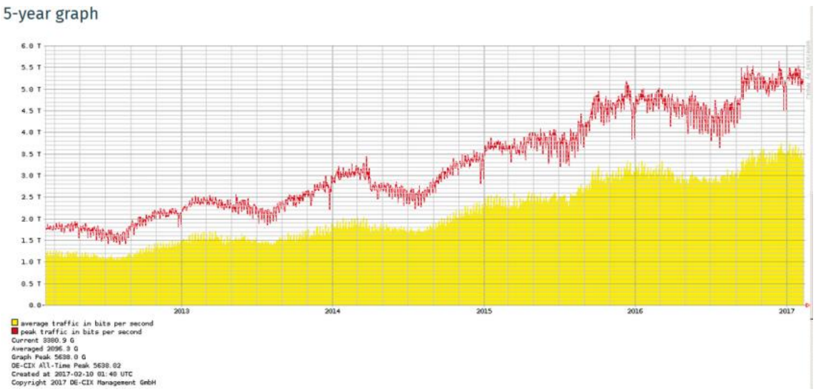
Given these properties and benefits it seems plausible to assume **that usage of IXPs will rather gain more importance in the next yea**r, particularly considering a **catch-up effect in developing countries** displaying higher growth rates.**[118]**

IXP traffic developments

Generally, peering at a public IX economizes on the costs for establishing cross connects, because it allows to reach several networks with one cross connection instead of establishing a cross connect with each individual network.**[119]** More generally, using an IX saves transactions costs. Besides this using IX peering allows networks saving in costs for IP transit.

Corresponding to the overall growth in Internet **traffic also the traffic volumes exchanged** at the biggest European IXPs **– DE-CIX, AMS-IX**[120]**, LINX**[121] **continue to grow.**

Figure A 12: Traffic development at the DE-CIX, 5-year graph[122]



The figure above depicts the traffic development at the *DE-CIX*. While the **peak** capacity exceeded a 2.000 Gbit/s in the last quarter of 2012 it spiked above 5.600 Gbit/s at the end of 2016. It was late in the last quarter of 2008 when the peak exceeded 500 Gbit/s. **Average** throughput climbed from less than 200 Gbit/s (end of 2007), to approx. 1.500 (end of 2012) to 3.428 (19 January 2017).**[123]**

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118 See also Internet Society, 15 Februar 2016, "IXPs level up in emerging Asia-Pacific", http://www.internetsociety.org/blog/asia-pacific-bureau/2016/02/ixps-level-emerging-asia-pacific.

119 However, this does not hold where two networks peer on a *private* basis at an IXP.

120 E.g. for 2016 see https://ams-ix.net/technical/statistics/historical-traffic-data?year=2016.

121 https://www.linx.net/tech-info-help/traffic-stats (displaying the development at the LINX since late 2011).

122 https://www.de-cix.net/de/locations/germany/frankfurt/statistics

123 https://en.wikipedia.org/wiki/List_of_Internet_exchange_points_by_size

Similar developments are observable at the AMS-IX. Peak capacity has reached 5.284 Gbit/s (19 January 2017).[124] Also the **average** throughput grew constantly at the AMS-IX: it grew from about 750 Gbit/s (end of 2011), to slightliy more than 1.000 Gbits (April 2012), now reaching is 3.451 (19 January 2017).[125] Corrspendingly, average througput at the LINX rose from approx. 600 Gbit/s (end of 2011), to 745 Gbit/s (18 March 2012), climbing to 2.089 3.451 (18 January 2017).[126]

US-corporation Equinix ranks 7 with regard to average throughput. However, it is not only providing IXP facilites in the US but also in Europa. The largest pure north-american IX *SIX* , providing facilities in the US and Canada, ranks 13 with an average throughput of 458 Gbit/s (19 October 2016).[127] And the largest pure US IX only ranks 19.

124 https://en.wikipedia.org/wiki/List_of_Internet_exchange_points_by_size
125 https://en.wikipedia.org/wiki/List_of_Internet_exchange_points_by_size
126 https://en.wikipedia.org/wiki/List_of_Internet_exchange_points_by_size
127 https://en.wikipedia.org/wiki/List_of_Internet_exchange_points_by_size