BoR (24) 177

BEREC Report on the IP Interconnection ecosystem

5 December 2024

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Executive Summary

The debate about IP interconnection (IP-IC) was revitalised in 2021/2022 and has gained momentum since then. To contribute to the ongoing debate on IP-IC, BEREC has re-evaluated its earlier findings by preparing this report on the IP-IC ecosystem. This is the third BEREC report on this matter following the publication of its reports on IP-IC in the context of Net Neutrality in 2012[1] and 2017[2].

Although the scope of this report is limited to the IP-IC ecosystem, it is worth noting that there may be some overlap with the debate on payments from large content and application providers (CAPs) to internet access services (IAS) providers. However, the objective of this report is not to replicate that specific debate. In this report, BEREC assesses the current status of IP-IC in Europe and the market developments since the previous reports. The focus of the report is the period from early 2017 to autumn 2023 and it also includes an analysis of the likely trends from 2023 to 2030, where objective data exists.

To prepare the report, BEREC conducted comprehensive desk research and carried out a data collection exercise by means of a quantitative and qualitative questionnaire distributed to internet access services (IAS) providers, as well as to RIPE NCC[3]. Additionally, BEREC organised a series of virtual workshops, where a variety of selected market players were invited to share their views on the current state of play of the IP-IC markets.

Based on this data analysis, the report provides observations related to the use of different IP-IC services (e.g. bilateral peering, internet exchange points, transit, on-net content delivery networks (CDNs)[4]). It is relevant to mention that on-net CDNs are installed in many IAS providers' networks and are thus important in terms of handling data traffic in the respective networks. Even though the data traffic growth rate has stabilised in the reference period, the increasing diffusion of ultra-high definition (UHD) video content could further contribute to the growth of data traffic and an increase in live-streaming content could potentially have an impact on peak traffic.

The report also analyses pricing and cost developments, by revealing that prices and costs for IP-IC services continue to exhibit a downwards trend. The key reasons identified for these falling prices and costs are the technological developments and competitive pressure.

Furthermore, BEREC notes that large CAPs have increasingly invested in their own infrastructure in recent years[5]. In this report, BEREC addresses the economic rationale for the

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[1] BoR (12) 130 An assessment of IP interconnection in the context of Net Neutrality (December 2012), (referred to as "2012 IP-IC report")

[2] BoR (17) 184 BEREC Report on IP-Interconnection practices in the Context of Net Neutrality (October 2017), (referred to as "2017 IP-IC report")

[3] Réseaux IP Européens Network Coordination Centre (RIPE NCC) is the Regional Internet Registry for Europe, Middle East and Central Asia.

[4] The notion of "on-net CDNs" refers to CAPs placing their cache servers in the IAS providers' access networks.

[5] BoR (24) 139 BEREC Report on the entry of large content and application providers into the markets for electronic communications networks and services (October 2024)

large CAPs to deploy their own infrastructure rather than buying services from providers of electronic communications networks and services (ECN-ECS). The analysis also shows that, when low latency and high bandwidth are required, peering is more likely to be a substitute for transit than vice versa.

Furthermore, BEREC reflects on IP-IC disputes, typically between CAPs and IAS providers, that have occurred since 2017. In particular, BEREC describes the generic structure of IP-IC issues outlined by several market players during its workshops.

To analyse whether there are issues in IP-IC markets which might require regulatory actions, BEREC has assessed the underlying issue of the relative bargaining power between CAPs and IAS providers. It can be concluded that several factors impact on the relative bargaining power between providers, such as the size of the players, the degree of substitutability between transit and peering, the cost structure of transit and peering, economies of scale, as well as market and technological developments.

The report also touches upon the relationship between the Open Internet Regulation (EU) 2015/2120 (OIR)[6] and IP-IC. In particular, BEREC examines the provisions of the OIR, which aim to ensure an open internet, for the part of the internet value chain for which the IAS provider is responsible.

BEREC considers that the IP-IC ecosystem is still driven by functioning market dynamics and by the cooperative behaviour of market players. Despite this, BEREC is aware that a few IP-IC disputes have occurred since 2017, and BEREC's workshops also revealed similar insights. BEREC notes that stakeholders typically did not call for regulation but suggested monitoring and a case-by-case assessment. BEREC will follow up on such issues[7], while also considering the relationship between IP-IC and the OIR as analysed in this report.[8] This is important as otherwise end-user customers would ultimately suffer from disputes between different market players across the internet value chain[9]. In this regard, BEREC referenced the NRAs' capacity to settle disputes between ECN-ECS providers and other undertakings benefitting from access or interconnection obligations for the purpose of providing publicly available ECS in the *BEREC's input to the EC public consultation on the White Paper "How to master Europe's digital infrastructure needs?"*[10]

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[6] Regulation (EU) 2015/2120 of the European Parliament and of the Council of 25 November 2015 laying down measures concerning open internet access and retail charges for regulated intra-EU communications and amending Directive 2002/22/EC and Regulation (EU) No 531/2012 (referred to as "the OIR")

[7] For instance, this may involve monitoring by means of data collection exercises.

[8] BEREC notes that other tools like NRA data collection powers and competition law might be applied. Aside from that, NRAs would have to assess on a case-by-case basis whether Article 26 of the European Electronic Communications Code (EECC) might be applicable in case of IP-IC issues.

[9] If (e.g.) a CAP and an IAS provider cannot agree to increase the capacity of the IP-IC interface between their networks, this may lead to a lower quality experienced by a user streaming a video.

[10] BoR (24) 100 provides that "*As regards issues that have emerged in a few national markets, the current regulatory framework provides some means to handle problems in areas which are governed by commercial agreements - like IP interconnection. These means include NRAs' capacity to settle disputes between ECN-ECS*

To conclude, BEREC considers that, since its creation, the internet has managed to cope with both traffic growth and higher peaks of traffic. These trends reflect changing usage patterns as well as increasing diffusion of IAS throughout societies. Against this background, BEREC's observation that the developments in the IP-IC ecosystem are an "*evolution rather than revolution*"[11] still holds.

1. Introduction

BEREC published reports on IP-IC in the context of Net Neutrality[12] in 2012 and 2017. In this updated *Report on the IP interconnection ecosystem*, BEREC re-evaluates its conclusions from 2017, as well as assesses the current status of IP-IC in Europe and the market developments since the previous reports, including the relationships between different parties, use of paid peering and CDNs.

The scope of this report is limited to the IP-IC ecosystem. However, it is worth noting that there may be some overlap with the debate on payments from large CAPs to IAS providers, although the objective of this report is not to replicate that specific debate. The focus of the report is the period from early 2017 to autumn 2023 and it also includes an analysis of the likely trends from 2023 to 2030, where objective data exists.

This report is organised as follows:

- Chapter 2 provides an overview of the data analysis carried out by BEREC;
- Chapters 3, 4 and 5 describe the developments with respect to traffic, prices and costs, as well as the services used in the IP-IC markets;
- Chapter 6 provides a description of the generic structure of IP-IC issues and elaborates on case studies related to IP-IC disputes;
- Chapter 7 contains an assessment of the bargaining situation (in particular) between CAPs and IAS providers[13];

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providers and other undertakings benefitting from access or interconnection obligations for the purpose of providing publicly available electronic communications services, and the NRAs' power to collect data from undertakings active in sectors that are closely related to the electronic communications. In addition, the concept of "non-circumvention" enshrined in the OI Regulation and the BEREC Guidelines provides an available tool to address issues in the IP interconnection market. […] BEREC is open to take on a role in this field in the future, in order to foster consistent practices throughout the Union."

[11] See BoR (17) 184, Chapter 7

[12] BoR (12) 130 An assessment of IP interconnection in the context of Net Neutrality;
BoR (17) 184, BEREC Report on IP-Interconnection practices in the Context of Net Neutrality

[13] In the BoR (22) 81 *BEREC Guidelines on the implementation of the Open Internet Regulation* (June 2022), BEREC uses the term "ISP" to refer to providers of internet access services (IAS). For the purpose of this report, the notions of "internet access service (IAS) provider" and "internet service provider (ISP)" are used as synonyms.

- Chapter 8 elaborates on the relationship between IP-IC and the Open Internet Regulation (EU) 2015/2120 (OIR).

For the purpose of this report, BEREC circulated a questionnaire on the basis of Article 20(1) of the European Electronic Communications Code (EECC), according to which national regulatory authorities (NRAs) and BEREC have the power to require undertakings who provide electronic communications networks and services (ECN-ECS), associated facilities, associated services, or who are active in closely related sectors, to submit information concerning such networks and services.

The questionnaire was distributed by NRAs on behalf of BEREC to IAS providers in their respective countries and to RIPE NCC. BEREC received more than 170 replies, containing data sets of traffic measurements with the majority referring to the months of September and October 2023 (see Annex III for further information). Given the importance of providing a sound and evidence-based analysis of the evolution in the IP-IC markets, BEREC stresses the need for NRAs and BEREC to have the appropriate powers to gather data on relevant services and networks provided by different types of actors.

Furthermore, in order to gather relevant feedback and insights, BEREC organised 12 internal virtual workshops in September and October 2023, where a variety of selected stakeholders[14] were invited to share their views on the current state of play of the IP-IC markets.

To follow up on the findings gathered from these workshops, BEREC distributed an ad hoc questionnaire to various stakeholders in May 2024. While the report excludes the results of this additional questionnaire due to scheduling constraints, the results have been documented internally and informed BEREC's ongoing work.

2. IP-IC data analysis overview

To prepare this report, BEREC carried out a data collection exercise by means of a quantitative questionnaire, complemented with qualitative questions. The main objective of this exercise was to support the analysis in the report with empirical data and to provide a better understanding of the interconnection between different actors in the internet ecosystem[15] at European level.

The analysis of the data in this report takes into account, for each responding IAS provider, up to the top 15 bilateral peering agreements, as well as up to the top 10 on-net CDN caches and up to the top 10 internet exchange point (IXP) agreements. The criterion used by the

[14] Stakeholders of the following categories were invited to the workshops: academics and civil society, internet community, cloud and hosting providers, content and application providers (CAPs), content delivery network (CDN) providers, internet exchange points (IXPs), internet service providers (ISPs), transit providers.

[15] BoR (22) 167 BEREC Report on the Internet Ecosystem (December 2022)

respondents for assessing the importance of each agreement was based on the configured capacity.

To focus on specific categories and trends in the analysis, IAS providers have been grouped according to the following criteria:

- highest – traffic above the 66,6 percentile (849 Gbit/s)[16];
- medium – traffic included between the 33,3 and 66,6 percentile;
- lowest – traffic below the 33,3 percentile (138 Gbit/s).

The group categorisation is obtained by ranking the inbound traffic by size (in ascending order) and calculating the values of the 33,3% and 66,6% percentiles, so that there are three groups with approximately the same number of IAS providers responding to the questionnaire. The resulting categorisation therefore is based on the relative size of IAS providers in terms of inbound traffic (and not, e.g. in terms of number of end-users or revenue shares).

The figures outlined in the following sections relate to information on inbound traffic of retail networks providing public IAS. In the context of this analysis, the term "transit" refers to global or partial transit services provided to these IAS providers.[17] Therefore, the traffic values are considered from the point of view of retail IAS providers.

Transit networks (e.g. Tier 1 providers which can reach the entire internet via settlement-free peering and thus do not buy transit), are providing a different service than retail public internet access, are not part of the sample. However, transit networks' traffic does feed into the empirical data, to the extent that this traffic constitutes inbound traffic for a retail IAS provider. This also holds where the transit network is part of a company group (i.e. when the IAS provider is vertically integrated).

[16] This absolute value in Gbit/s is the threshold of inbound traffic (without traffic from on-net CDN to end-users) of IAS providers which separates the groups. Accordingly, at the threshold of the 66,6 percentile, 66,6% of the responding IAS providers have equal or less inbound traffic and 33,3% have more inbound traffic.

[17] The questionnaire distinguishes the following types of relationship with interconnection partners:
- Global and partial transit [1:E, 1:n]: network #1 (respondent) employs network #2 to supply a transit solution to all or a number of third-party networks;
- Global transit [E:1, n:1]: network #1 provides network #2 with a transit solution to all or a number of third-party networks;
- Peering [1:1]: networks #1 and #2 mutually route traffic to their customers, their customers' customers, etc.

In order to avoid double counting of transit, the figures consider inbound global and partial transit [1:E, 1:n].

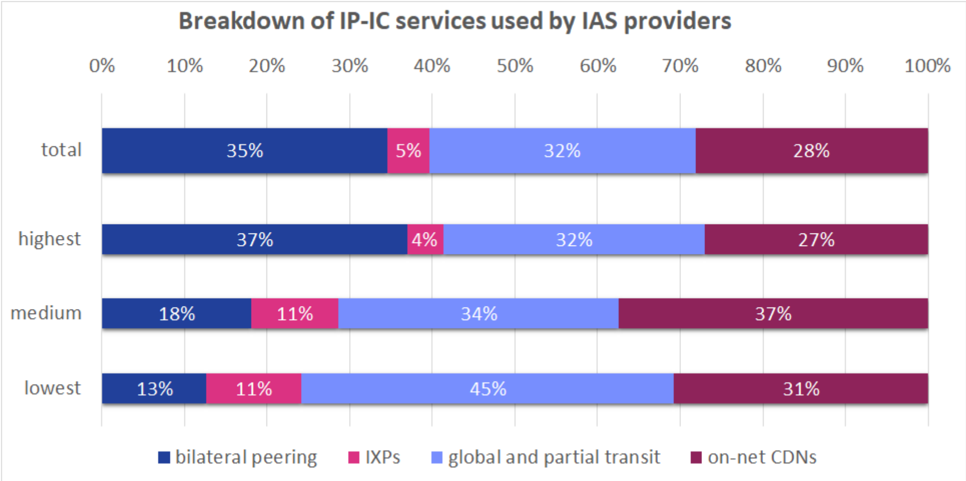

Figure 1. Breakdown of IP-IC services used by IAS providers,[18] Source: BEREC

Figure 1 shows the structure of interconnection and on-net CDN traffic across the total and the three groups of IAS providers.[19] The following main findings are worth noting:

- The higher the amount of inbound traffic the lower the relative importance of IXPs.[20]
- The relative importance of on-net CDNs is lowest (27%) for those ISPs which have the highest inbound traffic. Instead, they significantly rely more on bilateral peering (37%).
- Bilateral peering is increasing in relative importance with the amount of inbound traffic.
- The higher the amount of inbound traffic the lower the relative importance of transit. Nevertheless, the considerable share of transit (32%) in the group of highest inbound traffic can also be explained with those IAS providers in this group, which are vertically integrated with a transit provider and exchange a large share of traffic with the Tier 1 transit networks in the same company group.

[18] Reading aid: 35% of all traffic received by customer end-users in the sample (total sum of traffic) is traffic from bilateral peering.

[19] It is worth to highlight that the on-net CDNs traffic here relates to traffic from the CDN inside of the network of the IAS provider to end-user which does not cross the border of the network (while other traffic categories do).

[20] The questionnaire defines information on IXPs as referring to agreements with an IXP ("multilateral peering") for traffic across the IXP and not agreements already covered as bilateral interconnections.

3. Traffic developments

In its 2017 IP-IC report, BEREC highlighted, inter alia*,* that aggregated internet traffic volumes continued to grow significantly, which was mostly attributed to the increasing popularity of video streaming services at that time.[21]

In this chapter, BEREC identifies the main current traffic trends in Europe since 2017, following a thorough desk research exercise, as well as based on the outcomes of the stakeholder workshops and the data analysis. After highlighting the general trends, the analysis focuses on the evolution of IXP traffic and on traffic regionalisation. Finally, BEREC addresses the question of major trends that might occur until 2030.

3.1 General data traffic trends in Europe

In its 2017 IP-IC report, BEREC found that IP traffic was increasing but at a declining growth rate, confirming the trend which had been observed in 2012. Specifically, BEREC reported an expected compound annual growth rate (CAGR) of 20% for Western Europe and 27% for Central and Eastern Europe for the years from 2015 to 2020.

According to a study published by WIK-Consult in 2022[22], the trend highlighted by BEREC in 2017 is not continuing in Europe, as the growth rate remains constant[23]. In particular, in the period from 2017 to 2022, traffic volumes were expected to grow in Western Europe by 22% as well as in Central and Eastern Europe by 27% (CAGR). These figures are consistent with the ones reported by a more recent study by Telegeography[24] that outlines a +27% CAGR both for average and peak traffic in the period 2019-2023 in Europe. On the other hand, this study also highlights a drop in average and peak traffic growth in the same period, following a spike due to the COVID-19 pandemic.

As already analysed in BEREC's 2017 IP-IC report, traffic growth continues to be mostly driven by video traffic that, according to Sandvine[25], constituted about 62% of the total traffic in the EMEA (Europe, Middle East and Africa) region in the first half of 2022, followed by social networking (~14%) and messaging (~5%). A key factor in this context is the growing availability of UHD streaming content (4K) combined with the greater diffusion of devices required to access such content (e.g. 4K smart TV). 4K video requires about 15 to 18 Mbit/s in terms of

[21] BoR (17) 184, Chapter 7, conclusion a)
[22] WIK-Consult (referred to as "WIK"), Competitive conditions on transit and peering markets – Implications for European digital sovereignty (February 2022)
[23] See also WIK, Netzentgelte auf dem Prüfstand – Eine Betrachtung der "Fair-Share"-Debatte (December 2023)
[24] Telegeography, Total International Internet Bandwidth Now Stands at 1,217 Tbps (September 2023)
[25] Sandvine, Phenomena – The Global Internet Phenomea Report (January 2023), p. 27

bandwidth, that is twice the bandwidth of traditional HD video and nine times the bandwidth required for SD video[26].

Regarding the development of the peak-to-average traffic ratio, the data regarding average and peak traffic in Europe outlined in the Telegeography report indicates that this ratio has recorded minimal variations between 2019 and 2023. Live video streaming of high-attendance events, such as football matches, may lead to an increase in peak traffic.[27] However, it remains to be seen to what extent this actually happens in practice.

Moreover, the analysis carried out by BEREC shows that the inbound-outbound traffic ratio across all respondents is 5,6:1. Thus, inbound traffic is almost six times the outbound traffic.[28,29]

3.2 Focus on specific trends

This part focuses on two specific trends, namely IXP traffic developments (Section 3.2.1) and traffic regionalisation (Section 3.2.2), as well as on the related findings which were highlighted by the data analysis.

3.2.1 IXP traffic developments

A study issued by Euro-IX[30] in 2021 indicates that the aggregated peak IXP traffic within the Euro-IX membership exhibited a growing trend from 2017 to 2021. In particular, peak traffic has more than doubled between 2017 and 2021, with a notable growth during 2020 (+32% YoY) following the pandemic outbreak.

[26] Cisco, Cisco Annual Internet Report (2018–2023) (2020), p. 7

[27] Arthur D. Little, The evolution of data Growth in Europe – Evaluating the trends fueling data consumption in European Markets (2023), p. 28; Very similarly, one stakeholder during BEREC's workshops also expected a faster growth for peak than average traffic.

[28] For instance, in Germany, only the incumbent requires a certain ratio of inbound to outbound traffic for peering, see WIK-Consult, Competitive conditions on transit and peering markets – Implications for European digital sovereignty (February 2022), Table 2-6, p. 46,

[29] While Deutsche Telekom uses a traffic ratio of max. 1,8:1 as requirement for settlement-free peering (see WIK-Consult, p. 43) the speed ratio for their access lines ranges from 2,5:1 to 6,25:1. Against this background as well as BEREC's finding that the inbound-outbound traffic ratio across all respondents is 5,6:1, a "tight" traffic ratio at the wholesale level will in most cases "automatically" imply that the requirement for settlement-free peering is not met).

[30] European Internet Exchange Association, IXP Report 2021 (2021)

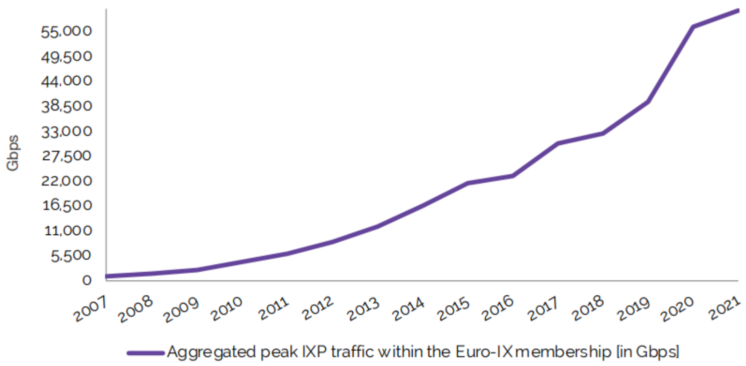

Figure 2. Evolution of the aggregated IXP traffic within the Euro-IX membership, Source: European Internet Exchange Association

Despite this growth, in its 2022 study, WIK highlights a decrease in relative importance of IXPs for traffic exchange, noting that there are indications that the growth of bilateral private peering traffic is higher than that of multilateral peering[31]. To provide further perspective, IXPs may potentially face increasing competition from data centres, as also reported by ACM[32]. This is because, as reported by Arcep[33], data centres can also provide interconnection services, in addition to hosting services, thus competing with IXPs. With regard to IXP traffic, it is also worth noting that the data analysis carried out by BEREC shows that IXP traffic has typically a greater relevance for those operators with lower inbound traffic.

3.2.2 Regionalisation of traffic

The 2022 WIK study reports evidence of an increasing regionalisation of IP traffic, noting that this trend is primarily driven by low-latency requirements and the consequential deployment of CDN caches inside IAS providers' networks or IXPs.[34] The deployment of on-net caches allows for a reduction in backbone internet traffic and, at the same time, improves latency and thereby the quality perceived by the end-user (quality of experience).

In light of the expected growth in video traffic in the coming years, and of the related development of on-net caches for the distribution of such content, both on demand and live, it seems plausible that this reduction in backbone internet traffic will continue.

[31] With bilateral peering two networks negotiate directly with each other and interconnect establishing a direct BGP (Border Gateway Protocol) session. In case of multilateral peering several networks interconnect at an exchange point that offers a route server and each network establishes a single BGP session and receives routes from any other network connected to this exchange.
[32] ACM, Marktstudie IP interconnectie 2021 (2021), p. 28
[33] Arcep, The state of the Internet in France – 2021 Edition (2021), p. 38
[34] Also, Arcep's Barometer of data interconnection in France (June 2022) shows a stepwise increase of the on-net CDN traffic since 2017, confirming the trend of a wider use of these technologies.

The high percentage of bilateral peering traffic reported in Figure 1, as well as the competitive pressure exerted by bilateral peering and CDN services on transit services, as highlighted in Chapter 5, can also be considered as indicators of a shift towards a higher level of regionalisation.[35]

With regard to on-net CDNs, BEREC carried out a thorough analysis of the data received from the IAS providers, and the main results are reported below. First of all, on-net caches are reported to be installed by large CAPs as well as by smaller players. Figure 3 shows an analysis of the share of operators with on-net CDNs for each group (see Chapter 2). The presence of on-net CDNs in the IAS providers' networks ranges from 65% in the group of IAS providers with the lowest incoming traffic up to 92% in the group with medium incoming traffic.

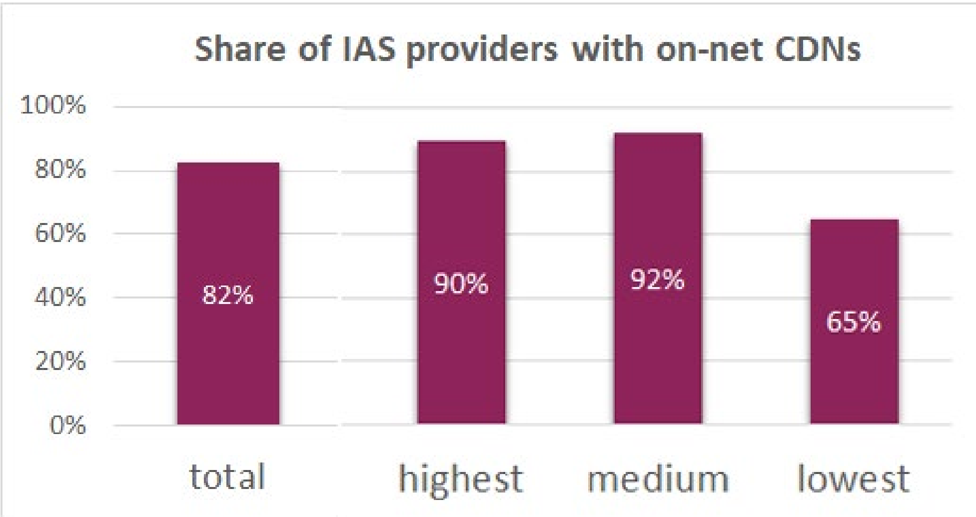

Figure 3. Share of IAS providers with on-net CDNs, Source: BEREC

Finally, the analysis has also calculated the ratio of on-net CDN outbound traffic to on-net CDN inbound traffic[36]. According to the data analysis, this ratio is 7,1:1 for the group of IAS providers with highest incoming traffic. Approximately seven times as much traffic flows from the on-net CDN to the end-user, than flows from the CAP (owning the on-net CDN) to the on-net CDN. For the medium group this ratio amounts to 4,2:1, while it is 3,8:1 for the group with lowest incoming traffic. In this regard, it is worth noting that IAS providers with highest incoming traffic also appear to entail a greater use of on-net CDNs, benefiting more from on-

[35] Already in its previous reports, BEREC referred to the regionalisation of traffic (e.g. BoR (17) 184, section 3.3.3 and BoR (12) 130, section 4.1) and more generally to the flattening of network hierarchies (BoR (12) 130, section 4.5).

[36] In this context, inbound traffic is the traffic to fill in the servers with contents, while outbound traffic is the traffic from the on-net CDNs to the end-users. The ratio between on-net CDN outbound and inbound traffic could therefore be considered as an indication of the capacity saved at the interconnection point.

net caches. This could be explained by the number of end-users because the more end-users a network has, the more content on an on-net-CDN is requested in terms of frequency.

3.3 Future trends

For the period 2022-2030, Arthur D. Little expects an CAGR of 25% and 19% in data consumption on mobile and fixed networks in Europe respectively.[37] As video will keep driving traffic growth, it is foreseeable that in the coming years the increasing diffusion of UHD video content will further contribute to the growth of data traffic. An increasing consumption of live-streaming content could add to this growth, and could potentially have an impact on peak traffic. It is also worth noting that the increasing efficiency of video codecs is likely to reduce the bandwidth required by UHD video content and, consequently, the relative impact in terms of traffic volumes.[38]

Regarding the evolution of the asymmetry of traffic, as reported previously, BEREC found that the ratio between inbound and outbound interconnection traffic was 5,6:1 (see Section 3.1). It is possible that traffic could tend to develop more symmetrically in the coming years. This may be due to increased usage of video communications or cloud services. However, it remains to be seen whether and to what extent this actually happens.

For example, in France, one of the major TV channels uses peer-to-peer[39] technologies to stream its content.[40] The French NRA Arcep assumed in its 2022 *Barometer of data interconnection* that an increase in the use of such solutions to stream content, as expected by Cisco[41], could explain the recent narrowing of the gap between inbound and outbound traffic.

In addition to the points mentioned above, virtual world applications, augmented and virtual reality, as well as artificial intelligence content are also expected to be major factors contributing to the growth of data traffic.[42]

Against the background of all these (possible) developments, BEREC reiterates that the internet has, since it was created, managed to cope with traffic growth and more accentuated peak traffic, all of which reflect changing usage patterns as well as increasing diffusion of IAS

[37] Arthur D. Little (2023), p. 18f

[38] Analysys Mason, Netflix's Open Connect program and codec optimisation helped ISPs save over USD1 billion globally in 2021 (July 2022)

[39] This report is referring to several technologies that enable content to be distributed not only from the CAP server to the end user but also between end users (peers). So, the users are expecting to send more traffic as they serve the content to other users. For example, the one developed by Streamroot, (now Lumen) or WebRTC, implemented notably in the Peertube free software.

[40] France Télévisions, Streamroot et France télévisions : histoire d'une rencontre (February 2019)

[41] Cisco, Visual Networking Index: Forecast and Trends, 2017–2022 (2019), p.14

[42] Arthur D. Little (2023), p. 4

throughout societies.[43] BEREC considers that, due to competition as well as technological progress, there is currently no indication that this is likely to change in the future.

3.4 Key findings related to traffic developments

- According to recent studies, the data traffic growth is a confirmed trend, with a stabilisation after a major spike during the COVID-19 pandemic. The peak-to-average traffic ratio appears to be overall stable between 2019 and 2023.
- According to BEREC's analysis, on-net CDNs are installed in the vast majority of the respondent IAS providers' networks.
- It is foreseeable that in the coming years, the increasing diffusion of UHD video content could further contribute to the growth of data traffic, as well as higher consumption of live-streaming content could potentially have an impact on peak traffic and on the peak-to-average traffic ratio. In this context, the deployment of on-net CDNs and more efficient compression techniques are expected to offset the overall impact of these developments.

4. Pricing and cost developments

Pricing and cost developments in IP-IC markets were examined in BEREC's reports in 2012 and 2017. Both reports concluded that prices for IP-IC services and costs for interconnection infrastructure were falling over longer time horizons. The key reasons identified for these falling prices and costs were competition and technological progress.

In this report, BEREC has analysed developments since 2017, including publicly available data and reports, stakeholder workshops and expert evidence to update these conclusions.

There are some signs that there are certain geographical regions[44] where transit is more expensive, but these observations are not so large as to alter the general trends. Overall, no evidence has emerged which questions the conclusion from the 2017 IP-IC report that "*BEREC considers that the Internet ecosystem's ability to cope with increasing traffic volumes is still given".* Taken together with the observed continuing decline in prices, BEREC can therefore conclude that the European market for peering and transit is still competitive.

[43] See BoR (17) 184, e.g. p. 4

[44] Analysys Mason, IP interconnection on the Internet: a European perspective for 2022 (September 2022), pp. 21-22.

4.1 Transit costs

Even though data usage has increased rapidly since 2017, downwards pressures on GB/price for transit have continued. Likely, this has been the result of technical improvements and capacity increases. Additionally, this trend is expected to continue, as more advanced and higher capacity ports will be introduced. Public data from Vodafone on the transit GB/price seem to confirm a similar observation by British Telecommunications (BT) in 2018.[45] The costs per gigabyte of data in Vodafone's network have declined from 2017 until 2021 with roughly 70% (see Figure 4). BT reported similar results, with 70% reductions in the cost of adding a Mbit/s of capacity between 2012 and 2018.

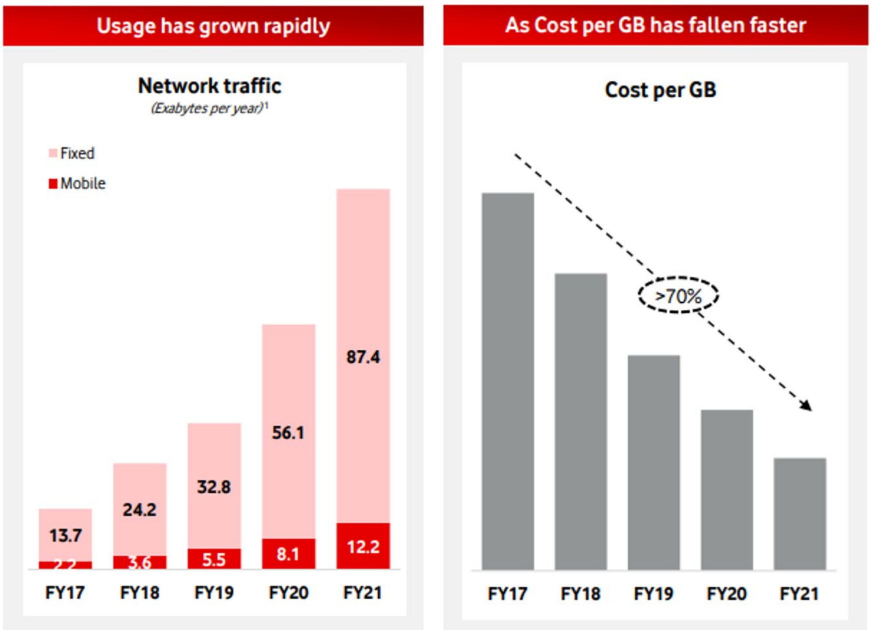

Figure 4. Evolution of network traffic and data unit cost since 2017, Source: Vodafone

BEREC considers that network costs are driven by peak traffic and not total traffic volumes.[46] This also holds for the price of transit, as transit is usually priced according to capacity rather than total gigabytes of traffic, and a proportion of transit capacity will be required to serve peak traffic. Data on transit costs reported by IAS providers in BEREC's data collection exercise suggest that technological developments (e.g. CDNs, more efficient infrastructure and codecs) may even prevent an increase in transit costs even if peak traffic were to increase.

[45] BT, Scaling for Ultrafast, G.FAST, FTTP, 5G and the Cloud (2018), p.9

[46] Analyses of the Disruptive Competition Project confirm this observations, Internet Traffic Growth is Not Out of Control, and Nothing Like Telcos Want you To Believe (November 2022)

4.2 Cost and price effects of technological developments

There have been a number of technological developments in internet architectures since the BEREC 2017 IP-IC report (see Chapter 5). These changes, which have largely been implemented cooperatively by a variety of market players, have increased the efficiency of networks which transmit data and reduced the distances which it is transmitted, and are a key reason why BEREC continues to observe falling prices and costs.

Some stakeholders argue that the evolution of the internet architecture (e.g. the increased prevalence and use of IXPs, and in particular the installation of on-net caches and CDNs which deliver content inside IAS providers' networks) has reduced the demand for transit, which will in turn reduce the price of transit[47].

The use of CDNs has increased significantly in the last years.[48] According to its data analysis, BEREC has observed that, in the majority of the reported agreements, the on-net CDN service is offered on a free basis (see Section 5.1.2 for further details on the agreements regarding the deployment of on-net CDNs). Paid agreements regarding on-net CDNs are usually in the form of set up fees, flat fees (usually monthly) to the on-net CDN provider for service/equipment rental and rarely revenue-share agreements. Traffic-based usage paid agreements were also rare in the provided answers (e.g. payments towards on-net CDNs owned by IAS providers). A wide variance in these on-net CDN charges was observed, depending on the specific bilateral agreement. Moreover, some IAS providers also reported the need to cover electricity and server cooling as well as rack/co-location costs.

The increased prevalence of CDNs in IAS providers' networks has been a primary reason for the continuing decrease in transit prices that are observed since 2017. Such on-net CDNs exert competitive pressure on these prices, as the demand for long distance transit declines due to local storage of content in CDNs.

The continued development and implementation of new technologies, like fibre broadband and more efficient mobile technologies, once deployed, also reduce the marginal costs to deliver transit. These technologies have effectively reduced the marginal costs of adding network capacity for ECS providers, as newer technologies permit higher capacities of data[49]. Additionally, economies of scale have contributed to decreasing prices, as scaling up to higher capacity equipment results in lower relative price per GB.

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[47] Analysys Mason (September 2022)
[48] WIK (2022) "*Globally, it [CDN traffic] almost tripled from 2017 to 2020 and will double again by 2022, according to expert estimates*", p. XIII; Analysys Mason (September 2022), p. 21
[49] Analysys Mason, [The impact of tech companies' network investment on the economics of broadband ISPs] (October 2022), p. 8

4.3 Peering prices

In this section, further information is outlined related to public and private peering prices (Sections 4.3.1 and 4.3.2 respectively).

4.3.1 Public peering

The market study published by ACM provides a price comparison of the major European Internet Exchanges.[50] Table 1 has been updated with data from the 2022 WIK study[51]. The average prices of 10 GE (Gigabit Ethernet) per Gbit/s port are 611 EUR and 3035 EUR for a 100 GE/Gbit/s. This comes down to an average price of 3,57 EURcts per Mbit/s for a 100 Gbit/s port, and 7,18 EURcts for a 10 Gbit/s port.[52]

Internet Exchange Points	100 Gbit/s Port Price in Euro	10 Gbit/s Port Price in Euro	100 Gbit/s port: Monthly Mbit/s price at 85% utilisation in euro cents	100 Gbit/s port: Monthly Mbit/s price at 40% utilisation in euro cents	10 Gbit/s port: Monthly Mbit/s price at 85% utilisation in euro cents	10 Gbit/s port: Monthly Mbit/s price at 40% utilisation in euro cents
AMS-IX (Amsterdam)	3600	720	4,20	9,00	8,50	18,00
LONAP (London)	1759	268	2,10	4,40	3,20	6,70
LINX LON1 (London)	3405	708	4,00	8,50	8,30	17,70
LINX LON2 (London)	2203	454	2,60	5,50	5,30	11,40
SwissIX (Zurich)	2388	430	2,80	6,00	5,10	10,80
BCIX (Berlin)	2628	514	3,10	6,60	6,00	12,90
ECIX (Germany)	3278	528	3,90	8,20	6,20	13,20
BNIX (Brussels)	2628	717	3,10	6,60	8,40	17,90
FranceIX (Paris)	4300	850	5,10	10,80	10,00	21,30
Equinix (Paris)	3861	792	4,50	9,70	9,30	19,80
NetNod (Copenhagen, Stockholm)	3340	742	3,90	8,40	8,70	18,60
Arithmetic mean of the prices	3035,45	611,18	3,57	7,61	7,18	15,30

Table 1. Peering Prices of Major European IXPs, Source: ACM

[50] ACM (2021)
[51] WIK (2022), p. 49
[52] WIK (2022), p. 49

4.3.2 Private peering

The prices of private peering remain non-transparent. Prices for IAS providers are estimated by ACM to be roughly between a few cents and several tens of cents per Mbit/s per month.[53] Estimations made by Arcep are higher and range between 25 EURcts and several euros per Mbit/s per month.[54] ACM considers the total costs for an IAS provider to install and maintain an interconnection with a single CAP to be relatively low, compared to the costs paid to an IXP for public peering. Furthermore, costs of maintaining the access and core networks are a much larger burden for IAS providers.[55]

In the BEREC 2017 IP-IC report, it was outlined that public and private peering continued to expand between 2012 and 2017. Research by Arcep demonstrated that peering relations are still growing, lowering relative demand for transit.[56] Using data of inbound traffic of the main ISPs in France, Arcep found that peering increased from 36% in 2012 to 52% in 2021, while transit fell from 64% to 48%. Additionally, Arcep observed that paid peering was applied to 48% of traffic of main ISPs.[57]

Furthermore, Packet Clearing House shows that more than 99% of all agreements, analysed in their report, are settlement-free or “handshake” agreements.[58] This finding is also supported by BEREC’s data analysis showing that across all IAS providers (settlement-)free peering is by far the dominant form of peering even if traffic volumes are assessed (Figure 5).[59] More specifically, the percentage is the lowest (1%) for those IAS providers who have the lowest amount of inbound traffic. Given that an IAS provider’s choice of an interconnection mode (be it settlement-free, paid peering or also transit) is a matter of network planning and cost optimisation this might be, because for this category of IAS providers (“lowest”) it may be economically rational to incur the costs for peering settlement-free at an IXP,[60] thereby interconnecting with many other IAS providers or CAPs. In addition, these IAS providers with the lowest amount of inbound traffic may have less bargaining power to conclude paid peering agreements. However, the somewhat higher percentage (4%) of paid peering for the category of IAS providers with highest amount of inbound traffic seems plausible as (e.g.) a paid peering contract between a large CAP and an IAS provider entails large traffic volumes.

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[53] ACM, Study into the Market for IP interconnections 2021 (2021)
[54] Arcep, The state of the Internet in France – 2021 Edition (June 2021)
[55] WIK (2022)
[56] Analysys Mason (September 2022)
[57] Arcep, The State of Internet in France – 2022 Edition (June 2022)
[58] Packet Clearing House, 2021 Survey of Internet Carrier Interconnection Agreements (December 2021), Of the total analysed agreements, 99.998% are “handshake” agreements and 99.9996% have symmetric terms, i.e. they are settlement-free (note: this can be inferred as Packet Clearing House does not assess transit agreements in its report).
[59] In this calculation the answer “Other” is omitted. Different from these European observations, research by Arcep has demonstrated that paid peering is more common among ISPs in France. See Arcep’s Barometer of data interconnection
[60] BoR (12) 130, section 3.2.1, p. 22, sets out the costs of peering.

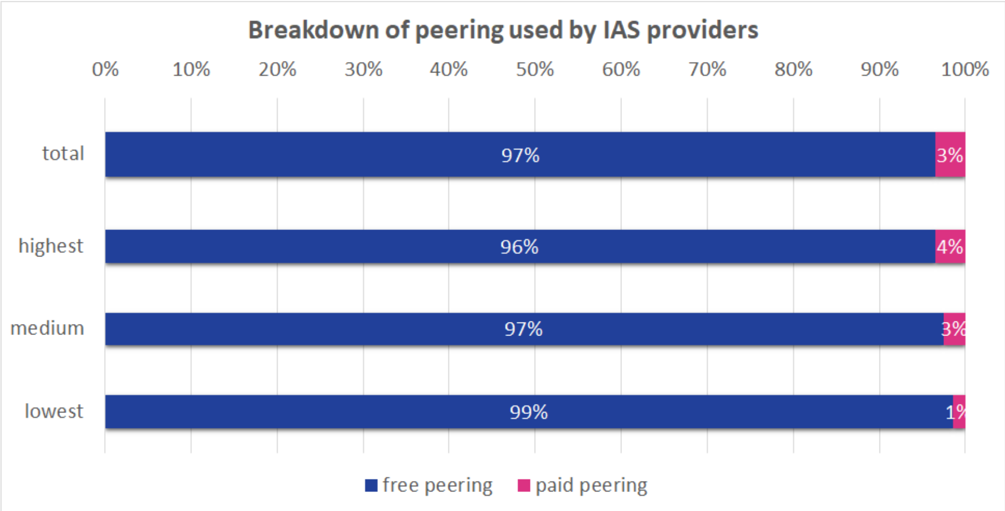

Figure 5. Breakdown of peering used by IAS providers, Source: BEREC

4.4 Infrastructure costs

It is observed that prices[61] for peering and transit relevant network elements, especially for medium sized traffic 10 GE (Gigabit Ethernet), have dropped.[62] Prices of LERs (Label Edge Router) relevant for peering, and LSRs (Label Switch Router) partially relevant for transit, have decreased with roughly a 55%-70% drop for 10 GE LERs and with a 48%-71% drop for 10 GE LSRs between 2016 and 2018.[63]

Also, it is observed that prices for equipment for multiplexer systems as ROADM-OTN (Reconfertible Optical Add-Drop Multiplexer/Optical Transport Network) have fallen between 2018 and 2020, making transportation cheaper. Between 2018 and 2020, prices for PIUs (plug-in unit) fell by 39%, prices for line cards fell by 58% and prices of repeaters dropped with 55%.

Overall, it is observed that per Gbit/s prices have continued to decline in the last years. However, not all players in the market benefit equally from reduced prices. Even though prices of equipment for smaller internet capacities have dropped relatively more in price between 2016 and 2018, this effect has ceased between 2018 and 2020. Larger players in the market are still more successful in reducing costs than smaller players, because equipment with high capacity strongly reduces prices per Gbit/s.

[61] Technological progress as well as competition induce downward pressure on infrastructure costs as well as prices.
[62] WIK (2022)
[63] WIK (2022)

4.5 Key findings related to pricing and costing developments

- Pricing and costs for IP-IC services continue to exhibit a downwards trend.
- Technological developments, such as the installation of on-net CDNs, are a key reason why increases in data traffic have not passed through to prices and costs.
- Network usage has increased, but due to continuous technological developments as well as competitive pressure, marginal network costs are observed to have declined to the point that they outweigh any increased costs associated with increased network use.

5. Market developments in IP-IC

In the 2017 IP-IC report and in the *Report on the entry of large content and application providers into the markets for electronic communications networks and services*[64], BEREC noted that large CAPs participated in different network infrastructure projects. In the present report, BEREC evaluates the respective developments since 2017, as well as the economic rationale for the CAPs to deploy their own infrastructures rather than buying these from other providers (Section 5.1).

Furthermore, BEREC looks at vertically integrated IAS providers with transit networks (Section 5.2) and assesses to what extent transit and peering are substitutes (Section 5.3).

5.1 Large CAP establishing own infrastructures

Large CAPs increasingly invest in their own infrastructure such as backbone networks (e.g. submarine cables), CDNs, data centres, hosting and cloud computing.[65] While some investments (like investments in submarine cables) could already be observed in previous years,[66] it seems that these investments gained momentum since 2018, as Figure 6 shows:

[64] BoR (24) 139
[65] For a comprehensive overview see BoR (24) 139.
[66] BoR (17) 184, section 3.3.2.

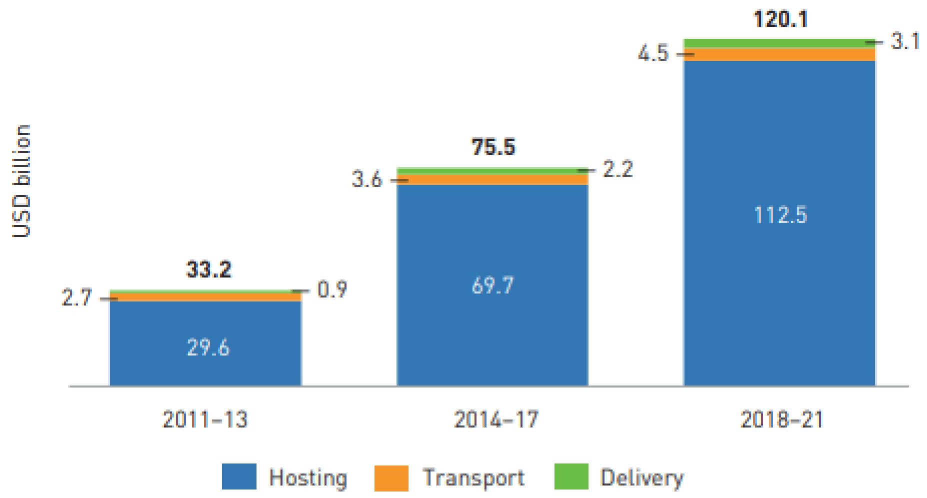

Figure 6. Average annual investments made by CAPs, Source: Analysys Mason (2022)[67]

5.1.1 Investments in transport infrastructures

Submarine fibre optic cables play a key role in maintaining a robust and high-capacity global network infrastructure. In 2023, they carried 99% of all intercontinental data traffic, including the services provided by CAPs to consumers.[68] Large CAPs increasingly have transformed from mere direct or indirect customers of wholesale capacity, to the owners and investors in transport network infrastructure. They are now even able to lease capacity on some of their cables to ECN-ECS providers.

These investments in transport infrastructure have several implications. Large CAPs reduce their dependency on “traditional” backbone providers. At the same time, this increases the competitive pressure on these transit providers as they can be bypassed. Relatedly, large CAPs increasingly interconnect directly with IAS providers. Such direct peering may also help to improve performance while at the same time providing greater control over the routing path and the performance.[69] End-users benefit in terms of quality of experience.

5.1.2 Investments in CDNs

On a global scale CDN traffic almost tripled from 2017 to 2022,[70] and it seems plausible that CDN traffic has increased since then and will continue to do so. The growth in video streaming

[67] Analysys Mason (October 2022), p. 6
[68] BoR (24) 139, section 5.1.
[69] BoR (12) 130, section 3.2.1
[70] WIK (2022), p. VIII

traffic contributed to this development. In the past, large CAPs mainly relied on specialised CDN providers which implied that traffic was exchanged either via peering or transit.

For several years now, large CAPs increasingly tend to build their own CDN infrastructures (in-house CDNs). Typically, these CAPs place their cache servers in the IAS providers' access networks (on-net CDNs).[71] This implies that there is no longer an exchange of traffic across network boundaries every time an IAS provider's customer uses content and/or applications, that is already available in the CDN, with a consequent notable reduction of the related interconnection traffic. CDNs and in particular on-net CDNs bring content closer to the user thereby providing qualitative enhancements for the end-users. They also imply savings for IAS providers as they have to buy less transit capacity.[72,73] Thus, (on-net) CDNs also exert competitive pressure on transit providers. Traffic exchanged via on-net CDNs increases more than traffic exchanged via peering and transit.[74] Figure 7 below illustrates the increasing relevance of in-house CDNs, both, vis-à-vis non-CDN traffic as well as commercial CDN traffic.

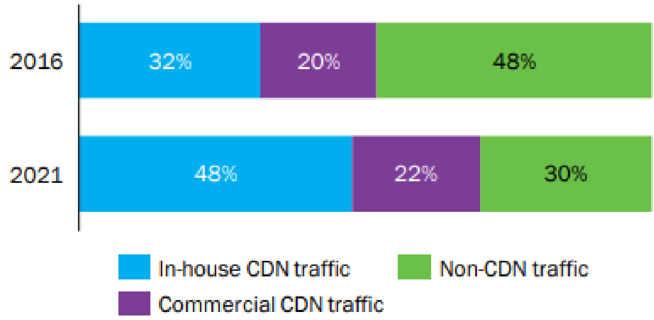

Figure 7. Internet traffic by CDN use, Source: Analysys Mason (2018)[75]

Against the background of the significant increase of traffic exchanged via on-net CDNs and given the fact that most IAS providers – with few exceptions – allow on-net CDNs, this can be interpreted as a sign of increasing cooperation in the IP-IC ecosystem.

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[71] WIK considers this shift towards on-net CDNs as the "*most dynamic development*" since 2017 whereas BEREC saw a less concentrated CDNs market with CAPs increasingly applying a multi-CDN strategy relying on several CDNs for resilience reasons (BoR (17) 184, p. 59). WIK also points out that even small and mid-sized IAS providers use on-net CDNs (WIK (2022), p. 61).

[72] In particularly larger IAS providers may also save own network costs.

[73] As BEREC already pointed out "*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*.", (BoR (17) 184, p. 8).

[74] WIK (2022), p. VII.

[75] Analysys Mason, Infrastructure Investment by Online Service Providers (December 2018) p. 5.

5.2 IAS providers vertically integrated with Tier 1 transit providers

During BEREC's workshops, different stakeholders pointed out the specificities related to the IP-IC with some large IAS providers. In particular, some companies/networks provide transit services (by means of another specific subsidiary or just through a different department within the same company) in addition to networks providing retail IAS. BEREC has also observed such specificities based on the analysis of the data collected from numerous IAS providers for the purpose of this report.

The data shows that the interconnections between such vertically integrated Tier 1 transit networks and CAPs are based on different services like internal global/partial transit as well as paid and settlement-free peering, ultimately depending on the interconnection policy employed by the vertically integrated Tier 1 transit networks. However, paid transit relationships generally appear to be more frequent. Furthermore, a vertically integrated company can coordinate its interconnection practices across its transit and retail networks.

The following figures are obtained from BEREC's data analysis by separating those IAS providers' retail networks[76] vertically integrated with Tier 1 transit networks from other IAS providers. For the latter, who are not part of a company group with a Tier 1 network, a new calculation of the categorisation (lowest, medium, highest), based on 33,3 and 66,6 percentiles of inbound traffic, is performed.[77]

Figure 8 below presents the share of the different IP-IC services, based on the inbound traffic, for each of the above-mentioned categories. For vertically integrated retail Tier 1 IAS providers, the share of bilateral peering is relatively small (9%) when compared with the same figure for the highest traffic group (48%). This smaller share (9%) is a consequence of the high usage of internal transit services (63%), i.e. via the transit network of the same company group.

Thus, while almost two thirds of the inbound traffic (63%) is accounted for by internally provided transit, IXPs (2%) and on-net CDN (24%) are used less frequently when compared to the other categories. At the same time the data shows that 88% of Tier 1 retail IAS providers have at least one on-net CDN present in their networks (not depicted in Figure 8).[78]

[76] Which can be of any size regarding the incoming traffic volume.
[77] The resulting thresholds to separate IAS providers (without Tier 1 affiliation) into lowest, medium and highest traffic categories are in this case 124 and 636 Gbit/s.
[78] The same percentage is obtained for the category of IAS providers with medium inbound traffic (not belonging to the Tier 1 company group). On the other hand, only 63% of IAS providers outside of the Tier 1 company groups with the lowest inbound traffic have at least one on-net CDN present in their networks. Of those with highest traffic, 94% of them have at least one on-net CDN present in their networks, therefore a larger share than Tier 1 retail ISPs.

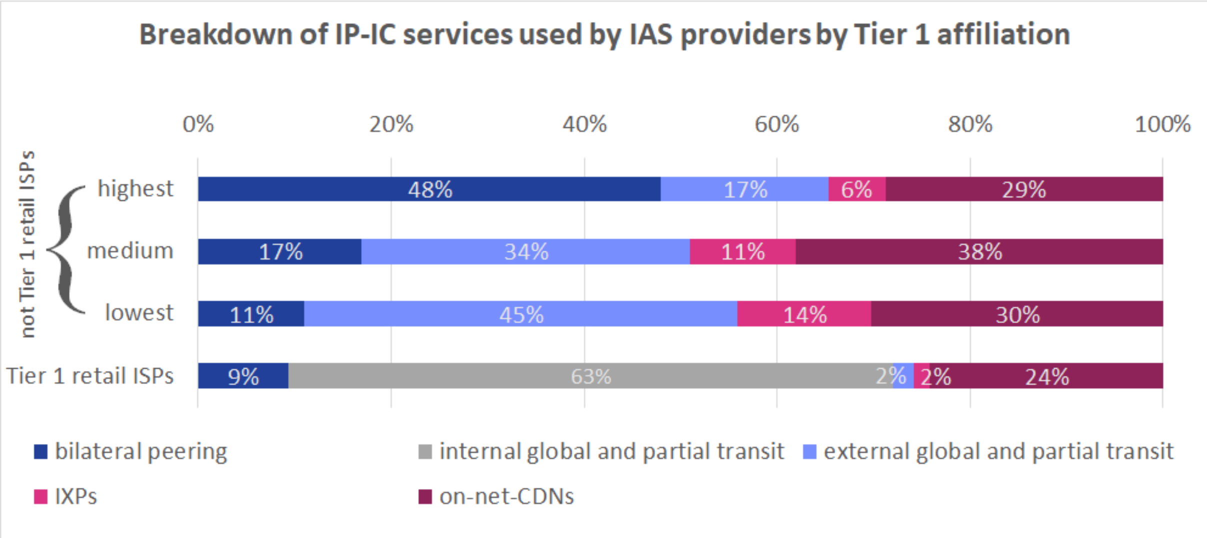

Figure 8. Breakdown of IP-IC services used by IAS providers by Tier 1 affiliation[79], Source: BEREC

The following Figure 9 shows the share of free and paid peering services from total peering services by the different groups of IAS providers.[80] Although the usage of free or paid peering or transit services by the transit network is not considered, with 11% they have a higher share of paid peering than the categories of IAS providers outside of this group (while the share of bilateral peering overall is low).

[79] For the purpose of BEREC's data analysis, "internal transit" refers to transit coming from a network of the same company group the ISP belongs to, while "external transit" is related to transit coming from another (third-party) transit provider.

[80] In this calculation, the answer "Other" is omitted.

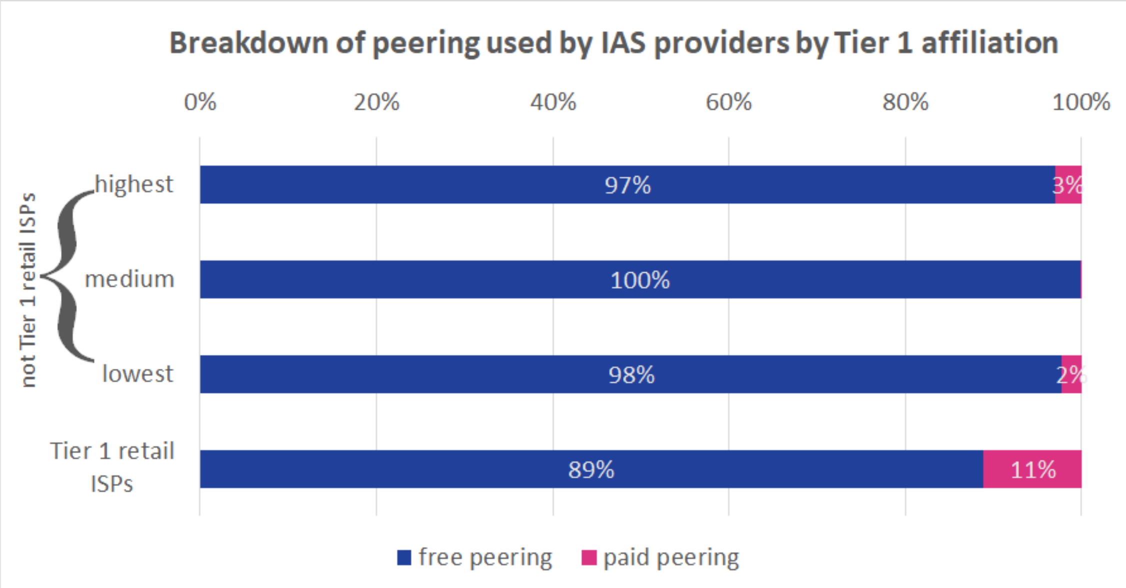

Figure 9. Breakdown of peering used by IAS providers by Tier 1 affiliation, Source: BEREC

5.3 Substitutability

In general, the availability of alternatives contributes to competition and mitigates competitive bottlenecks. In interconnection markets, the substitutability[81] can for example relate to the ability to

- switch between types of services actors use (e.g. peering, transit, on-net-CDNs, ...);
- switch between single providers (e.g. access to several transit providers);
- apply multi-homing for several services (e.g. using several transit providers at the same time);
- internalise the service by deploying their own infrastructure (see section 5.1).

Information on the structure of IP-IC (Chapter 6) and traffic developments (Chapter 3) confirm that there is generally a large range of different interconnection services for ISPs and CAPs to establish connectivity.

Even IAS providers with low inbound traffic peer directly, although to a smaller degree. As long as small ISPs have access to IXPs, on-net CDNs and transit to competitive conditions

[81] In this report, the term of "substitutability" is not to be considered as in the meaning of the review of relevant markets, as no analysis on the basis of a SSNIP (small but significant non-transitory increase in price) test has been conducted.

and (small and large) CAPs alike, the size of market players seems less important for market outcomes.

Already in 2017, BEREC stated that "*[w]hile transit is declining as a proportion of traffic it remains a very significant form of interconnection. Hence the availability and pricing of transit might be expected to constrain negotiations over the settlement basis of peering agreements. However, transit's ability to substitute for peering may be less clear in case of video streaming, where demand for capacity is very large and a high quality is required.*"[82]

Nevertheless, under certain circumstances, transit can technically be provided in such a way that it may serve as a substitute for peering.

For large French ISPs, Arcep's *Barometer of Data interconnection 2022* shows that the share of transit (in comparison to peering) continues to decline.[83] Also, WIK concludes that peering can be considered a substitute for transit because of the qualitative advantages (but transit is less of a substitute for peering).[84] Transit prices continue to decline (see Section 4.1), indicating that transit markets are highly competitive, but are also under pressure, from both peering and CDN services.

There are nevertheless limits to substitution: BEREC observes the increasing importance of latency and bandwidth in recent years, which means transit is less of a substitute to peering. For instance, video streaming or cloud services require large bandwidth or immediate interaction between the client and the server.[85] Large CAPs therefore often establish their own infrastructure, while CDN and cloud service providers prefer peering directly with ISPs (see Section 5.1). Additionally, substitution is limited if vertically integrated Tier 1 providers leverage their termination monopoly to transit.

5.4 Key findings regarding market developments in IP-IC

- BEREC observes that large CAPs' investments into backbone infrastructure continue to exert a competitive pressure on transit providers.
- At BEREC workshops, some stakeholders reported that CAPs may struggle to find alternatives to reach end-users if practices of vertically integrated IAS and transit providers leverage their termination monopoly.
- IAS providers vertically integrated with Tier 1 transit providers generally use their own transit services. In this instance, CAPs typically pay for interconnections (via peering or transit services).

[82] BoR (17) 184, p. 4
[83] Arcep, Barometer of Data Interconnection in France (June 2022)
[84] WIK (2022)
[85] BoR (17) 184, section 4.2, p. 13-14

> ➢ BEREC holds that there is limited substitutability between transit and peering when low latency and high bandwidth are required. Consequently, for qualitative reasons, certain services offered by some CAPs may be best when provided via peering connections.

6. Generic structure of IP-IC issues

Previously, in its 2017 IP-IC report, BEREC pointed to examples of IP-IC disputes in the US during 2013/2014 between CAPs (Netflix) and IAS providers (e.g. Comcast) which involved congested interconnection links. Since those days, a number of (similar) cases could be observed in Europe (see Annex I). These cases typically involved CAPs who, due to network congestion, had issues reaching the end-users of incumbent IAS providers with sufficient latency and bandwidth, which resulted in quality degradation and differentiated treatment. It seems that these incumbents try to extract additional rents from CAPs for traffic termination by offering uncongested alternative routes with sufficient capacity, in return for payments from CAPs.

These cases are in particular:[86]

- Init7 vs. Swisscom[87];
- Deutsche Forschungsnetz vs. Deutsche Telekom[88];
- Hetzner vs. Deutsche Telekom;
- [CONFIDENTIAL] vs. Deutsche Telekom;
- as well as the cases mentioned in Annex I.

Aside from the cases, BEREC's workshops revealed similar insights from different stakeholders' perspectives, which suggested this is a long-standing issue. Generally, stakeholders considered that IP-IC markets function with a high degree of cooperation between market players. However, several stakeholders pointed to IP-IC issues with certain IAS providers who are vertically integrated (i.e. not only providing IAS but also transit services). These cases were viewed as persistent exceptions to the rule.

[86] See WIK (2022) for a description of these cases.
[87] A final ruling is expected in 2024. See Annex I for further information.
[88] Monika Ermert, Deutsches Forschungsnetz und Telekom: Peeren in Zeiten von Corona, Heise.de (March 2020)

The following paragraphs display the generic structure of such IP-IC issues as mentioned by several stakeholders.[89]

Case I

In this first case, the CAP uses the services of a Tier 1 transit provider in order the reach the IAS provider's customer end-user[90,91]:

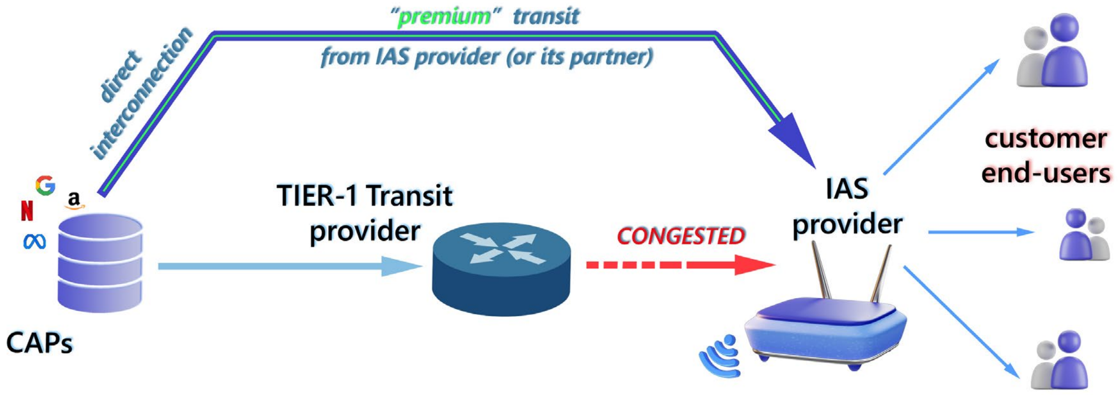

Figure 10. Generic structure of IP-IC issues: case I, Source: BEREC

Case II

In this second case, the CAP uses a third party CDN (or hosting) provider which then uses the services from a Tier 1 transit provider:

[89] It is not intended here to display in an exhaustive manner all the IP-IC issues and their variations referred to by stakeholders.
[90] This may be the case because the CAP does not have access to sufficiently advantageous peering with the given IAS provider in terms of price and/or quality, or due to the IAS provider's restrictive peering policy.
[91] It is assumed, both in case I and case II, that the IAS provider does not provide direct peering, interconnection, or on-net CDN and that the only way to reach end-users is trough transit.

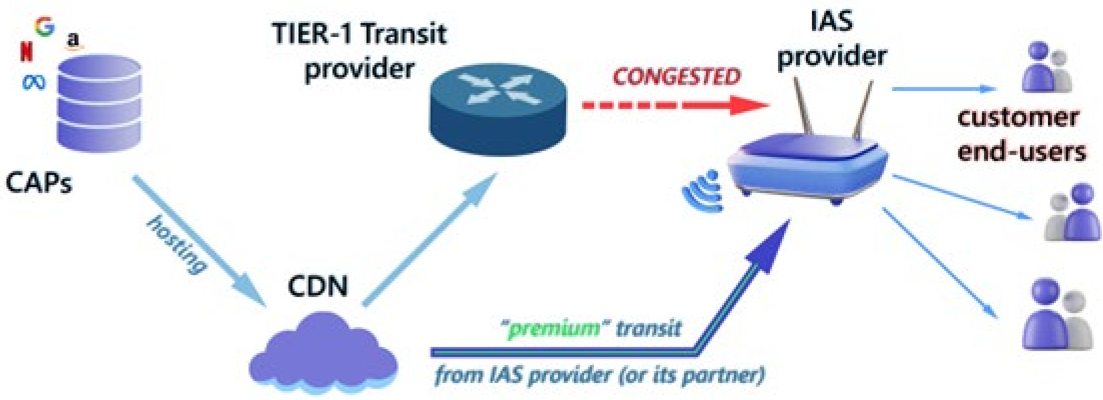

Figure 11. Generic structure of IP-IC issues: case II, Source: BEREC

Stakeholders reasoned that in these two cases the vertically integrated[92] IAS provider would let the interconnection link to the Tier 1 transit provider artificially congest.[93] This would then lead to a qualitative degradation which is experienced by this IAS provider's customer when using the services from this CAP (e.g. higher latency).

During BEREC's workshops, various stakeholders argued that the vertically integrated IAS provider would then offer a "premium transit" service to the CAP (case I) or to the CDN provider (case II).[94] Stakeholders claimed that such a "transit" service required for *de facto* traffic termination was sold at a level which is a multiple[95] of competitive transit prices, pointing out that transit charges are used to "mask" termination fees. It should be noted that, in general, transit prices saw a significant price decrease over the last two decades.[96]

Aside from the scenarios as set out above it is also conceivable that an IAS provider refuses to peer settlement-free in its home country while it may do so elsewhere. Thus, the network that wants to interconnect with the IAS provider can choose between paying for interconnection in the IAS provider's home country or interconnect without payments in another country which then adds latency ("tromboning"). Some stakeholders highlighted these practices.

[92] The IAS provider does not only provide internet access services but also transit services.
[93] During the workshops, the stakeholders also pointed out some further variants of the above-mentioned cases that they were confronted with in practice. These have in common that an IAS provider tries to enforce payment from the other market parties. For example, an IAS provider may buy transit outside its home country. If e.g. a CAP wants to interconnect locally in order to assure a better qualitative experience for the end-users, it needs to become a customer of that IAS provider.
[94] Such a "premium transit" could either be provided by the IAS provider itself for by a transit provider partner who has a partnership with this IAS provider. In both cases the CAP's Tier 1 provider – as displayed in the figure – would be "circumvented".
[95] During BEREC workshops, some stakeholders specified that prices are five times higher than competitive transit prices.
[96] See Chapter 3 of this report and BoR (17) 184, section 3.2.

BEREC holds that the costs for upgrading the interconnection links are very low.[97] This was also confirmed by several stakeholders. One could assume that, given the mutual interdependence between CAPs and IAS providers[98], it would be more efficient to simply upgrade IP-IC links as this would be mutually beneficial (see Chapter 7). Nevertheless, some stakeholders stated that it does not happen even in those cases where CAPs were willing to bear the complete costs for the upgrade. It was argued that these IAS providers would prefer to generate recurring revenues.

BEREC points out that transit services provide connectivity to the whole internet whereas in this case connectivity (via such "premium transit") is only provided to this IAS provider's customer end-users.

ACM addressed the issue of artificial congestion in a case involving a CDN provider and concluded that "*The capacity of Tier-1 peering interconnections has been (artificially) scarce in order to prevent the use of (partial) transit over these networks from becoming a substitute for direct interconnection with DT. Transit competition was limited in order to impose excessive prices for direct interconnection*".[99]

While this playbook was referred to by various stakeholders, the IAS providers rather argued that CAPs would cause congestion issues as they would intentionally route traffic via congested interconnection links.[100]

BEREC considers that such a practice is accompanied by the risk of causing unintended effects, which raises doubts that it was a viable practice in reality. Some stakeholders also pointed to this. Furthermore, BEREC holds that such a practice by CAPs would not be plausible in those instances where CAPs in the first instance were willing to bear the complete costs of upgrading the IP-IC links.

What can be derived from these issues as described above?

- Generally, the IP-IC ecosystem is driven by functioning market dynamics and by the cooperative behaviour of market players. Nevertheless, BEREC observes that some IP-IC disputes could be observed in the market since 2017. Several stakeholders also pointed out such disputes during BEREC's workshops. However, they typically did not call for (general) regulation of IP-IC markets but rather suggested monitoring markets, ensuring transparency and – in case of disputes – examining the individual case.

[97] BoR (22) 137 BEREC preliminary assessment of the underlying assumptions of payments from large CAPs to ISPs (October 2022), Chapter 3
[98] BoR (22) 137, Chapter 4
[99] WIK (2022), section 5.2.2.4
[100] BEREC had observed in 2017 that already the disputes in the US (2013/2014) involved mutual recriminations of CAPs and IAS providers about which party caused the congestion, see BoR (17) 184, Chapter 4.

BEREC considers that the low number of disputes is one – although not the only – indicator for a generally functioning market.[101]

- Basically, all these disputes involved (larger or smaller) CAPs and/or CDN providers on the one side and incumbent IAS providers on the other side. BEREC observes that customers are ultimately the ones who suffer from such disputes as they cannot access services or use content with the quality they expect. This holds in particular when one considers that safeguarding end-users' rights is an essential aim of the OIR.[102] BEREC also recalls that the European Court of Justice (ECJ), in its judgments of 2 September 2021, clarified that it understands the principle of equal treatment as a general obligation to treat all traffic equally. Thus, this principle does not only apply to technical discrimination but also to commercial practices associated with traffic management measures (see also Chapter 8).

- Such cases seem to indicate that certain IAS providers leverage their termination monopoly into the transit/peering market and introduce termination fees for IP-IC vis-à-vis CAPs.[103] Charging a "price premium" for transit is only possible if the opportunity costs for the CAP are high enough. Similarly, Analysis Mason considered the cases in its 2022 study on IP-IC as examples of the IAS provider's continuous ability to gain bargaining power on the transit and paid peering markets by exploiting their data termination monopoly.[104]

- Conceptually, such a strategic playbook plays out when there is no alternative transit provider available which has suitable, uncongested interconnection to this IAS provider, and when no other alternatives (such as direct interconnection, peering or on-net CDNs) are available.[105]

- However, BEREC notes that this is not the only situation in which such a strategic playbook is conceivable. Even if not all alternative transit routes are congested, a tight traffic ratio applied by an IAS provider as requirement for settlement-free peering could lead to a situation where (e.g.) a transit provider cannot take on additional traffic from a CAP as this may imply that this traffic ratio is exceeded and the settlement-free

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[101] Another indicator for a functioning market is e.g. the fact that the continuous decline in costs is translated into a corresponding decline in prices.

[102] See Chapter 7

[103] As regards the question whether a strategy of causing congestion could be rationale strategy for an IAS provider BEREC refers to the findings from the US. The New York Attorney General (NY AG) comments, p. 7, citing Time Warner Cable internal strategy presentation: "*[T]he short-term costs" that Spectrum-TWC incurred from the more expensive routing would therefore "eventually lead to longer-term revenue growth and cost containment.""; NY AG comments, p. 8: "Spectrum-TWC was well aware that its customers suffered significant service degradation as a result of its interconnection disputes*".

[104] Analysis Mason (September 2022), paragraph 3.2.

[105] Theoretically, it would be possible that interconnection with an IAS provider takes place at an internet exchange. However, there are certain IAS providers who do not – or only with a very limited capacity – interconnect at public IX thereby foreclosing this way out. Also, in issues involving congested interconnection links as observed by different stakeholders, CAPs would not have the option of placing their servers in the IAS provider's access network.

relation turns into a paid relationship with the IAS provider. If the transit provider still takes on that traffic, it may then pass on cost charged by the IAS provider to his customers (i.e. CAPs). In that specific case, the availability of uncongested transit would not prevent the IAS providers exploiting their termination monopoly.

- Some IAS providers claim that routing decisions would be solely taken by CAPs over which IAS providers would have no influence. BEREC does not agree with this view. IAS providers have full control over their own network (Autonomous System), they operate and thus determine which interconnection interfaces are used to exchange traffic with specific destinations. Typically, ISPs set up different interconnections and announce their network to the routes from which they want to receive traffic bearing in mind in particular reachability, capacity and performance considerations. ISPs can implement alternative routes or upgrade existing interconnections, and thus improve the performance of delivery of specific applications to end-users. These actions may be taken by the ISP following concertation with CAPs.

- This chapter sets out in a generic way the generic structure of IP-IC issues without judging whether in individual cases any such strategies are actually used. However, regarding the question whether such cases are possible, BEREC refers to findings from the US.[106]

- Several stakeholders pointed out that providers could be hesitant to speak out publicly on such issues as they are afraid of "retaliation" by IAS providers. BEREC also observes that different stakeholders, independently from each other, referred to – basically the same – strategic behaviour by certain IAS providers. Furthermore, BEREC notes that, while non-disclosure agreements as such are not unusual in markets, they make it more difficult to identify if such practices are applied.

> - BEREC considers that the IP-IC ecosystem is driven by functioning market dynamics and by the cooperative behaviour of market players. Despite this, BEREC is aware that some IP-IC disputes have occurred since 2017 and this was also raised by several stakeholders in BEREC's workshops.
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> - BEREC notes that stakeholders typically did not call for regulation but suggested monitoring and a case-by-case assessment.

[106] NY State 2017 Open Internet Comments, p. 1: "*These investigations have uncovered documentary evidence revealing – for the first time – that from at least 2013 to 2015, major [internet access] providers made the deliberate business decision to let their networks' interconnection points become congested with Internet traffic and used that congestion as leverage to extract payments from backbone providers and edge providers [i.e. providers of internet content, applications, and services], despite knowing that this practice lowered the quality of their customers' Internet service.*
This practice was not limited to a single instance or locality: NYOAG has found that this practice was used for years by at least two of the country's biggest [internet access] providers who operate in New York and in many other states".

> ➢ According to BEREC's stakeholder workshops, most disputes stem from vertically integrated IAS providers attempting to leverage their termination monopoly into the transit/peering market and to introduce (higher) fees for IP-IC directly from CAPs.

7. Bargaining situation (in particular) between CAPs and IAS providers

In order to assess whether there are problems in the IP-IC markets that might require regulatory actions, it is first important to address the underlying issue of the relative bargaining power between CAPs (must have content) and IAS providers (termination monopoly). Several questions arise: Do IAS providers let IP-IC links congest or can CAPs "cause" such issues (e.g. by intentionally buying transit from a backbone provider who has a "bad" peering with the eyeball ISP)? Under what conditions would this be a viable practice for these parties? How can it be explained that some IAS providers can charge transit providers prices which are significantly higher than market prices?[107]

Within the current market set-up, some IAS providers argue that CAPs choose not to enter negotiations for interconnection. Is this a reflection of greater 'bargaining power' or are there other reasons (e.g. Net Neutrality prevents IAS providers from taking action if CAPs decline requests, CAPs have alternative traffic routing opportunities)? Bargaining may refer to more than negotiations regarding financial transfers. IAS providers and CAPs have an incentive to provide internet service and content to their customers at the highest possible quality of service and quality of experience. These converging incentives have led to cooperative agreements, for example CAPs paying to install CDNs in IAS providers' networks. These agreements have positive outcomes for both parties, and their customers, and may suggest that bargaining is possible if incentives are converging.[108]

Bargaining power is relative and may not be permanent – e.g. the market environment for large CAPs has changed a lot in 2022 (rising interest rates, stock prices falling). BEREC considers that there is a mutual interdependence between CAPs and IAS providers.[109] The demand from IAS providers' customers for content drives demand for broadband access and the availability of broadband access drives demand for content. Given this mutual interdependence, it seems plausible to assume *prima facie* that overall there is a balance in the IP-IC bargaining relation between CAPs and IAS providers.

[107] Already in 2017, BEREC raised similar questions (such as possibility to exploit the termination monopoly, countervailing bargaining power, switching barriers for customers), (BoR (17) 184, section 4.2.).

[108] The 2022 WIK study shows that in many cases the relation between IAS providers and CAPs became more cooperative. This is particularly due the development of on-net CDNs with require a high degree of coordination between the parties involved. See WIK (2022), inter alia sections 5.3.1 and 5.3.3.

[109] BoR (22) 137, p. 10-11

Already in 2012 and 2017, BEREC had identified that the IP-IC ecosystem is largely driven by competitive forces. The markets developed very well without regulatory intervention. IP-IC disputes were typically solved in the market. And the IP-IC ecosystem managed to adapt IP-IC arrangements reflecting changes in technology, relative market power, demand patterns and business models. These broad lines seem to be generally intact today. The 2022 WIK study supports this evidence. WIK's survey of NRAs also confirmed that there have only been a few cases of NRA intervention into the contractual freedom of market players.[110] The few incidents of regulatory intervention support the view that the bargaining relationship between market players is broadly in balance.

The following paragraphs identify some of the factors that impact on the relative bargaining power. Based on this, one may make general statements (*ceteris paribus*) how the relative market power may shift between market players.

The relative bargaining situation is inter alia affected by the degree of substitutability between transit and peering (see Section 5.3). The bargaining power of an IAS provider is balanced by the extent to which it is a viable option for a CAP to use transit if the IAS provider declines to peer on a settlement-free basis.[111] Other developments may shift the relative bargaining power towards the IAS providers. Streaming has become a mass market product in the last decade. The take-up of cloud services also grew significantly during that period. In case of these services, CAPs may instead choose peering services for qualitative reasons. Thus, in these cases transit might not be a substitute for (direct) peering. This leads to a relative shift in bargaining power towards IAS providers in these cases.

Another aspect that impacts on the relative bargaining power (in particular) between smaller and larger CAPs follows on from the different cost structures between transit and peering (see Chapter 4). These differences then translate into different economies of scale for providers of different size.

Transit typically implies variable costs per Mbit/s whereas peering involves fixed costs, thereby leading to degressive costs per Mbit/s.[112] Generally, it follows that smaller CAPs (i.e. with lower traffic volumes) would rather use transit as they do not exhibit the economies of scale necessary to incur the fixed costs of peering. However, the higher the traffic volumes of a CAP the more (direct) peering becomes an economically viable option.[113] Similarly, smaller CAPs may lack the economies of scale allowing them to place cache servers (on-net CDNs) in access networks. These different cost structures lead to a relative bargaining disadvantage for smaller CAPs compared to larger CAPs when trying to peer directly with an IAS provider

[110] WIK (2022), p. 67

[111] This is reflected in BEREC's conclusion that the availability and pricing of transit might be expected to constrain negotiations over the settlement basis of peering agreements, see BoR (17) 184, section 7, conclusion h.

[112] BoR (12) 130, sections 3.1 and 3.2., and also WIK (2022), section 1.2.5.

[113] And with higher traffic volumes it may pay off for a CAP to invest in own backbones.

(of a given size).[114,115,116] It should be noted however, that it is not only these different cost structures that have an impact on the CAPs' decision but also qualitative considerations (see above) as well as network planning aspects[117]. Moreover, the following related arguments also support the argument that smaller CAPs have a relative disadvantage compared to large CAPs when bargaining with IAS providers: a) a smaller CAP would face (relatively) higher transaction costs, b) it may less likely avail of "must have" content and c) it may be more difficult for a smaller CAP to enter into a commercial partnership on its services.[118]

The aforementioned relative disadvantages of small CAPs related to cost structures and economies of scale explain why, for smaller CAPs transit services, IXPs[119] as well usage of commercial CDN providers play a relatively greater role than for large CAPs. All these options can be interpreted as allowing smaller CAPs to benefit from the economies of scale of transit, IXP and commercial CDN providers.

In the IP-IC disputes in the US in 2013/2014, Netflix ultimately signed a *paid* peering agreement with the IAS providers.[120] This indicates that availing of "must have" content or a high market capitalisation does not automatically imply that large CAPs have higher bargaining power vis-à-vis IAS providers. The relative bargaining power of an IAS provider (inter alia) increases with the number of its end-users. The relevance of this factor impacting both, on the relative bargaining situation and the ability to request peering/termination payments is also stressed by the FCC.[121,122] Even the largest CAPs may have no choice but to interconnect with an IAS provider with a significant number of end-users on their network, because CAPs require access to these end-users. This, *ceteris paribus*, increases the likelihood that the CAP finally enters into a paid peering arrangement with the IAS providers. At the same time, this means that a "very large" IAS provider has a relative competitive edge relative to an IAS

[114] See also BoR (23) 131d BEREC response to the European Commission's Exploratory Consultation on the future of the electronic communications sector and its infrastructure – Annex to complement section 4 of the BEREC response (May 2023), p. 8.

[115] BEREC notes that this could also mean that small CAPs would actually pay more per bit in case a direct peering is agreed upon.

[116] BEREC points out that the relative bargaining disadvantage does not only relate to smaller CAPs vs. large CAPs, but also for e.g. small vs. large CDNs or small vs. large hosting providers when negotiating with ISPs.

[117] BoR (12) 130: "*The decision whether to peer or to buy transit is a matter of network planning and cost optimization, as transit causes costs for conveying traffic but saves CAPEX investments in one's own network infrastructure and hence saves operating costs while simultaneously assuring an appropriate performance level.*", p.23.

[118] BoR (23) 131d, section 4.1, p. 8.

[119] WIK points out that for large CAPs as well as IAS providers IXPs increasingly serve as backup- or resilience providers, (WIK (2022), p. XII).

[120] See BoR (12) 130, section 4.1 and WIK (2022), section 5.3.3. for a brief description of these disputes.

[121] The FCC stated: "*Our economic analysis suggests that the ability of a BIAS provider to charge for access to subscribers increases with the number of subscribers; the greater the number of subscribers, the more the BIAS provider can charge on a per-subscriber basis*", (FCC, 2016, Charter/TWC Merger Order, paragraph 115).

[122] The FCC observed "*The success of a BIAS provider charging paid peering depends on the two factors: the number of subscribers (or "eyeballs") that the BIAS provider serves (and thus the portion of an edge provider's business that those BIAS subscribers represent) and the BIAS providers' control over interconnection capacity into its network.*" (FCC, 2016, Charter/TWC Merger Order, paragraph 100); (the notion of "BIAS" stands for "broadband Internet access service").

provider with a smaller number of end-users. Against this background and given the mutual interdependence between CAPs and IAS providers it seems unlikely that a small IAS provider would be able to enforce termination rates vis-à-vis CAPs.

Furthermore, given the relative bargaining position of large IAS providers compared to small IAS providers, and *assuming* that large CAPs could actually exploit their bargaining position and strategically route traffic vis-à-vis large ISPs, then BEREC would assume that this would happen even more vis-à-vis smaller ISPs. However, BEREC is not aware that this is the case in practice.

The disputes mentioned above involved larger providers, both on the CAPs' side as well as on the side of the IAS providers. While smaller CAPs may have a relative bargaining disadvantage compared to larger CAPs as illustrated above, WIK doubts that smaller CAPs would have been affected by similar restrictions from the IAS providers[123]. At first sight, this might seem plausible given that small CAPs maybe less likely have "must have" content, BEREC points out that small CAPs might be affected. Assuming these small CAPs use services from e.g. CDNs or transit providers who have to pay high termination fees towards an IAS provider, then these costs could be passed-on to the small CAPs (as otherwise CDN or transit provider would have no incentive to provide a service for this CAP.)

In principle, both customers of CAPs as well as customers of IAS providers could switch if they experience a bad quality. However, BEREC doubts that IAS providers' customers will switch to such an extent that it limits IAS providers' relative bargaining position. Firstly, switching involves transaction costs[124] (time, technical feasibility). Secondly, discussion in Internet forums show that many users do not know the source of the problem (in particular if only certain applications are affected) or they are referred to blog posts basically arguing that CAPs had caused the issues.[125] Thirdly, Ofcom has shown that switching rates are low[126] and

[123] "*In this context, however, it is questionable whether smaller CAPs, whose share of traffic at peak times is relatively small, could also be affected by comparable restrictions*", (WIK (2022), section 5.3.3., p. 79).

[124] The FCC concluded: *""[W]e find that broadband Internet access providers have the ability to use terms of interconnection to disadvantage edge providers and that consumers' ability to respond to unjust or unreasonable broadband provider practices are limited by switching costs.*", (FCC 2015, AT&T/DirecTV Merger Order, paragraph. 217).

[125] Deutsche Telekom blog post often referenced to by Deutsche Telekom as response to customer complaints in its forum.

[126] Nicole Chan, Why consumers are not switching their broadband and mobile providers? (15 February 2024), "*The switching rates for both broadband and mobile, 15% and 10% respectively for 2023, are relatively low compared to other utilities (20% for electricity and 18% for gas in 2020 before prices reached the Energy price cap and removed any financial incentive to switch providers). … the switching rates are low due to consumers facing a range of barriers including confusing switching processes, bundling, loyalty to their current provider and general concerns such as service downtime and mistakes made when switching.*"

similar evidence is provided by the Federal Communications Commission (FCC).[127,128] Its findings are also supported by an econometric analysis.[129]

Aside from the above-mentioned points BEREC highlights that even in the example where a CAP could choose between different routes (e.g. if different transit providers are available), due to the nature of the termination monopoly there is typically only one route to reach the IAS providers' end-users.[130]

- BEREC considers that, on a general level, the IP-IC bargaining situation between market players seems balanced. BEREC also notes that smaller players typically bear higher relative costs which may affect their bargaining position.
- BEREC notes that relative bargaining power may change over time.
- Several factors impact on the relative bargaining power between providers such as the degree of substitutability between transit and peering, the cost structure of transit and peering, economies of scale as well as market and technological developments.

8. Relationship between IP-IC and OIR

At its core, the OIR provides (in Article 3(1)) a guarantee of open internet access for end-users in the sense that the latter are all entitled to *access*, via their IAS, to all content, applications and services as well as to *supply and distribute* them without restrictions (insofar as said content, applications, and services are lawful). As clarified by case law, "end-users" include businesses because they rely on an IAS to reach their customers[131].

To ensure the effectiveness of the aforementioned end-user rights, the OIR lays down specific guarantees with corresponding obligations for IAS providers. Most notably:

- Agreements between ISPs and end-users on commercial and technical conditions and the characteristics of IASs (such as price, data volumes or speed), as well as any

[127] The FCC also stated that "*(…) The available evidence suggests that consumers, possibly for a combination of these aforementioned reasons, do not switch BIAS providers when confronted with poor edge provider performance. (…)*" (FCC 2016, Charter/Time Warner Cable Merger Order, paragraph 111).
[128] The FCC explained that *"(…) the evidence suggests that any subscriber departures, if they occur, would be minimal.*" (FCC 2016, Charter/Time Warner Cable Merger Order, paragraph 112).
[129] This econometric analysis assessed Comcast's churn rates. It turned out that in "competitive" regions, where this ISP competed with other ISPs, there was no significant increase in customers switching – when they experienced a degraded quality – compared with "non-competitive areas" (Sappington, Dish Comcast Merger Reply, pp. 159-161 of the pdf, paragraphs 21-23).
[130] As regards the issue **"**control over how traffic is routed**"** see Chapter 6 above.
[131] See Joined Cases C-807/18 and C-39/19, *Telenor Magyarország Zrt.*, ECLI:EU:C:2020:154, paragraphs 36-39.

commercial practices conducted by ISPs cannot limit the exercise of those end-users, i.e. materially reduce end-users' choice (Article 3(2)).

- ISPs have a general obligation of equal treatment in relation to the traffic they manage when providing an IAS (Article 3(3)). This obligation precludes, in particular, the blocking, throttling, alteration, restriction, degradation or interference with specific content, applications or services or specific categories thereof, as well as any discrimination between them. "Reasonable traffic management measures" (as specified under Article 3(3) second subparagraph) and the exhaustively listed situations (of Article 3(3) third subparagraph) where "unreasonable" traffic management are nevertheless optimised.

- Specialised services (i.e. "*services other than internet access services which are optimised for specific content, applications or services, or a combination thereof, where the optimisation is necessary in order to meet requirements of the content, applications or services for a specific level of quality*") can be freely provided, including by ISPs, under specific conditions (Article 3(5)).

As the above points suggest, the OIR focuses solely on the provision of *IASs* to end-users[132]. Still, BEREC has clarified 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 Article 3(1). For example, this may be relevant in some cases, such as if the interconnection is implemented in a way which seeks to circumvent the Regulation*"[133].

The basis for this position is two-fold. First, the OIR was clearly intended to "*promote the ability of end-users to access and distribute information or run applications and services of their choice*" [134] in a way that is consistent with the internet as "*an open platform for innovation with low access barriers*"[135]. An open internet, in other words, was always meant to be the primary objective[136]. Its effectivity and, thereby, the effectiveness of the OIR, would thus easily be compromised if IP-IC were completely irrelevant. Second, and relatedly, the OIR itself, specifically and repeatedly, calls upon competent authorities to be wary of attempts to "*circumvent provisions of this Regulation safeguarding open internet access".*[137]

In any event, pursuant to Article 2(2) of the OIR, an IAS is defined as "*provid[ing] access to the internet, and thereby connectivity to virtually all end points of the internet*". Yet, in practice, this implies that all IAS providers must, not only be somehow interconnected with one another,

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[132] BoR (17) 184, p. 6; BoR (22) 81, paragraph 50
[133] BoR (22) 81, paragraph 6
[134] OIR, Recital 3.
[135] OIR, Recital 3. See also Opinion of Advocate General Sànchez-Bordona in Joined Cases C-807/18 and C-39/19, *Telenor Magyarország Zrt*., ECLI:EU:C:2020:154, paragraphs 26-30.
[136] See Joined Cases C-807/18 and C-39/19, *Telenor Magyarország Zrt*., ECLI:EU:C:2020:708, paragraph 27 and the reference therein to paragraphs 27-29 of Advocate General Sànchez-Bordona's Opinion (Joined Cases C-807/18 and C-39/19, *Telenor Magyarország Zrt*., ECLI:EU:C:2020:154).
[137] See OIR, Recitals 7, 16 and 17.

but also that they interconnect in a way that ensures that they, individually, do "*not restrict connectivity to any accessible end-points of the internet"*[138]. In that sense, the behaviour of the IAS provider in the IP-IC ecosystem is covered by the OIR.

Given the foregoing considerations, it follows that practices such as those discussed in Chapter 6 can constitute OIR violations. For instance, selective routing policies and/or artificially manufactured scarcity (e.g. by abstaining from upgrading capacity on congested routes and/or by reducing or limiting the number of interconnections) may, in a given case, ultimately degrade the quality of the IAS experienced by end-users in an application-specific manner. In a technical sense, data packets might not be differentiated within the ISP's network, which is a key concern the OIR seeks to address[139]. However, practices implemented upstream may both be based on identical incentives and result in identical outcomes. Accordingly, ensuring the effectiveness of the OIR requires that competent authorities are empowered to intervene in these types of situations as well. Such a finding would require a case specific examination of all the circumstances within which a contentious practice related to IP-IC takes place, in particular its objective purpose and the legal and economic context of which it is part.

- The OIR, which aims to ensure an open internet, provides rules to this effect for the part of the internet value chain for which the IAS provider is responsible. The latter, therefore, is the addressee of the corresponding obligations laid down in the OIR, notably Article 3.
- Ensuring the effectiveness of the OIR necessarily entails a responsibility for IAS providers to abstain from any conduct that has the object and/or the effect of compromising the provision of an open IAS for end-users, including conduct that is technically implemented at the interface between the access network and other connected networks.
- Finding that the OIR has been infringed, specifically through circumventing conduct deployed in the context of IP-IC, requires a case specific examination. To this end, the relevant NRA should consider all of the circumstances within which the contentious practice takes place, notably its objective purpose and the legal and economic context of which it is a part.

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[138] See in this sense OIR, Recital 4.

[139] See European Commission, Roaming charges and open Internet: questions and answers MEMO/15/5275 (June 2015), ("*Will there be paid prioritisation services in the open internet? No. Under the legislation, paid prioritisation in the open internet will be banned – in fact, discrimination will be prohibited irrespective of whether or not it is in return for payment. Any traffic management must be based on objective technical requirements rather than on commercial considerations, and must treat equivalent types of traffic equally. Based on this new legislation, all content and application providers will have guaranteed access to end-users in the open internet. This access will not be dependent on the wishes or particular commercial interest of internet service providers. These providers will not be able to block or throttle traffic in their networks or give priority to some particular content or services in exchange for payment. At the same time, end-users and providers of internet access will continue being able to agree on different access speeds and data volumes as they do today*").

9. Conclusions

In its 2017 IP-IC report, BEREC described the developments in the IP-IC markets since 2012 as “evolution rather than revolution”. Now, a few years later, BEREC confirms that this observation still holds true.

Traffic volumes continue to increase, however, growth rates are currently stabilising. At the same time, competition and technological progress exert downward pressure on costs, which then feed through to prices (e.g. for transit or CDN services). In light of these developments and of the analysis carried out, BEREC reiterates that since its creation, the internet has managed to cope with traffic growth and more accentuated peak traffic, both of which reflect changing usage patterns as well as increasing diffusion of IAS throughout societies.[140] BEREC considers that, due to the above-mentioned progress, there is currently no indication that this is likely to change in the future.

The IP-IC ecosystem continues to evolve. It does not only reflect changing usage patterns as well as technological changes, but also economies of scale, thereby reinforcing the trend towards infrastructure investment by large CAPs. Since 2017, the usage of on-net CDNs but also of bilateral peering has accelerated. Thus, BEREC’s finding from its previous reports that “traditional” transit providers are therefore under competitive pressure still applies.

For quality reasons, peering may serve as a substitute for transit. However, to the extent that vertically integrated Tier 1 IAS providers use their own transit services, this reduces the ability to substitute transit with peering. Therefore, BEREC also confirms its previous finding from 2017 that “*the availability and pricing of transit might be expected to constrain negotiations over the settlement basis of peering agreements*”.[141]

Generally, the IP-IC ecosystem is still driven by competitive forces which are functioning without regulatory intervention.[142] Despite this, BEREC is aware that there are a few IP-IC disputes that have occurred since 2017, and BEREC’s workshops also revealed similar insights. Market players – CAPs, CDN providers etc. on the one hand and IAS providers on the other – hold each other responsible for causing such issues. BEREC will follow up on such issues[143], while also considering the relationship between IP-IC and the OIR, as analysed in

[140] See BoR (17) 184, e.g. p. 4.
[141] See BoR (17) 184, Chapter 7, conclusion h).
[142] See BoR (17) 184, Chapter 7, conclusion i).
[143] For instance, this may involve monitoring by means of data collection exercises.

this report.[144] This is important, as otherwise end-user customers would ultimately suffer from disputes between different market players across the internet value chain.

In this report, BEREC has provided an overview of developments in the IP-IC ecosystem over the past seven years. More specifically, BEREC has identified the following points:

Traffic developments

1) According to recent studies, the data traffic growth is a confirmed trend with a stabilisation after a major spike during the COVID-19 pandemic. The peak-to-average traffic ratio appears to be stable between 2019 and 2023.

2) According to BEREC's analysis, on-net CDNs are installed in the vast majority of the respondent IAS providers' networks.

3) It is foreseeable that in the coming years, the increasing diffusion of UHD video content could further contribute to the growth of data traffic, as well as a higher consumption of live-streaming content could potentially have an impact on peak traffic and on the peak-to-average traffic ratio. In this context, the deployment of on-net CDNs and more efficient compression techniques are expected to offset the overall impact of these developments.

Pricing and costing developments

4) Pricing and costs for IP-IC services continue to exhibit a downwards trend.

5) Technological developments, such as the installation of on-net CDNs, are a key reason why increases in data traffic have not passed through to prices and costs.

6) Network usage has increased, but due to continuous technological developments as well as competitive pressure, marginal network costs are observed to have declined to the point that they outweigh any increased costs associated with increased network use.

Market developments in IP-IC

7) BEREC observes that large CAPs' investments into backbone infrastructure continue to exert a competitive pressure on transit providers.

8) At BEREC workshops, some stakeholders reported that CAPs may struggle to find alternatives to reach end-users if practices of vertically integrated IAS and transit providers leverage their termination monopoly.

[144] BEREC notes that other tools like NRA data collection powers and competition law might be applied. Aside from that, NRAs would have to assess on a case-by-case basis whether Art. 26 EECC might be applicable in case of IP-IC issues.

9) IAS providers vertically integrated with Tier 1 transit providers generally use their own transit services. In this instance, CAPs typically pay for interconnections (via peering or transit services).

10) BEREC holds that there is limited substitutability between transit and peering when low latency and high bandwidth are required. Consequently, for qualitative reasons, certain services offered by some CAPs may be best when provided via peering connections.

Generic structure of IP-IC issues

11) BEREC considers that the IP-IC ecosystem is driven by functioning market dynamics and by the cooperative behaviour of market players. Despite this, BEREC is aware that some IP-IC disputes have occurred since 2017 and this was also raised by several stakeholders in BEREC's workshops.

12) BEREC notes that stakeholders typically did not call for regulation but suggested monitoring and a case-by-case assessment.

13) According to BEREC's stakeholder workshops, most disputes stem from vertically integrated IAS providers attempting to leverage their termination monopoly into the transit/peering market and to introduce (higher) fees for IP-IC directly from CAPs.

Bargaining situation (in particular) between CAPs and IAS providers

14) BEREC considers that, on a general level, the IP-IC bargaining situation between market players seems balanced. BEREC also notes that smaller players typically bear higher relative costs which may affect their bargaining position.

15) BEREC notes that relative bargaining power may change over time.

16) Several factors impact on the relative bargaining power between providers such as the degree of substitutability between transit and peering, the cost structure of transit and peering, economies of scale as well as market and technological developments.

Relationship between IP-IC and OIR

17) The OIR, which aims to ensure an open internet, provides rules to this effect for the part of the internet value chain for which the IAS provider is responsible. The latter, therefore, is the addressee of the corresponding obligations laid down in the OIR, notably article 3.

18) Ensuring the effectiveness of the OIR necessarily entails a responsibility for IAS providers to abstain from any conduct that has the object and/or the effect of compromising the provision of an open IAS for end-users, including conduct that is technically implemented at the interface between the access network and other connected networks.

19) Finding that the OIR has been infringed, specifically through circumventing conduct deployed in the context of IP-IC, requires a case specific examination. To this end, the relevant NRA should consider all of the circumstances within which the contentious practice takes place, notably its objective purpose and the legal and economic context of which it is a part.

Annex I: Country cases related to IP-IC

A. Switzerland: Init7 vs. Swisscom

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 condition for settlement-free peering by Swisscom. Init7, which greatly exceeded this maximum traffic exchange ratio at that time, rejected an agreement that would lead to payments for exceeding traffic limits. 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-IC markets in cooperation with the Swiss competition authority (ComCo).

During this market investigation, the Swiss competition authority ComCo found indications of an unlawful IP-IC agreement, between Swisscom and its main transit provider Deutsche Telekom AG, affecting competition. In 2015, ComCo 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 lead to restricted competition through collusion on prices, volumes and geographic markets. However, since the involved parties agreed to adjust the contract and to delete the problematic clauses, in addition to the fact that the involved revenues were modest, the competition authority closed at the end of 2016 the preliminary competition law procedure and did not open a formal investigation, which would be a precondition for imposing sanctions.

The Swiss NRA ComCom suspended its ongoing sector-specific regulatory procedure Init7 against Swisscom during the related investigation by the competition authority. Resuming the case in 2017, ComCom rejected in 2018 the request to regulate Swisscom's peering conditions.[145] ComCom concluded, that there were sufficient substitutes for direct interconnection with Swisscom. According to ComCom, there were adequate disciplinary effects to prevent Swisscom from behaving independently from competitors. Therefore, ComCom did not find sufficient indications of a dominant position on the market.

This decision by the NRA was overruled by the Federal Administrative Court (FAC) in 2020. As a last resort, the FAC ruled that Swisscom must be considered as having a dominant position on the market for IP access to the Swisscom's end-users for the period during which the agreement between Swisscom and Deutsche Telekom was in force (2013-2015). For the period after the termination of the agreement in question, Swisscom's market position remains

[145] See e.g. DPC/RPW 2022/2, Gutachten: Interconnect Peering, p. 545.

unclear, according to the FAC. Consequently, pursuant to the Swiss Telecommunications Act, the FAC instructed ComCom to set cost-oriented prices with Swisscom for the peering requested by the complainant for the period from 2013 to 2015 (ex-post procedure). In addition, the FAC instructed ComCom to examine the market conditions and the position of Swisscom in the market from 2016 onwards, in collaboration with the competition authority. These decisions by the NRA are still pending.

B. Germany: Telekom Deutschland vs. Meta

Telekom Deutschland GmbH (Telekom) has filed a lawsuit against CAP Meta Inc. (ex Facebook) subsidiary Edge Network Services (Meta) regarding the settlement of fees for the transport of data.[146] According to Telekom, the transit fees in question relating to IP traffic from Ireland were covered by Meta in the past. The dispute appears to have occurred some years ago when Telekom started charging transit fees for data termination, which Meta found excessive.

The Cologne Regional Court has fully upheld the civil lawsuit brought by Telekom against Meta. The contract for IP data transport agreed between the parties was not effectively terminated by Meta, meaning that Telekom is entitled to payment of 20.737.608 EUR due to non-payment. Meta has refused the service remuneration since 1st March 2021, but has continued to send data via Telekom's private interconnects without restriction. According to Meta, there was no longer a contract and therefore no contractual basis for Telekom's claim.[147] The Cologne Regional Court ruled that Meta implicitly concluded an agreement with Telekom by continuing to use its services.

The contract was also not void under antitrust law. Although Telekom was granted a full monopoly on the market, Telekom's market power was countered by Meta's countervailing power, which ruled out an abuse of market power. In the present constellation, Meta is dependent on the connectivity guaranteed by Telekom, but at the same time Telekom benefits from the appreciation of the customers, who can perceive and use the content quickly and in high quality. This mutual dependency means that Meta can sufficiently use its negotiating power against Telekom.[148]

On 25 September 2024, both companies published a press release[149]. While both sides point out that traffic is now routed via a transit provider, they reproach each other arguing that the other side has overwhelming bargaining respectively market power.

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[146] Matthew Newman, Facebook sued by Deutsche Telekom over Internet connection fee in Germany, MLex.com (17 May 2022)
[147] Achim Sawall, Telekom verklagt Meta auf Zahlungen für IP-Datentransport, Golem.de (5 December 2022)
[148] Regional Court Cologne, Decision of 12.03.2024, 33 O 178/23
[149] Deutsche Telekom, Meta is not above the law (25 September 2024);
Meta, Why We're Having to End Our Direct Peering Relationship With Deutsche Telekom (25 September 2024)

As of 20 November 2024, BNetzA has no indications that there are problems.

C. Italy: DAZN live-streaming case

In March 2021, the live-streaming service DAZN was awarded Serie A broadcasting rights for 2021-2024. As a result, starting from season 2021/22, all Serie A football matches have been distributed over the internet. The transition from traditional satellite distribution to an internet-based service introduced unprecedented challenges in the Italian telecom market, as live football was a potential "killer application" for the development of network infrastructure and for the take-up of VHCN-based services.

In this context, several operators have requested AGCOM to intervene to facilitate cooperation with DAZN. The aim was also to prevent possible congestion issues due to the high data traffic related to DAZN streaming. As a matter of fact, top matches are usually followed by millions of users, all accessing the same content at the same time, thus causing extraordinary traffic peaks in IAS providers' networks.

Following these events, in July 2021 AGCOM adopted the Decision 206/21/CONS ("Atto di indirizzo"), asking DAZN, *inter alia*, to provide and install caches of its own CDN (DAZN Edge) in the network of the main Other Authorised Operators (OAOs), in order to (i) prevent congestion issues; (ii) guarantee a better Quality of Service (QoS); and (iii) guarantee technical and economical sustainability of live-streaming traffic growth. The Decision also stated that the number of CDN caches has to be proportionate with the operators' market share.

From a legal perspective, it is worth noting that article 72 (1) of the new Italian Electronic Communications Code (Legislative Decree no. 207/2021), which transpose Article 61 (1) of the EECC, states that AGCOM *"encourages and, in case, guarantees (…) an adequate access, an adequate interconnection and interoperability of services, applying its competencies so as to promote efficiency, sustainable competition, development of VHCN networks, efficient investment and innovation, bringing the maximum benefit to the end users."*

In light of this provision, too, a permanent forum of discussion between DAZN and IAS providers has been launched and coordinated by AGCOM, in order to facilitate the cooperation between the involved parties. AGCOM is constantly assessing the outcomes of this cooperation by means of an ad-hoc traffic monitoring exercise.

Annex II: NRA's activities in the context of IP-IC

A. France

Arcep collects data about IP-ICs since 2012 (twice a year), while the *Barometer of Data Interconnection*[150] is updated once a year (an English version is provided when possible). The decision giving the Authority the necessary powers to collect such specific data was updated in 2017. Notably, Arcep introduced in this last update new metrics for the tracking of the development of on-net CDNs. The published data is always aggregated and concerns the four major ISPs in France. The data calculated by Arcep is always expressed in terms of traffic volumes.

In the last five years, Arcep observed a steady increase in inbound traffic, that nearly tripled: at the end of 2022, the total inbound traffic reached around 43,2 Tbit/s, while at the end of 2017, there was nearly 12 Tbit/s.

The collected data shows the impact of the Covid-19 pandemic: in particular, the increase in inbound traffic was more significant in the beginning of the pandemic, than in the previous years. More precisely, traffic increased by around 18% at the end of 2018, versus around 28% at the end of 2019 and around 50% at the end of 2020, to approach normal growth rates after 2021.

The asymmetry ratio (the difference between inbound and outbound traffic) increased slowly, but seems to lower a bit since 2022. Arcep assumes that some changes in the way content was distributed over the internet (with the use of technologies close to peer to peer, that make a greater use of outbound traffic) could explain this.

The capacity provisioned at the interconnection point increased steadily. In this case, the impact of the pandemic also shows, with a steep upgrade of capacity in 2020 and a similar pattern than inbound traffic, with a slowing down to normal upgrade rates after 2021.

In France, traffic distribution between peering and transit is quite stable since 2017. When it comes to distribution between settlement-free and paid peering, the progression from 2017 is more interesting. In 2017, paid peering accounted for around 39% of incoming peering traffic, against around 46% in 2022.

Finally, Arcep's data analysis shows the impressive growth of on-net CDNs, that account for around 20% of inbound traffic in France in 2022. In 2017, the NRA counted nearly 1 Tbit/s of traffic from the caches to the IAS providers' networks against around 10 Tbit/s in 2022. On the

[150] Arcep, Baromètre de l'interconnexion de données en France (July 2023), the last version of the report is currently only available in French.

contrary, the traffic increase seems to follow the capacity upgrade of the caches as it takes places in successive stages.

Punctually – in France as elsewhere in the world – some end-users' quality of experience can be degraded. The cause of this deterioration can be ascribed to congestion in the interconnection between an ISP and an other operator.

Generally speaking, thanks to the information gathering campaigns on IP-IC and routing, Arcep has the needed information to form an initial assessment of the situation.

In addition, public network operators are required to grant other public network operators interconnection requests submitted in order to provide the public with ECS. The interconnection request may be refused only if it is justified by the applicant's needs on the one hand, and the operator's ability to satisfy it on the other hand. Any refusal of interconnection must be justified.

If difficulties arise, the Authority could exercise the powers granted to it by the legislator[151], either through an ex-ante regulatory decision, or by a dispute settlement decision at the request of an actor.[152]

Lastly, even if interconnection is not identical to internet access and is not covered as such by the OIR, practices using interconnection to restrict specific flows and therefore limit users' rights could be analysed from the perspective of the OIR[153].

B. Germany

In February 2022, WIK published a study (*Competitive conditions on transit and peering markets – Implications for European digital sovereignty*[154]) that had been commissioned by Bundesnetzagentur. The study examines the developments in transit and peering markets, building on previous BEREC reports (most recently 2017) and analysing whether significant market/competitive changes have taken place in this area since then.

A major finding was that usage of on-net CDNs has tripled between 2017 and 2020. Direct bilateral peering arrangements have gained further weight. These factors exert competitive pressure on transit providers. In addition, the study showed that transit prices continue to fall steadily. Large CAPs increasingly invest in own infrastructures (backbones, CDNs). IXPs have become less important, but are particularly relevant for smaller players. The interaction of the networks – at least by a large proportion of the players – is cooperative. However, a few IAS providers do not allow on-net CDNs to be installed in their access networks. Closely related

[151] Article L. 34-8 of the French postal and electronic communications code
[152] Procedure provided by Article L. 36-8 of the French postal and electronic communications code
[153] Considering recital 7 of the OIR as well as paragraphs 5 and 6 of the BEREC Open Internet Guidelines
[154] WIK (2022)

with this, the study also identifies a few IP-IC issues that have occurred since 2017. The study also takes a look at South Korea and shows that the introduction of a Sending Party's Network Pays Regime largely led to negative effects.

In December 2023, WIK published a report[155] which looks at developments in the debate on payments from large CAPs to ISPs, with a focus on recent developments. The report assesses whether certain economic arguments put forward by stakeholders stand up to scrutiny. It scrutinises revenues and profitability of large network providers as these figures are essential for their ability to finance network investments. WIK e.g. refers to ETNO figures showing that the earnings before interest and taxes (EBITDA) of ETNO members remained stable between 30% and 36% between 2015 and 2021.[156] The study then analyses the investments necessary to meet the European connectivity targets. This is followed by an examination of the relationship between traffic volumes and network costs. WIK concludes that overall cost drivers are less the actual traffic-sensitive costs of the access networks, but rather the fixed costs resulting from the expansion of new access technologies and mobile network generations. The report also examines the relationship between OTT-traffic and energy consumption and CO2 emissions. Aside from these aspects it elaborates on the latest developments in South-Korea. It also provides an overview of recent theoretical economic literature on such network contribution payments.

C. Italy

In Italy, AGCOM has been monitoring data traffic developments since the pandemic outbreak in 2020, analysing peak and volume traffic variations on operators' networks. This monitoring exercise has revealed a notable growing trend in data traffic consumption, especially on mobile networks, with peak variations of up to 245% from the February 2020 benchmark value (peaks seem to be related to live-streaming of most watched football matches). The latest update of this monitoring exercise is publicly available on AGCOM website[157].

D. The Netherlands

The ACM has published a market study on the Dutch IP-IC markets[158] in 2021, following a routing decision by Telekom that impacted T-Mobile Netherlands' internet access subscribers in 2019. The study was done by conducting interviews with a great number of stakeholders on various sides of the IP-IC markets, and quantitative analysis of *inter alia* public peering prices and interconnection policies of ECNs. One of the main findings concerns the growing

[155] WIK, Netzentgelte auf dem Prüfstand – Eine Betrachtung der "Fair-Share"-Debatte (December 2023)
[156] European Telecommunications Network Operators' Association (ETNO), State of digital communications 2023 (January 2023), p. 22; cf. WIK (2023), p. 10
[157] AGCOM (2024), Communication Markets Monitoring System (No. 3/2024)
[158] ACM (2021), Case no. ACM/20/039450 / Document no. ACM/UIT/558129

presence and importance of CDNs in relation to transit. On the bargaining power balance between CAPs and ECNs, the study concluded:

"A more balanced relationship seems to have emerged between content providers with sufficient scale on the one hand and internet providers with many connections on the other. Whereas back in around 2015, content providers and internet providers openly questioned who should pay for the content providers' traffic costs, this now no longer seems to be an issue. Both sides have an interest in good connections between end-users and the content providers they want to engage."

In the wake of proposals for a levy on CAPs to fund network operators, the Dutch Ministry of Economic Affairs and Climate commissioned an economic assessment by Oxera which was published in 2023.[159] In conjunction with the Oxera report, the Ministry published a position paper containing a critical examination of the proposal and its potential impact on net neutrality and the market.

[159] Oxera, Proposals for a levy on online content application providers to fund network operators – An economic assessment prepared for the Dutch Ministry of Economic Affairs and Climate (January 2023)

Annex III: Methodology

In the context of the preparation of the *BEREC Report on the IP interconnection ecosystem*, BEREC carried out a data collection exercise by means of a quantitative questionnaire, complemented with qualitative questions. The main objective of this exercise was to support the analysis in the report with empirical data and to provide a better understanding of the interconnection between actors in the internet ecosystem at European level. The online questionnaire was an information request pursuant to article 20 of the European Electronic Communications Code[160] and it was distributed by NRAs on behalf of BEREC to IAS providers in their respective countries in September 2023. This data collection exercise addressed fixed and mobile IAS providers representing at least 80% of the national market in terms of the number of internet access connections respectively. Additionally, NRAs were kindly asked to also include at least one smaller provider of fixed IAS in the data collection exercise. The questionnaire was only addressed to market players owning a network themselves (having at least one Autonomous System, AS).

Furthermore, this questionnaire was also distributed in the RIPE NCC's network and thus other types of actors were offered the opportunity to contribute to this data collection exercise.

The data collected provides a snapshot of interconnection structures of IAS providers in terms of traffic values, utilised services and commercial agreements. The majority of the data provided by respondents refers to the months of September and October 2023. The national markets are fairly represented, since the biggest players typically responded to the information request and submitted their data.

Respondents were asked to provide individual details on their top 15 agreements with other AS partners, their top 10 internal CDNs/cache servers (owned and by other companies) and their top 10 agreements with an IXP (multilateral peering), by considering the definitions and calculation method outlined in the following sections. The questionnaire also encompassed questions querying about any IP-IC disputes that occurred and major developments observed in the market since 2017.

BEREC collected 174 replies to the questionnaire, of which it validated 113 after eliminating incomplete or erroneous replies, analysing and requesting further clarifications to some stakeholders.

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[160] Directive (EU) 2018/1972 of the European Parliament and of the Council of 11 December 2018 establishing the European Electronic Communications Code (Recast)

A. Definition of terms used in the questionnaire

Term or data field	Definition
AS	An Autonomous System (AS) is a self-contained network of routers under the control of a single entity, typically an ISP or a large organization that exchanges information via a common routing policy. Each AS is identified by a unique number: the ASN, or Autonomous System Number. See: http://www.ietf.org/rfc/rfc1930.txt. These numbers can be consulted in the RIPE database under https://www.ripe.net/manage-ips-and-asns/db or on PeeringDB under https://www.peeringdb.com.
AS #1	ASN of the *respondent*, to which the questionnaire refers to.
AS #2 (IP interconnection)	ASN of the *partner*, with which traffic is exchanged.
AS #2 (internal CDN, if applicable)	Internal CDN and cache server are often addressed with the ASN of the operator's network in which the internal CDN or cache server is placed. Nevertheless, specify the relevant ASN of the partner owning the internal CDN, if it is available.
Configured capacity (Gbit/s)	Indicate the most recent value of the maximum total capacity technically available after software or hardware configuration of the installed interconnection links, in Gbit/s (rounded to the nearest decimal place). In case there are several interconnection points for one entry (line), the configured capacities of those points are to be summed up. For CDNs, configured capacity refers only to the outgoing capacity.
Data collection period	The data collection period is between **15 September and 14 October 2023**.
Financial terms & conditions	Specify the financial terms and conditions of the relationship and choose one option from the list, e.g.: • free (settlement-free agreement); • paid (commercial agreement about the provision of traffic between the two parties, e.g. payments may be made beyond a certain cap or ratio); • other (please specify).
Incoming traffic (IP interconnection)	Traffic from AS #2 towards AS #1. Indicate, in Gbit/s and preferably using the 95th percentile (rounded off to the nearest 10th), the quantity of data received during the data collection period. In case there are several interconnection points for one entry (line), the measured traffic (in Gbit/s) of those points are to be summed up.
Incoming traffic (internal CDN)	Traffic from the owner of the CDN/content provider to the internal CDN/cache server. Indicate, in Gbit/s and preferably using the 95th percentile (rounded off to the nearest 10th), the quantity of data that the internal CDN/cache server received during the data collection period.

Information on the point of interconnection	Number of distinct interconnection points with Indicate in each column, if applicable: • **country** where the point of interconnection, internet exchange point (IXP), internal CDN or Cache server is located (please select one country from the list); • **city** where the point of interconnection / IXP / internal CDN or Cache server is located; • in case of a public IXP, the **name** of the point of interconnection/IXP where the interconnection occurs or, alternatively, the name of the party occupying the premises where the interconnection / IXP is located.
Interconnection point	An interconnection link at a distinct location. Each location is to be counted separately, while a single interconnection point at one location can have several ports.
Number of interconnection points	Number of distinct interconnection points with AS #2.
Number of interconnection points	Number of distinct interconnection points with individual / bilateral agreements with other AS, broken down per type of relationship.
Outgoing traffic (IP interconnection)	Traffic from AS #1 towards the partner AS #2. Indicate, in Gbit/s and preferably using the 95th percentile (rounded off to the nearest 10th), the quantity of data sent during the data collection period. In case there are several interconnection points for one entry (line), the measured traffic (in Gbit/s) of those points are to be summed up.
Outgoing traffic (internal CDN)	Traffic from internal CDN/cache server to the end-users. Indicate, in Gbit/s and preferably using the 95th percentile (rounded off to the nearest 10th), the quantity of data that the internal CDN/cache server transmitted to the end-users, during the data collection period.
Owner of the internal CDN/cache server	Indicate the name of the owner of the cache/CDN servers hosted in the operator's network.
Partner's name	Enter the name of the legal entity responsible for managing the AS with whom the relationship has been established.
Pricing scheme (€)	Provide details on the pricing structure in place and the rates charged for the different components, specifying the validity period. The pricing scheme must include both recurring and non-recurring components (including set-up or hosting fees if applicable) in EUR.
Remarks	Use this field to supply any additional information (e.g. rate of asymmetry of traffic streams which resulted in one of the AS being billed, methodology remarks….).

Total incoming (outgoing) traffic (Gbit/s)	Please provide for all individual / bilateral agreements with other AS total traffic (outgoing and incoming separately) during the data collection period, not only the 15 specified in this questionnaire, summing up the measured traffic (in Gbit/s and preferably using the 95th percentile rounded off to the nearest 10th) of each of the interconnection points, broken down per type of relationship.
Type of relationship	Indicate the type of relationship between the two parties, using one of the following categories: • **Global transit [1:E]** – AS #1 (respondent) employs AS #2 to supply a transit solution to all third-party AS; • **Global transit [E:1]** – AS #1 provides AS #2 with a transit solution to all third-party AS; • **Partial transit [1:n]** – AS #1 employs AS #2 to supply a transit solution to a number of third-party AS; • **Partial transit [n:1]** – AS #1 supplies AS #2 with a transit solution to a number of third-party AS; • **Peering [1:1]** – AS #1 and #2 mutually route traffic to their customers, their customers' customers, etc.

Table 2. Definition of terms and explanations on the information to be reported in the questionnaire, Source: BEREC

B. Calculation method used to compute traffic exchanged

To ensure consistency, BEREC's preference to calculate traffic exchanged has been the use of the 95th percentile measured with a sampling every 5 minutes for workdays (between Monday to Friday) during the data collection period. The following figure illustrates measurements of incoming traffic (at an interconnection point with another AS) in the data collection period with their average and the requested 95th percentile. In this calculation, 95% of the measured values are at or below 23 Gbit/s (inclusive definition).

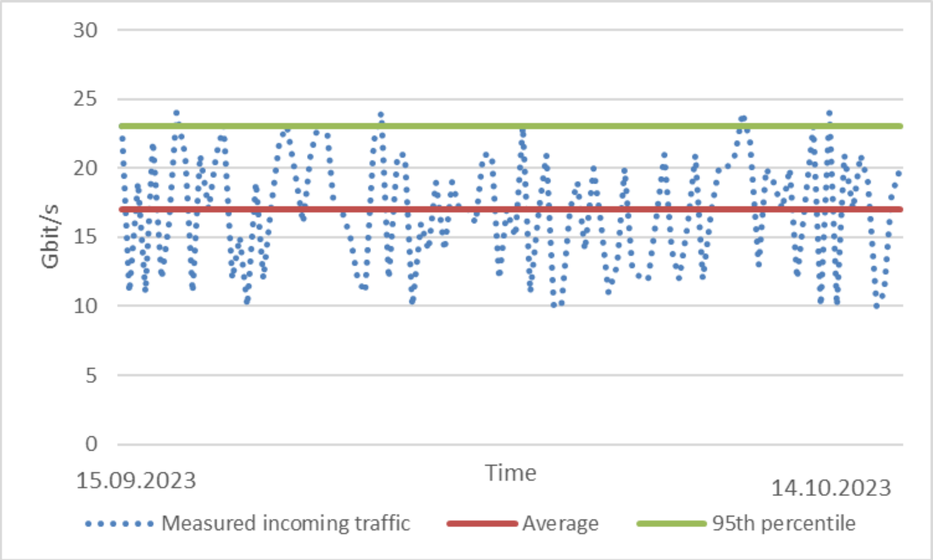

Figure 12. Illustration of measured incoming traffic values, average and 95th percentile, Source: BEREC