BoR (22) 167

BEREC Report on the Internet Ecosystem

8 December 2022

Contents

Executive Summary

Electronic communication services (ECS) and electronic communication networks (ECN) are part of a vast internet ecosystem which allows users and society as a whole to offer and benefit from the extraordinary potential of a large variety of services provided via the internet. Like any other ecosystem, the internet is composed of many interrelated elements that affect each other.

This report presents a broad analysis aimed at understanding how users' internet experience is affected by the different elements of the ecosystem and how the interactions among them may have an impact on BEREC's and/or NRAs' regulatory intervention.

For this analysis, BEREC takes a holistic approach by first providing a graphical representation and some depictive models of the internet ecosystem and its elements (chapters 2 and 3), as well as an overview of the main legal (in effect and currently under discussion) provisions applying to them (chapter 4). BEREC then identifies the main players which are providing services and products for the different elements within the internet ecosystem (chapter 5), and analyses competition dynamics and openness issues, including users' experience and choice on all the elements (chapters 6 and 7). This report highlights the barriers to entry and expansion, the potential bottlenecks, and the practices of the main providers, as well as the impact on access to and distribution of information and services. Building on this analysis, BEREC finally proposes some topics which would deserve to be further assessed in the future (chapter 8).

The main findings of the report are summarised here below.

First of all, the most relevant actors for the client and server sides of the internet ecosystem are Google/Alphabet, Apple, Meta, Amazon and Microsoft (referred to as "the Big Tech companies"). ECN/ECS providers are mainly focused on providing internet access service (IAS) and infrastructure elements, thus supporting the communication between the client and server side, or between users. Additionally, ECN/ECS providers may make over-the-top (OTT) video content (pay TV) available to end-users, in competition or cooperation with content and application providers (CAP), and/or by providing their own OTT interpersonal communications services. On the other hand, the Big Tech companies facilitate provider-specific ecosystems, by providing internet-based services and platforms related to a significant variety of different elements (from applications to internet access network). Such provider-specific ecosystems may be built around operating systems (OS) (e.g. Google, Apple and Microsoft) or around some key applications (e.g. Meta and Amazon). Each provider-specific ecosystem consists of a different combination of elements. For instance, Apple produces devices running its own OS, which is solely compatible with Apple's own application store and web browser engine; Google or Microsoft's services/products are tightly integrated, such as through a singular identification service for access to multiple services, and common user interface elements.

Secondly, the Big Tech companies have traditionally provided services on the client and server sides of the internet ecosystem, and generally not on the internet infrastructure-related elements. However, in recent years, they have invested increasingly in telecommunication infrastructures and have been providing additional services related to the network and ECS markets. Some typical examples include virtualised network services, content delivery networks (CDN), cloud computing with increasing ubiquity, the deployment of extensive international networks (e.g. submarine cables), as well as trends towards the provision of IAS. As a result, nowadays the Big Tech companies are present across practically all the elements, or they can enjoy a significant presence in a relevant part of the elements in the internet ecosystem and can often leverage their position among different services and products, e.g. partnering with ECN and ECS providers, but also directly competing with them. Moreover, the Big Tech companies may unilaterally implement some practices (e.g. redirecting traffic to their own servers from the device) which deserve to be further assessed.

Thirdly, the way in which the provision of an internet-based service is implemented has technical, economic and behavioural implications which need to be taken into account. For example, there are two architectures which can be used to access or provide online content and services: native applications[1] and/or web applications[2]. Native applications are based on application programming interfaces (APIs) set by the providers of the OS, while websites and web applications are based on common standards implemented by the web browser, and web pages/script code can run in any web browser. Since the market for mobile OSs is currently almost exclusively dominated by Google and Apple, the app software infrastructure is provided by two parallel provider-specific ecosystems. While CAPs may choose to use both architectures (native and web), they are subject to the choices taken by the two main mobile OS providers concerning technical formats, editorial choices and business models. This could have significant impacts in terms of openness, i.e. the potential of the internet to provide an open, easy-to-access and common infrastructure where non-proprietary, free software, contents and applications – potentially governed by open communities, such as the internet protocols (i.e. TCP/IP) – would enable the preservation and/or development of some digital services as common goods.

Fourthly, the analysis of the competition dynamics of the internet ecosystem's elements shows that there are several issues and potential bottlenecks especially concerning commercial CDNs, cloud computing, enabling and discovery elements, devices, attention-intensive applications,[3] e-commerce, instant messaging and the Internet of Things (IoT). Whilst the issues identified in ECN/ECS markets are addressed by the telecom regulatory framework, some of the bottlenecks identified in this report are not yet tackled.

Commercial CDN and cloud markets are largely concentrated and significant investments are required to have the necessary geographical coverage and capillarity. The infrastructure of cloud computing services (IaaS) also relies on large investments, due to the existence of very

[1] A native application is a piece of software developed to run on a specific underlying platform or operating system.
[2] By accessing the World Wide Web
[3] Attention-intensive applications are applications which compete especially for user's attention in terms of time, for example social networks and video-sharing platforms.

significant economies of scale in this market where large companies can leverage their power on other parts of the ecosystem.

With regards to devices, many original equipment manufacturers are horizontally and/or vertically integrated, often enjoying a termination monopoly[4]. The integration into a provider-specific ecosystem (e.g. Apple) creates lock-in effects and may also result in lack of transparency and potential restrictions on data portability. Other bottlenecks may arise from self-preferencing, commercial agreements, exclusive partnerships or discriminatory practices restricting competition (e.g. Google).

Enabling and discovery elements (OSs, app stores, web browsers and search engines elements) are characterised by very strong direct and indirect network effects. These elements are key to the openness of the internet ecosystem, as they allow users to interact with the whole internet ecosystem to create, offer and access new applications, content and services. The structural barriers to entry and expansion on these elements are reinforced by vertical integration into provider-specific ecosystems, high switching costs for users, and significant costs for developers to adapt and update apps to run on several OSs.

Concentration of OS market has a strong impact on the market for application stores, as users rarely use alternative app stores (when available). Furthermore, in case of lack of access for independent application developers to integrated application stores, competition in the downstream market for those apps can be hindered or eliminated.

Web browsers are also rather concentrated, especially in the mobile markets, as users tend to choose and use apps that are pre-installed on the device, and are therefore heavily dependent on the OS and/or device providers. Online search is also a very concentrated market, and largely dominated by a single provider (Google). Attention-intensive applications (social networking and video-sharing platform services) are concentrated around two players (Meta and Google) and several concerns may also arise on issues such as lack of transparency, access to data and discriminatory conducts.

In the IoT market, despite the apparently high number of players, some big and vertically integrated companies, such as Google, Amazon and Apple, play an important role. By having their own provider-specific ecosystems and by controlling proprietary technology, these companies have the ability and may have the incentive to adopt discriminatory practices (e.g. pre-installation, default-settings, tying), limiting interoperability and creating lock-in effects.

Finally, the analysis for most of the internet ecosystem elements generally shows that, in addition to significant network effects, consumer inertia is strong, resulting in low switching

[4] A termination monopoly refers to the power exerted by a provider when its users are in ex-post dependency on a specific service/product. For instance, users' dependency on services belonging to the same ecosystem can limit the conditions of access to or usage of competing products or services. By buying a specific device, users are not only often obliged to use the corresponding OS, but also the software application store and applications developed for this OS. Since users usually do not have the possibility to use other services/products provided by competitors, the provider can exert a de facto monopoly. The term is also mentioned by CERRE's Report on Device neutrality (June 2021) Ibid footnote 79

and thus reinforcing strong market positions/concentration. Examples of this include Google in search engines, Google and Apple in the mobile segment of the enabling and discovery layer, Meta in the attention-intensive elements and instant messaging, Microsoft in the desktop/laptop OS and Software as a Service (SaaS) elements, Amazon in cloud computing IaaS and Platform as a Service (PaaS), and in e-commerce. The business models for these large providers rely, in many cases, on extensive data collection, analysis and monetisation. Concerning cloud services, the European Commission's proposal for a Data Act aims to facilitate switching and data portability. In its high-level opinion on this proposal[5], BEREC strongly welcomes the provisions to facilitate switching between data processing services, and considers that the reduction and eventual removal of switching charges will lead to increased competition in the data processing services market.

This report highlights how the internet experience for users is affected by many different elements, such as devices, OSs, and application stores. These elements are not directly within NRAs' and BEREC's regulatory realm, but can still have an impact on ECN and ECSs – which are subject to NRAs' monitoring and regulation.

The analysis also shows that some internet ecosystem's elements are largely dominated by few players organised in provider-specific ecosystems. While such companies were initially providing services/products complementary to telecom operators, their entry into ECN and ECS markets and the impact on the current regulatory framework deserves to be further addressed. Moreover, the analysis of the evolution of CDN and IP interconnection markets also appears to be crucial and closely connected with ECN/ECS markets.

Together with BEREC's previous work on the regulation of digital gatekeepers[6], this report shows how a small number of digital platforms have reached a position allowing them to shape

[5] BoR (22) 118, BEREC High-Level Opinion on the European Commission's proposal for a Data Act. 15.07.2022. https://berec.europa.eu/en/document-categories/berec/opinions/berec-high-level-opinion-on-the-ecs-proposal-for-a-data-act

[6] BoR (21) 130, BEREC Report on the outcome of the public consultation on the Draft BEREC Report on the ex-ante regulation of digital gatekeepers, 30.09.2021. https://berec.europa.eu/eng/document_register/subject_matter/berec/reports/10042-berec-report-on-the-outcome-of-the-public-consultation-on-the-draft-berec-report-on-the-ex-ante-regulation-of-digital-gatekeepers;
BoR (21) 85, BEREC Report on the interplay between the EECC and the EC's proposal for a Digital Markets Act concerning number-independent interpersonal communication services, 10.06.2021. https://berec.europa.eu/eng/document_register/subject_matter/berec/reports/9966-berec-report-on-the-interplay-between-the-eecc-and-the-ec8217s-proposal-for-a-digital-markets-act-concerning-number-independent-interpersonal-communication-services;
BoR (21) 93, BEREC proposal on the set-up of an Advisory Board in the context of the Digital Markets Act, 10.06.2021. https://berec.europa.eu/eng/document_register/subject_matter/berec/others/9963-berec-proposal-on-the-set-up-of-an-advisory-board-in-the-context-of-the-digital-markets-act;
BoR (21) 94, BEREC proposal on remedies-tailoring and structured participation processes for stakeholders in the context of the Digital Markets Act, 10.06.2021. https://berec.europa.eu/eng/document_register/subject_matter/berec/others/9964-berec-proposal-on-remedies-tailoring-and-structured-participation-processes-for-stakeholders-in-the-context-of-the-digital-markets-act;
BoR (20) 138, BEREC Response to the Public Consultations on the Digital Services Act Package and the New Competition Tool, 07.09.2020.

and impacts both the competition dynamics on different elements of the internet ecosystem and the relative openness under which content, services and information can be accessed and shared.

In line with BEREC's strategic priority to support competitive, sustainable and open digital markets, and with the role that BEREC will play within the High-Level Group for the enforcement of the Digital Markets Act, BEREC keeps monitoring and analysing the evolutions in the internet ecosystem, particularly in markets that are significantly impacted by those practices of the gatekeepers which may not be addressed by the current legislative initiatives.

---

https://berec.europa.eu/en/document-categories/berec/others/berec-response-to-the-public-consultations-on-the-digital-services-act-package-and-the-new-competition-tool

1. INTRODUCTION

The internet ecosystem is composed of many different interrelated elements. While BEREC's work has traditionally focused on the part of the internet ecosystem directly related to electronic communication networks (ECN), electronic communication services (ECS) and internet access services (IAS), several other subjects affecting BEREC's traditional competences have become increasingly relevant in the last years.

First of all, ECNs and ECSs are part of a broader ecosystem of products and services that allow end-users, business users and the whole society to offer and benefit from the potential of a vast variety of services provided via the internet. However, within this ecosystem, user experience when accessing the internet is nowadays increasingly affected not only by ECNs and ECSs, but also by platforms acting as a gateway to content and applications. In order to correctly design and apply ex ante regulation for ECNs and ECSs, it is crucial to analyse all the elements of the ecosystem and the interactions among them.

BEREC has already analysed the levels of the internet ecosystem beyond the ECN and ECS layers in different reports, such as "BEREC Report on the impact of premium content on ECS markets and the effect of devices on the open use of the Internet"[7] with a focus on the issues raised by e.g. app stores, and the "BEREC Report on the data economy"[8] highlighting relevant aspects of ECS as a key infrastructure supporting the data economy as well as the impact of data economy on ECS competition. More recently, BEREC has also analysed competition dynamics and proposed a regulatory model concerning the regulatory intervention towards some specific platforms in the "BEREC Report on the ex ante regulation of digital gatekeepers".[9]

BEREC considers that its experience regulating ECSs and ECNs may be useful for addressing potential issues as market failures, encouraging competition or ensuring openness in the whole internet ecosystem. This is also confirmed by the inclusion of BEREC in the European High-Level Group for the enforcement of the Digital Markets Act (DMA).[10] BEREC welcomes

---

[7] BoR (18) 35, BEREC report on the impact of premium content on ECS markets and the effect of devices on the open use of the Internet, 08.032018. https://berec.europa.eu/eng/document_register/subject_matter/berec/reports/8013-berec-report-on-the-impact-of-premium-content-on-ecs-markets-and-the-effect-of-devices-on-the-open-use-of-the-internet

[8] BoR (19) 106. BEREC report on the Data Economy,. 13.06. 2019. https://berec.europa.eu/eng/document_register/subject_matter/berec/reports/8599-berec-report-on-the-data-economy#:~:text=The%20report%20reviews%20the%20concept,economy%20at%20the%20European%20level

[9] BoR (21) 131, BEREC Report on the ex ante regulation of digital gatekeepers, 30.09.2021. https://berec.europa.eu/eng/document_register/subject_matter/berec/reports/10043-berec-report-on-the-ex-ante-regulation-of-digital-gatekeepers

[10] Regulation (EU) 2022/1925 of the European Parliament and of the Council of 14 September 2022 on contestable and fair markets in the digital sector and amending Directives (EU) 2019/1937 and (EU) 2020/1828 (Digital Markets Act). https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32022R1925&from=EN

this opportunity to contribute to an effective enforcement of the ex ante regulation of gatekeepers.

With these objectives, this report provides a high-level view on the internet ecosystem identifying the elements implied in the provision of services supported by the internet, the relations among them, the main actors, competition dynamics and issues related to openness and user experience.

The report is organised as follows. Chapter 2 provides a general view of how the internet ecosystem is organised, identifying its main architectural characteristics. Chapter 3 groups the elements in the ecosystem according to their functionalities and provides a reference for the analysis done in the other chapters. The most relevant legal provisions on the different elements of the internet ecosystem are addressed in chapter 4, also providing a high-level view on which elements of the ecosystem are affected by different regulatory pieces. Chapter 5 shows how the main actors of the internet ecosystem cover different elements resulting in provider-specific ecosystems. Competition dynamics in the different elements are analysed in chapter 6, while openness issues are addressed in chapter 7. The lines for future work to be done by BEREC are described in chapter 8 and chapter 9 presents the main findings of the report.

Please note that along the report, when referring to “end- users” and “business users”, BEREC is following here the definition in the DMA.[11] Thus, for the purpose of this report, “end-user” means any natural or legal person using services other than a business user and “business user” means any natural or legal person acting in a commercial or professional capacity using services for the purpose of or in the course of providing goods or services to end-users. When using “users” hereafter, BEREC refers to both end-users and business users. This definition of “end-user” differs from the one in Art. 2(14) of the European Electronic Communications Code (EECC) where “end-user’ means a user not providing public ECNs or publicly available ECSs.

It should also be noted that for the purpose of this report, the term “market” is used in a more general way, and not as the result of the market definition as carried out in ECS ex ante regulation or in ex post competition law.

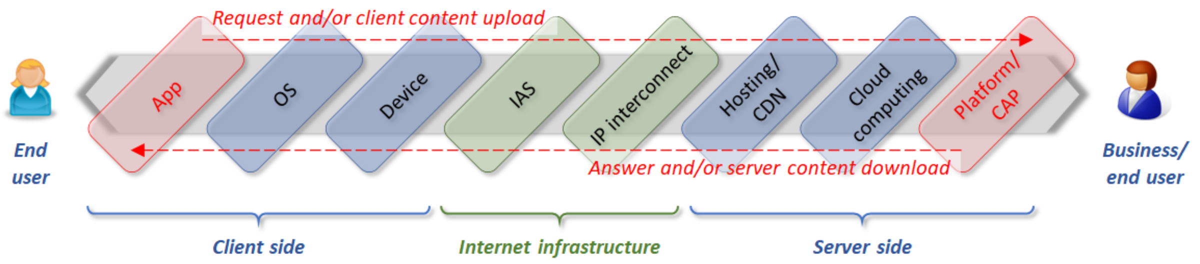
[11] Ibid footnote 10

2. OVERVIEW OF THE INTERNET ECOSYSTEM

2.1 Basic model of the internet ecosystem

The provision of an internet-based service[12] is typically distributed between the client device and one or more server computers connected to the internet.[13] The way this is implemented has technical, economic and behavioural implications which are elaborated on in this report. As a tool to facilitate the discussion, the report uses depictive models of the internet ecosystem.

Figure 1 – Linear simplified model of the internet ecosystem



In further detail, in the linear model above, on the client side, the service is typically initiated by the end-user through an application[14] (often referred to simply as an ‘app’). The app is running on the operating system (OS) on the end-user’s device (e.g. desktop computer, laptop, smartphone, tablet, etc.).[15]

The client side is communicating over the internet with the server side, via the IAS. Communication is further provided via IP interconnection services to reach the server side. The IP interconnection is either implemented as a shared resource (peering and/or transit) or as a dedicated, private capacity.[16]

---

[12] Internet-based services are sometimes referred to as “over-the-top services” (OTTs)”. The BEREC Open Internet Guidelines also uses the term “application” to refer to internet-based services. Internet-based services are to be distinguished from “specialised services” which may be provided in parallel but are not running over the open internet. Internet-based services and specialised services are provided based on different business models.

[13] The end-user on the left-hand side of the transmission chain might be connected on the right-hand side to either a business user (for example an e-commerce platform) or another end-user, in which case the transmission chain has to be completed on the right-hand side in a symmetric way.

[14] For the purposes of this Report, ‘app’ here also includes web browsers installed on the device. It should also be noted that ‘applications’ includes not only ‘mobile apps’ but also other software applications running on devices such as personal computers or laptops.

[15] Internet-based services encompass a rich variation of implementations. This report focuses on services that are the most used on the internet. However, there also exists other types of services that are not discussed explicitly in this report, such as Peer to Peer communications.

[16] For example, capacity owned by a larger CAP for interconnecting data centres.

On the server side, the communication is received by one or more server computers which may be run by hosting/content delivery network (CDN) providers and/or cloud computing providers, which the content and application provider (CAP) uses. These functions may also be provided by a single provider.

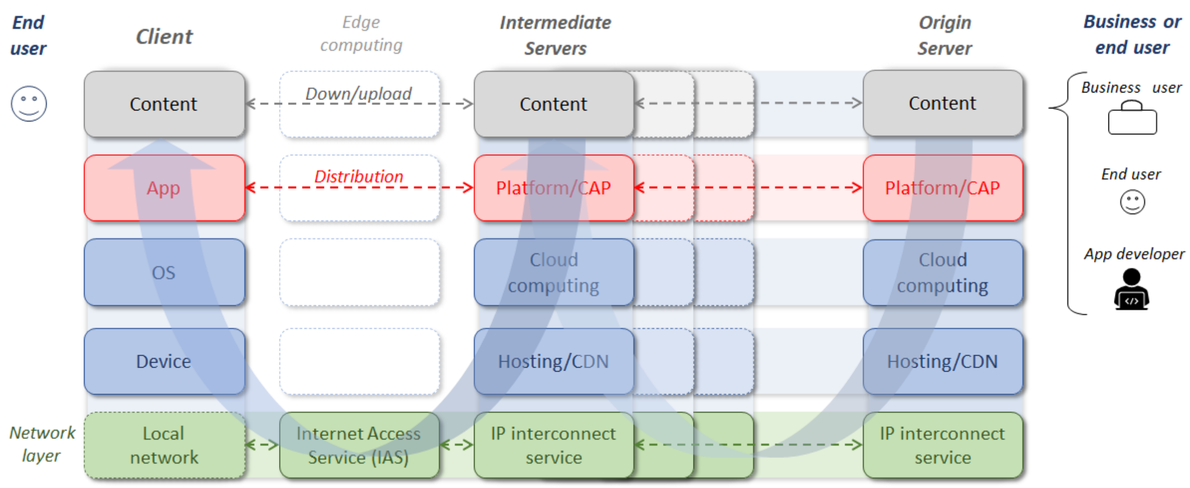
In some cases, the CAP is referred to as a platform provider, which exists in different types. Relevant types include online intermediation services, online social networking services and video-sharing platform services (VSP), among others.

When the service runs, communication over the internet is initiated by the client and then runs two-way between client and server sides until the service is finished. A typical sequence consists of requests from the client side and content then returned from the server side. In some cases, content is also uploaded from the client side.

2.2 Further expansion of the model

To better understand the relationship between the different elements of the internet ecosystem, the linear model can be expanded into a two-dimensional model. In this case, different elements of the ecosystem are distributed horizontally over different clients and servers connected to the internet, and vertically over different layers (see Figure 2).

Figure 2 – Two-dimensional model of the internet ecosystem



The end-user accesses the content through an app on the client device, whereby the app provides a user interface to the corresponding application server. The app is a core element which is first developed and provisioned by business users[17], and then discovered and downloaded by the end-user[18] before the app can provide its service to the end-user.

Horizontally, the client device communicates with one or more server computers. Internet-based services may be distributed over several servers, enhancing the performance in case of many clients communicating to the server side. The origin server duplicates its content (so-called caching) to a set of caching servers.

In some modern communication networks, such as 5G mobile networks, local data storage and computing is also facilitated closer to the end-users. This method is referred to as “edge computing” or “mobile edge computing” (MEC).[19]

Vertically, the two-dimensional model is divided into different layers. The lowest layer is referred to as the “‘network layer”. This is where we find the underlying electronic communications networks and services, IAS and IP interconnection services, which are the bearers of the internet-based service.

On the client side, similarly to the description of the linear model, the next layers above the network layer consist of the physical device, the OS, one or more apps running the internet-based service on top of IAS, and finally the content that is carried by the apps (see Figure 2 above).

On the server side, the different layers may be distributed to a set of intermediate servers connected to different locations on the internet. The Figure 2 is illustrating a configuration with intermediate servers that are caching content from the origin server. Furthermore, different intermediate servers may provide different “depths” depending on how many layers they are providing (e.g. content may be cached in an intermediate CDN-server, but the content may be generated from another server, e.g. the origin server). This is configured by the provider of the internet-based service to optimise the performance.

The different layers above the network layer on the server side, similarly to the linear model, consist of hosting/CDN, cloud computing, the application of the CAP (sometimes referred to as the platform), and finally the content provided by the application/platform.

In the *active phase* of the service execution, the *content of users* resides on the platform servers on the right-hand side, for example, information about the available rooms of a hotel. Similarly, shared videos are stored on a video sharing platform, or apps offered by app developers are stored on an app store platform.

However, in the *preparatory phase* of the service execution, the user connects to the platform and *uploads its content* from a similar chain of elements from the left-hand side. For example,

---

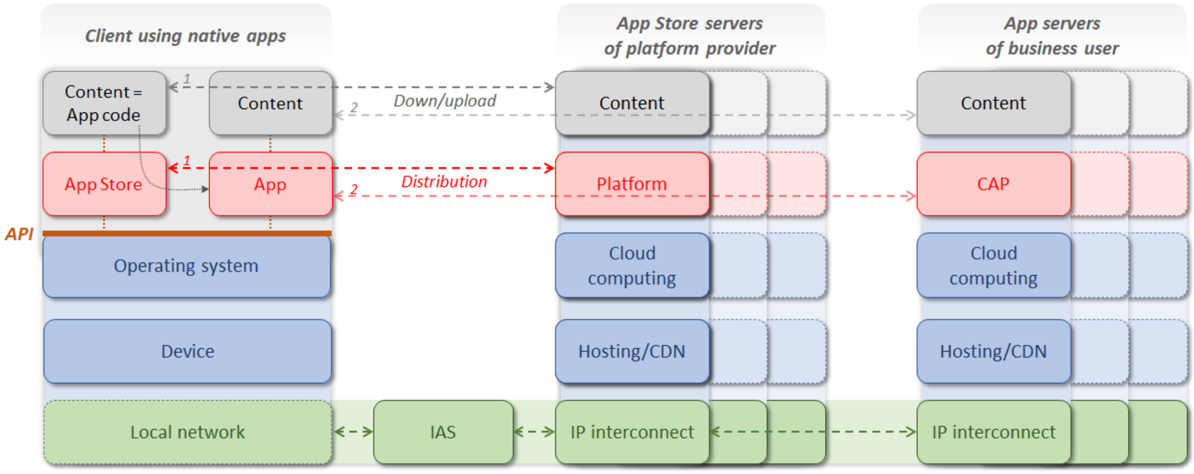
[17] Business users can be non-profit entities.
[18] In some cases, the app is pre-installed on the device.
[19] BoR (22) 144, BEREC Report on the 5G Ecosystem, 06.10.2022. https://berec.europa.eu/en/document-categories/berec/reports/berec-report-on-the-5g-ecosystem

hotels upload information about available hotel rooms, but also shared videos and apps from app developers are uploaded.

2.3 App architecture vs. web architecture

From a functional point of view, users can have access to internet content and services through two different architectures: via native applications[20] and/or via web applications by accessing the World Wide Web (WWW). A CAP may choose to use one of these ways or provide both in parallel. For example, YouTube may be accessed both as a native application, downloadable through an app store, or by entering the web page www.youtube.com as a web application.

Figure 3 – Provisioning of internet-based services via app architecture



The app architecture, from the client side, consists of dedicated software ("app") provided by the OS/device manufacturer or a third-party which can be downloaded to or pre-installed on the user's device, and can be used as a stand-alone application on the device. The app runs directly on the OS via the application programming interfaces (API) of the OS. When providing an internet-based service, the "native" app used on the client side communicates over the internet with its corresponding server of the CAP. A particular type of app is the app store, which provides search, installation and updating functionalities for apps (see Figure 3 above).

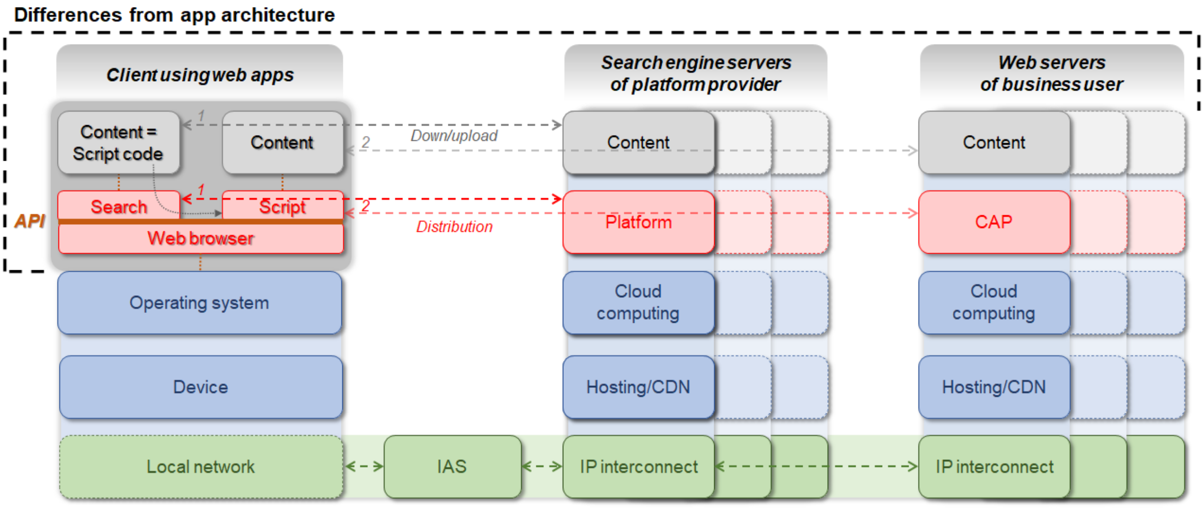
Unlike web applications, native apps are integrated relatively tightly with the device and OS used by the device. This facilitates smooth running of the client-side software which can be adapted to the execution system of the client. At the same time this means that the native app used by the client is tailor-made to that OS and would need different implementations to run on alternative OS. From the user's point of view, a useful feature of running native apps is that

[20] A native application is a piece of software developed to run on a specific underlying platform or operating system.

it offers some functionalities even when the device is offline. However, in this scenario the app would only work with content that has already been downloaded. For example, a music streaming application may store content on the device for listening to music even without access to the internet.

The Figure 3 above also illustrates how an app store works as a platform for the provisioning of internet-based services via native apps. The business user of the platform is providing its services through the app store of the platform provider. The end-user discovers and downloads the relevant apps through the app store on his device.

Figure 4 – Provisioning of internet-based services via web architecture



The web architecture, from the client side, is based on an internal structure similar to the app architecture, although in this case the web browser provides the API for running services. Each internet-based service is running as script code within a web page downloaded to the browser, which communicates over the internet with the corresponding web server operated by a CAP.[21] Web pages can be addressed directly by the user[22], or they can be located by a search engine (see Figure 4 above).

As a part of the web architecture, the web browser contains a standardised API for running the client software. This API is provided in the web browser by implementing open web standards, which means that any browser supporting these web standards can be used, whereby the running of the client code is independent of the underlying OS. However, this requires an extra layer of software processing, which may lead to lower performance.

[21] In this document provisioning of internet-based services is particularly relevant. However, in many cases, web pages only contain static content which is displayed in the browser window.

[22] End-user address web pages by typing the pages' web address (for example, the Uniform Resource Locator [URL]) which includes the domain name.

The Figure 4 above illustrates how the search engine works as a platform for provisioning of internet-based services via the web architecture. In this case, the user discovers and downloads the relevant web page through the search engine of the web browser. However, the web site of the business user may also be discovered by other means, for example by word of mouth.

Comparison between native app and web architecture

In both the native application architecture and the web architecture, an API for running the client-side software is used to communicate with the server of the CAP.

For native apps, it is the OS that provides the API. Since the market for mobile OS is currently almost exclusively dominated by Google and Apple, the app architecture is currently provided by two parallel provider-specific ecosystems. On the personal computer (PC) side, MS Windows has around 75% market share of the OS market.[23]

On the other hand, web applications can in principle work on any provider-specific ecosystem as long as a web browser is installed on the OS and the OS provider or web browser provider do not limit access to the web browser functionalities. This is due to the fact that websites and web apps are based on open standardised APIs in the web browser, whereby downloaded web pages/script code can run in any web browser. To some extent, web pages may be tailor-made for specific web browsers, but there is an API that is standardised by World Wide Web Consortium (W3C).

Web functionality has had a considerable development of enhanced functionality in the recent years. Functions that are traditionally provided through dedicated applications are today also provided through web browsers. Noteworthy examples are office suites (such as Microsoft Office Online, LibreOffice Online, Google Workspace or Apple iWork for iCloud), geographic information systems (such as Google Maps, Apple Maps, Bing Maps, OpenStreetMap) and telephony (Web Real-Time Communication, WebRTC).

To some extent, one could view the web browser as a particular type of “operating system” which runs at a layer higher than the basic OS of the hardware platform.

A relevant question to consider when providing services by running software in a web browser versus on an OS is which functionalities and resources have been made available to the software from the underlying execution platform. On the one hand, native and installed applications can often take better advantage of resources like memory, computing power or every connected interface the OS supports and gives access to (such as Near Field Communication (NFC), Bluetooth, USB, etc.). However, installed apps still reserve storage space even if not used.

[23] See https://gs.statcounter.com/os-market-share/desktop/worldwide

In case functions of the OS are not made available to the web browser API, this will limit the possibilities web developers have to compete with native apps that run directly on top of the OS.

The look and feel of the web have improved significantly over the years, with quick response to user requests, local storage etc. Dynamic web pages have been available for many years, and in the recent years progressive web applications have been standardised, resembling native apps and often referred to as "web apps", which are supported by most browsers today.

3. THE DIFFERENT ELEMENTS

In this chapter, the simplified model from Chapter 2 is expanded to prepare for the analysis of the different elements of the internet ecosystem. For this purpose, also the different categories of applications are identified, based on their particular role in the internet ecosystem.

Figure 5 shows a general overview of the elements that constitute the internet ecosystem from a functional point of view. Each box represents an element or a set of related elements playing a role in the internet ecosystem. The interactions among these elements, from the moment that a user requests a specific content till the content is delivered, are shown in a model facilitating further analysis in the next chapters.

Figure 5 – The elements in the internet ecosystem

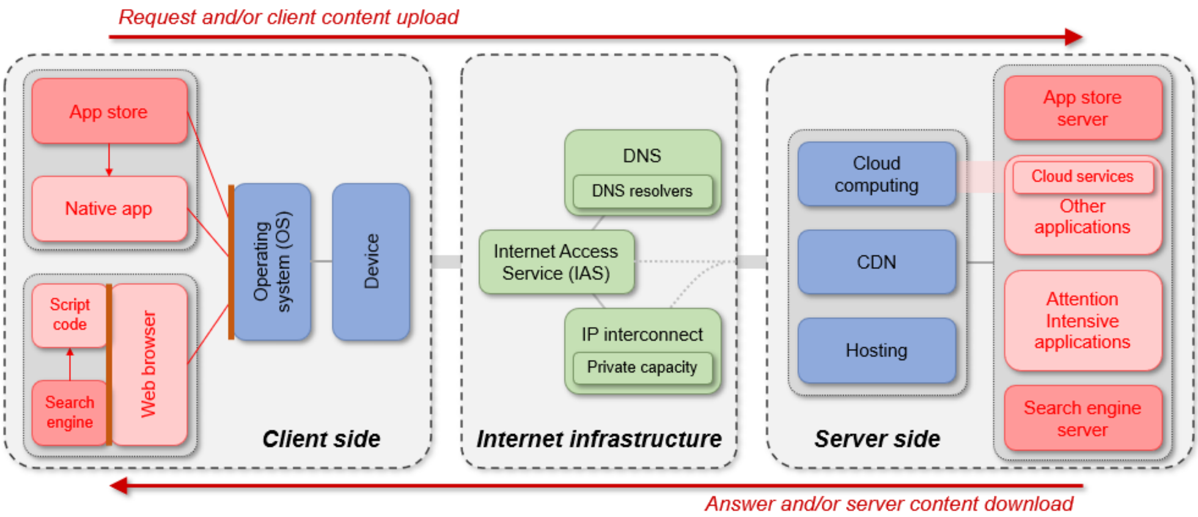


Figure 5 separates the client side (that includes device, OS in the device as well as the applications installed on top of the OS), the elements supporting the internet communication between the client and the server side (Internet infrastructure), as well as the server side that includes all elements used by the CAP to provide the service.

Starting from the client side, as explained in Chapter 2, when accessing content and applications provided by a CAP, users generally use a web browser or, increasingly, a native application (app). Among the apps, app store and search engine work as “discovery elements” for the app and web architecture respectively, as they are able, by giving prominence, ranking and/or displaying selected content, to guide the cognitive process of discovery of the end-user over the internet ecosystem.

The app in the client side is communicating at the application layer with corresponding elements on the server side (marked also in red in the diagram). In order for a CAP to provide an application, it has to be present both at the client side (so that the *user-interface* is presented to the user) and at the server side (in order to *process* the requests that the user initiates and produce an answer). As explained in Chapter 2, two possible architectures can be implemented: app and web architecture.

The elements on the client side are supported by the OS, that is the general-purpose software running applications. OSs are embedded in user’s devices (such as mobile phones, PCs, tablets, voice assistants or desktops).

In summary, on the client side the internet ecosystem covers these elements:

- App architecture
    - App stores (discovery element)
    - Native apps (pre-installed or downloaded from app store)
- Web architecture
    - Search engines (discovery element)
    - Web browsers (interpreting code from downloaded web pages)
- OSs (enabling element)
- Devices

The user’s device communicates over the IAS provided by internet service provider (ISP) to look for the requested content and applications. The ISP uses the lookup service provided by Domain Name Systems (DNS) to locate the destination IP address[24] corresponding to the domain name which the user would like to access.

[24] For example, a domain name such as www.youtube.com could correspond to an IPv4 version address such as 208.65.152.0. In the case of IPv6 version, an example address could be 2001:db8:3c4d:15::1a2f:1a2b

Figure 6 – The elements in the DNS

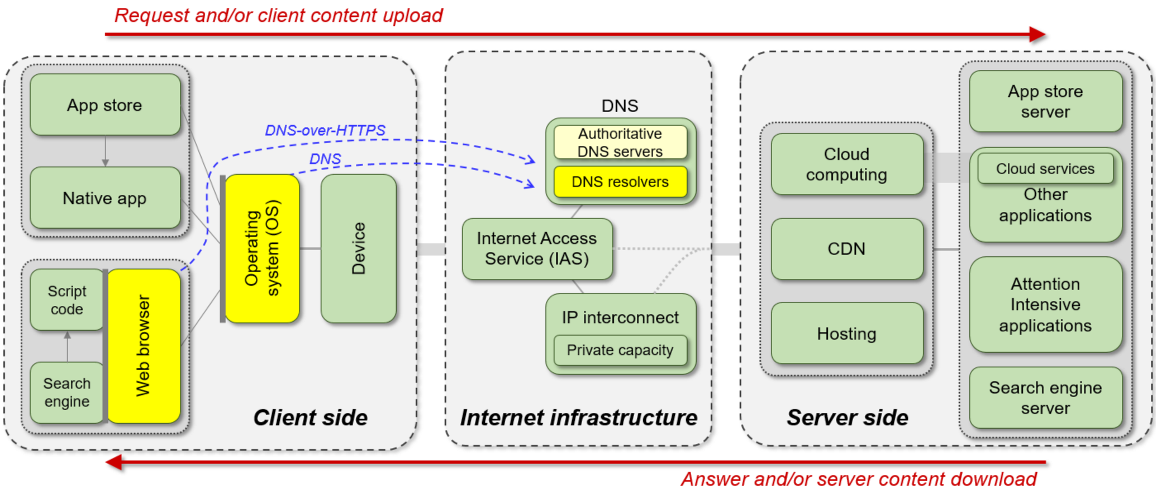


Figure 6 illustrates the part of the internet ecosystem related to the provision of DNS. The translation (name resolution) from textual domain name to numeric IP address is performed by a set of name servers. The DNS consists of two main types of name servers, referred as "DNS resolvers" (handling the iterative name request) and "authoritative DNS servers" (containing the hierarchical catalogue of domain names), respectively.

The client computers request name translation from a default DNS resolver, which is usually run by the ISP providing the IAS. However, nowadays, encrypted DNS is increasingly used, for example using DNS-over-HTTPS (DoH). This may typically be provided, if the web browser sends encrypted requests towards a particular DNS resolver (DoH resolver), which is run by the provider of the web browser, such as Google Chrome or Mozilla.

Regarding the domain names stored in the authoritative DNS servers, these are managed at the top level by the international organization ICANN (Internet Corporation for Assigned Names and Numbers). Entities acquiring top-level domain names (e.g. ".com") are called registries. Registries engage with registrars to conduct the business of domain name delegation to users. Many registrars are at the same time also acting as hosting providers.

If the destination address is outside the ISPs network, an IP interconnection service is used to transmit the request through the internet towards the CAP. The IP interconnection is either implemented as a shared resource (peering and/or transit) or as a dedicated, private capacity (typically used for interconnecting servers of larger CAPs).

In summary, for the internet infrastructure the internet ecosystem covers these elements:

- Internet Access Service (IAS)
- Domain Name System (DNS)
- IP interconnection

The distinction between the different elements on the server side of the ecosystem is nowadays becoming more blurred. *Distributed storage and CDNs* provide the means for delivering large amounts of content over the internet by storing it closer to the user, and *cloud computing* allows for easily scaling of resources for running server applications. However, there are hybrid models such as “cloud storage” and “cloud CDNs”, whereby the different techniques for storage and computing on the internet are becoming intertwined.

Furthermore, these underlying elements running applications may also be integrated with the server applications. The most obvious example is the cloud *services* executing on top of a cloud *computing* layer, both provided seamlessly from a single CAP. Other examples may be e-mail provided as webmail and content distributed by video sharing sites. The term “cloud” is in such cases used in a more general way to cover any element of servers connected to the internet. Thereby, the term “cloud” may sometimes also be used in a more unprecise way covering both underlying storage/computing as well as the specific server applications.

Cloud computing and cloud services represent a way to outsource IT resources. For a more precise use of the term “cloud”, it can be mainly categorised into three different types:

- *Infrastructure-as-a-Service (IaaS)* is understood as the basic layer of services, which encompasses access to IT infrastructure. With IaaS, the hardware is outsourced (servers, storage devices, etc.).
- *Platform-as-a-Service (PaaS)* adds middleware to the preceding in the form of a software environment that runs one or more applications. PaaS offers building blocks for developers to build own applications and software within a certain cloud environment. With PaaS, hardware plus a development and hosting software platform are outsourced.
- Finally, *Software-as-a-Service (SaaS)* is made of the specific applications, based on cloud infrastructure, typically accessed by users using a thin client, e.g. via a web browser. With SaaS, the outsourced resource is application software. For the general public, SaaS is often synonymous with “cloud services”, as it is the most visible part for users.

The analysis in this report distinguishes between *content storage* at third-party hosting services or in large scale caching services such as CDNs on the one hand, and applications running in *cloud computing* servers hosted by third parties (covering IaaS and PaaS) on the other hand. Furthermore, server-side applications can be divided between attention-intensive applications and other applications, including cloud services (SaaS).

In summary, on the server side the internet ecosystem includes these elements:

- Underlying storage and processing platform
  - Hosting (storage of information)
  - CDN (temporary storage of information, so-called caching)
  - Cloud computing (covering IaaS and PaaS)
- Application server elements corresponding to client-side app elements
  - App store server
  - Search engine server

- Servers for attention-intensive applications
- Servers for other applications (including SaaS)

Each of the elements is described and analysed in detail in Chapters 6 and 7, where the main issues regarding competition dynamics and openness for them are summarised. However, before going into the details of the analysis, it is important to highlight the recent evolution that has characterised the ways users access the internet ecosystem.

Users increasingly access internet-based services not only by means of “traditional” networking elements (e.g. modem, routers), but also through an integrated system of other relevant devices and applications, i.e. access to internet-based services is increasingly mediated by continuously evolving “smart” devices (e.g. smartphones, smart TV, voice assistants and other Internet of Things (IoT) devices), that in turn are often integrated with applications (e.g. voice assistants with search functionalities).

Figure 7 – The elements in the IoT ecosystem

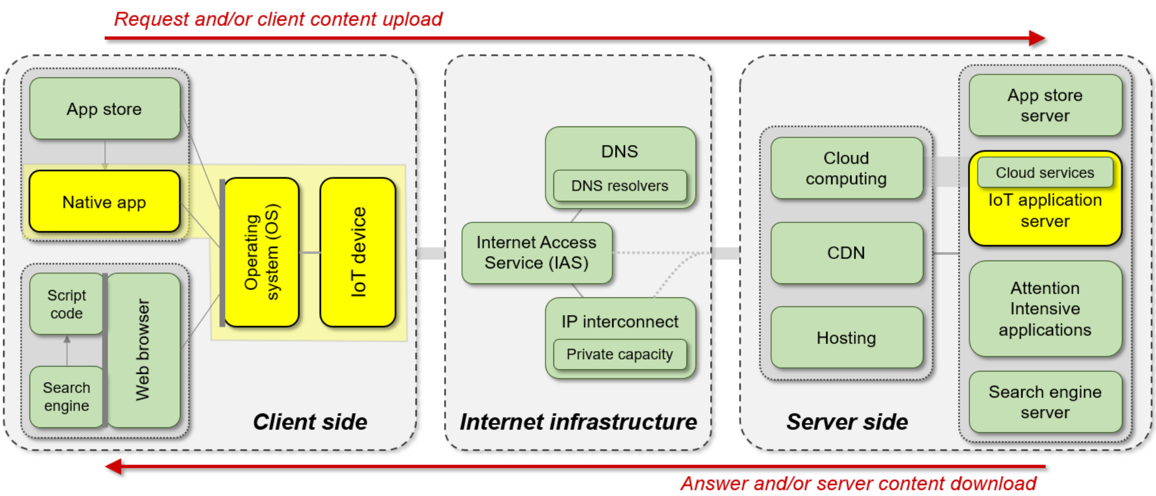


Figure 7 illustrates the specific variant of the internet ecosystem for the provision of services based on IoT devices. An IoT device is typically integrated tightly with the OS and app elements. In a comprehensive setup for professional use, the IoT provider takes the same role as the CAP, running an IoT application server, and the IoT device takes the same role as the smartphone and other user device. Given the relevance of the IoT developments in recent times, the report provides a dedicated competition and openness analysis on this matter.

In addition to specific developments on IoT, it is becoming increasingly evident that some specific elements in the internet ecosystem appear to be more influential in shaping the ways users access internet-based services. For example, OSs, app stores, web browsers and search engines seem to have a central role, as they are “enablers” of other application layer elements and shape users’ experience within the internet ecosystem. This report thus groups all these elements under the common umbrella of “enabling and discovery layer”.

More precisely, such elements are crucial as they provide resources, technical means and contractual arrangements that influence the ways users access internet-based services. As an example, OS settings can have a strong influence on which apps can run on a specific device, and which performance they can ensure on a device. App stores are crucial for users to discover, select, download, rank, install and update apps. Web browsers are also important as they display content for users and they influence the speed of webpage loading, their design and operation etc. Other CAPs such as search engines are also very relevant, as they can be a powerful tool to steer users towards certain internet-based services, thanks to the prominence they are able to give to some of them.

There is another group of application layer's elements, such as social media and video-sharing platforms, that are particularly good at capturing the attention of users for long periods of time. Given this, they might be able to "nudge" users and direct traffic towards specific content or applications. Those are "attention-intensive applications" that might also be particularly important in influencing users in using specific internet-based services. Even if there are many different applications that are designed to capture consumers' attention for long periods of time, the analysis in this report focuses here on a selection of them, namely social networks and video-sharing platforms. Those services are characterised by the fact that they enable the exchange of user-generated content between different groups, including business users and consumers. This particular feature of those services enables the creation of communities of users whose attention is captured mainly by the process of exchanging information regarding personal, societal and political issues.

Lastly, there is a third group of application layer elements, that include among others, streaming and video-on-demand (VoD) content providers, e-commerce platforms, cloud services or number-independent interpersonal communications services (NI-ICS), that were grouped under the label of "other applications". This kind of applications might also be relevant in influencing the ways users access audio-visual content (e.g. streaming and VoD providers), store and process information they care about, communicate with friends and businesses (e.g. NI-ICS) or choose and consume physical goods (e.g. e-commerce).

4. RELEVANT LEGAL PROVISIONS

A wide and varied body of European regulations comprises the European legal framework relevant to the various actors in the Internet ecosystem. Regulations can be specific to certain sectors or specific modes of conduct in markets found throughout the internet. Regulation is set in place to protect rights of users and prevent market distortions / failures, for instance by lowering barriers to entry and by promoting innovation, openness, interoperability, transparency and non-discrimination.

4.1 Internet access services and IP interconnection networks and access

The electronic communications services, responsible amongst others for the public's access to the internet, are regulated through the EECC[25] and its implementation in national law. The EECC merges and rearranges the former four distinct Directives[26] that constituted the electronic communications framework and forms the latest stage in the regulatory framework supporting the liberalisation of the European electronic communications market, aimed at achieving several general objectives as per Article 3(2) EECC including sustainable infrastructure competition to ultimately benefit users in terms of choice, price and quality of electronic communication services. Most of the regulatory aspects of the element IAS are addressed in the EECC and the Open Internet (OI) Regulation. [27]

At the core of the EECC is the mandate for national regulatory authorities (NRAs) to perform ex ante market analyses on national electronic communications markets and, consequently, to subject undertakings with significant market power (including ISPs) to wholesale network access obligations, in order to ultimately reach effective competition in ECS markets. The EECC complements the market analysis procedure with symmetrical regulation as another form of wholesale access regulation, through which competitors can obtain wholesale access to electronic communications infrastructure where duplication by competitors is not economically feasible. Both forms of regulation provide entrants with an opportunity to participate in retail competition where effective infrastructure competition is not economically feasible due to high barriers to entry. Furthermore, the EECC contains several universally applicable provisions on access and interconnection between electronic communications networks.

European net neutrality is enshrined in the OI Regulation. The OI Regulation guarantees the openness of publicly available IAS. The concept of openness in this context should guarantee network neutrality, i.e. non-discriminatory transmission of internet traffic to and from users, in order to ensure the continued functioning of the internet as an engine of innovation. Furthermore, the OI Regulation promotes technological neutrality of user equipment used to access the internet.

---

[25] Directive (EU) 2018/1972 of 11 December 2018 establishing the European Electronic Communications Code. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32018L1972.

[26] The EECC repealed Directives 2002/19/EC (Access Directive), 2002/20/EC (Authorisation Directive), 2002/21/EC (Framework directive), and 2002/22/EC (Universal Service Directive). Directive 2002/58/EC (ePrivacy Directive) and. Directive 2008/63/EC on competition in the markets in telecommunications terminal equipment continue to be in effect at the time of writing.

[27] Regulation (EU) 2015/2120 of 25 November 2015 laying down measures concerning open internet access and amending Directive 2002/22/EC on universal service and users' rights relating to electronic communications networks and services and Regulation (EU) No 531/2012 on roaming on public mobile communications networks within the Union.
https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex%3A32015R2120.

4.2 Digital Services and Platforms

The DMA[28] contains ex ante prohibitions and obligations for some large platforms defined as "gatekeepers" for the aim of creating contestable and fair markets. The DMA attempts to tackle bottlenecks for entrants in markets dominated by one or several gatekeepers. The introduction of regulations in the sector emerges after several long-lasting ex post investigations and rulings on cases of abuse of dominance [29] by large technology companies, such as the European Commission's (EC) Google Android[30] Decision.

A set of specific services of the economy, identified as core platform services fall within the scope of the DMA, namely online intermediation services, online search engines, online social networking services, video-sharing platforms, NI-ICS, OS, and cloud computing services, virtual assistants, web browsers, as well as any online advertising services provided in conjunction with these core platform services.[31] The set of obligations for gatekeepers includes, among others, mandates of interoperability and openness, prohibitions of price parity clauses, steering, bundling and self-preferencing, and limitations on the anti-competitive usage of aggregate user data.

Businesses dependent on two-sided platforms may be at risk arising from the imbalance in market power and information. The aim of the Platform to Business (P2B) Regulation[32] is to remedy such risks by mandating transparency, fairness and effective redress from platforms when providing services to businesses. Transparency obligations for platforms concern conditions of restriction, suspension and termination, ranking of search results, differentiated treatment and access to data.

The Digital Services Act[33] (DSA) modernizes the liability regime for online intermediary services, as originally established in the e-commerce Directive[34] and covers all online intermediary services, including "'mere conduit" services, caching services, hosting services and online platforms. Those IASs which are classified as '"mere conduit"[35] services benefit

[28]Ibid footnote 10
[29] Articles 101 and 102 of the Treaty on the Functioning of the European Union.
[30] Case AT.40099.
[31] The agreement in the trialogue among the European Parliament, the Council and the EC is finally extending these core platform services also to web browsers and virtual assistants.
[32] Regulation (EU) 2019/1150 of the European Parliament and of the Council of 20 June 2019 on promoting fairness and transparency for business users of online intermediation services; https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex%3A32019R1150.
[33] Regulation (EU) 2022/2065 of the European Parliament and of the Council of 19 October 2022 on a Single Market For Digital Services and amending Directive 2000/31/EC (Digital Services Act): https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32019R1150&from=en
[34] Directive 2000/31/EC of the European Parliament and of the Council of 8 June 2000 on certain legal aspects of information society services, in particular electronic commerce, in the Internal Market ('Directive on electronic commerce'); https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=celex%3A32000L0031.
[35] Article 3, para. g(i) of the DSA declares that a 'mere conduit' service *consists of the transmission in a communication network of information provided by a recipient of the service, or the provision of access to a communication network*.

from liability exemptions for the content of the information that is being transmitted, since they do not control or manipulate the data being sent from one endpoint to another over the internet. Under some conditions[36], neutral providers of caching and hosting services benefit from liability exemptions in a similar manner. Online platforms[37] as a type of hosting service also benefit from liability exemptions in a similar manner, however they will be subjected to additional due diligence obligations regarding the hosted content, and the obligation to have a notice-and-takedown procedure in order to provide for the reporting of illegal content present on the platform.[38]

4.3 Data

Data, and especially personal data, forms an important aspect of the internet ecosystem and is subject to regulatory scrutiny from different policy perspectives. Personal data forms an input to ads-funded online services which are therefore often possible to provide their services free of monetary charge to the user. Given that the user is typically more price-sensitive and that the provided data is less tangible than a monetary fee, the user will use the service more often than otherwise. Data on consumer behavior in dynamic e-commerce markets can provide an important advantage to the platforms compared to their business users. Furthermore, data forms an essential input for the development and functionality of innovations such as Artificial Intelligence (AI) and IoT.

The commodification and commercial exploitation of personal data may cause friction with the fundamental rights to privacy and data protection enshrined in the General Data Protection Regulation[39] (GDPR). The right to data protection includes the right to be forgotten, which gives people the right to have their personal data cleared from search results on search engines and social media. In addition, the right to data portability foreseen in the GDPR allows data subjects to export their personal data in a structured, commonly used, machine-readable and interoperable format, as well as to upload those file(s) to another data controller. Such data portability, subject however to the necessary safeguards, can promote switching, interoperability and remedy potential lock-in practices.

---

[36] Conditions for such liability exemptions for hosting providers are the hosting provider not having knowledge of the illegality of hosted content, and the expeditious removal or blocking of such content upon obtaining knowledge of said content.

[37] Article 3, para. i of the DSA proposal defines 'online platform' as *a provider of a hosting service which, at the request of a recipient of the service, stores and disseminates to the public information, unless that activity is a minor and purely ancillary feature of another service and, for objective and technical reasons cannot be used without that other service, and the integration of the feature into the other service is not a means to circumvent the applicability of this Regulation.*

[38] Article 16 of the DSA

[39] Regulation (EU) 2016/679 of the European Parliament and of the Council of 27 April 2016 on the protection of natural persons with regard to the processing of personal data and on the free movement of such data, and repealing Directive 95/46/EC (General Data Protection Regulation) https://eur-lex.europa.eu/eli/reg/2016/679/oj.

There are several legislations or legislative proposals concerning data: provisions on data portability set out in the GDPR and the DMA, the Regulation on a framework for the free flow of non-personal data in the EU[40] and those on intellectual property rights to data from the Database Directive[41] and general copyright law. Moreover, the draft Data Act elaborates on data portability and interoperability and provides for the publication of a rulebook defining implementation and compliance tools, of standard contractual clauses, and technical specifications, as well as a monitoring mechanism of switching barriers.[42]

The proposed ePrivacy Regulation[43] is set to replace the current ePrivacy Directive and complements and particularises the GDPR with provisions aimed at protecting the online privacy of users, such as (new) rules on cookies, spam and telemarketing for electronic communications service providers.

4.4 Schematic diagram of the relevant legal provisions

Table 1 – Relevant legal provisions

Regulation	**Main subject(s)**	**Main objective(s)**	**Main Elements concerned**
EECC	ECN, ECS providers	Competition, Access, interoperability, user rights, promotion of competition	IAS, other applications (NI-ICS)
OI Regulation	IAS providers	Innovation, Openness, transparency, non-discrimination	IAS
DSA*	Providers of intermediary services	Content moderation, protection against illegal content, transparency, online user protection	Hosting, CDN, Cloud, some enabling and discovery layer elements (e.g. search engine), attention-intensive applications
DMA	Gatekeepers in markets	Contestable and fair markets	Devices, enabling and discovery layer elements, attention-intensive applications, other apps

[40] Regulation (EU) 2018/1807 of 14 November 2018 on a framework for the free flow of non-personal data in the European Union. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32018R1807.
[41] Directive 96/9/EC of 11 March 1996 on the legal protection of databases. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex%3A31996L0009.
[42] Proposal for a Regulation on harmonised rules on fair access to and use of data. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52022PC0068.
[43] Proposal for a Regulation concerning the respect for private life and the protection of personal data in electronic communications and repealing Directive 2002/58/EC. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52017PC0010

P2B	Platforms	Transparency, fairness, redress	Enabling and discovery layer elements, some attention-intensive applications and other applications
GDPR	Data controllers, data processors	Data protection	Cloud computing, Enabling and discovery layer elements, attention-intensive applications, other apps
ePrivacy Regulation*	ECS providers	Privacy and data protection in electronic communications	IAS
Data Act*	IoT device manufacturers, Data processing services providers	Fair and innovative data economy, business to business (B2B) and business to government (B2G) Data sharing	Cloud computing, IoT

* Legislative proposal / Not yet adopted at the time of drafting this report

5. MAIN ACTORS OF THE INTERNET ECOSYSTEM

As explained in Chapter 3, the internet ecosystem comprises a large number of different elements that are operated by many different actors. Some of these actors are only present on one or on very few elements, while there are some actors operating a significant number of elements in an integrated way. This chapter presents a general view about the main actors providing the different elements, with an emphasis on key actors covering several elements and configuring "provider-specific ecosystems" within the whole internet ecosystem.

These provider-specific ecosystems allow, in many cases, for leveraging effects from one element to other elements. They may also provide the ability to use data derived from one element in another element, which also contributes to these leveraging effects, as it allows for providing a better user experience. Additionally, the ability to use ancillary services (such as payment or authentication) in parallel with these elements further allows for this leveraging effect.

For selecting the main actors to be analysed, BEREC has considered the Big Tech companies (Google, Apple, Meta, Amazon and Microsoft) as the firms covering many elements in a more integrated way and configuring provider specific ecosystems. These internet-based platforms also tend to raise more potential issues related to competition dynamics, as the antitrust cases show,[44] and are also key candidates to be considered as gatekeepers for different elements

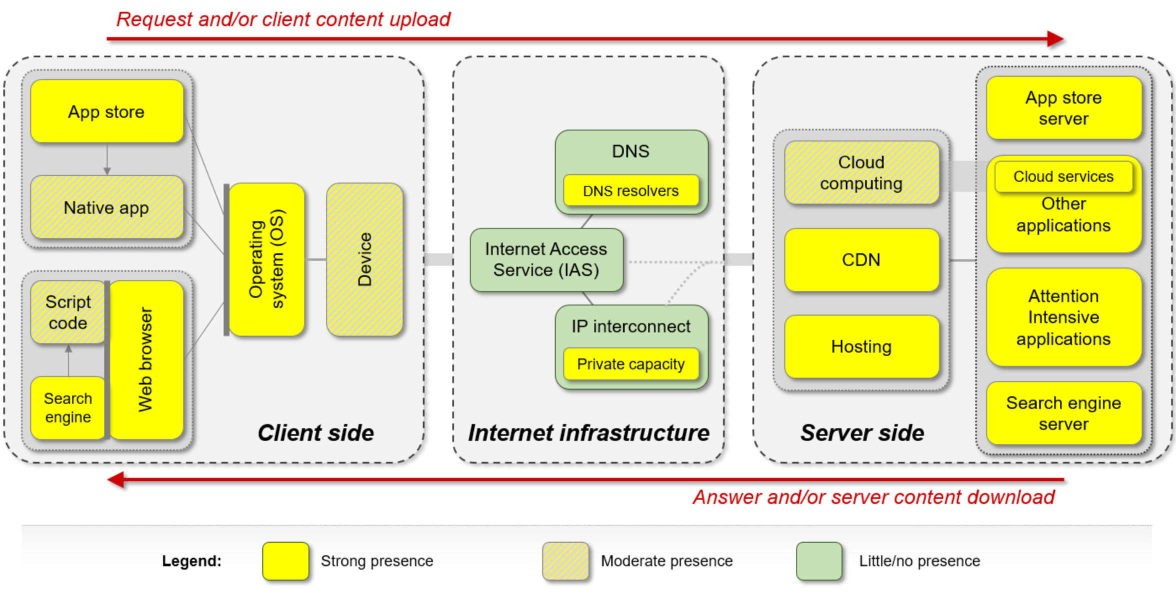
[44] Examples for relevant closed antitrust cases are AT.39740 Google Search (Shopping) and CASE AT.40099 Google Android.

under the DMA. In addition to these platform providers, BEREC has analysed the role of ECS providers, since they are key players for exchanging information between the client and the server side. The IAS provided by these actors falls under the regulatory scope of BEREC.

The illustrations in the subchapters below show a qualitative assessment on the presence of the corresponding actor in the different elements. An element filled in full yellow indicates that the actor under study has a remarkable presence offering services related to the element, a light striped/shaded yellow tone signals that the actor has a moderate presence not being one of the key actors for the element, and the green colour indicates no presence or a negligible one compared to other actors.

5.1 Alphabet

Figure 8 – The provider-specific ecosystem of Alphabet



Alphabet is a multinational US-based company offering a large variety of technology services to customers and businesses globally. Starting off as a search engine start-up in 1998, Google expanded over time into different markets on both the client and server side. In 2021, Google's holding company Alphabet reported a global annual revenue of $257.63 billion[45], mainly coming from advertising. The Google Search website is the most visited website in the world and Google's search engine has a market share of 92.7% in Europe (see Figure 15). In 2006,

[45] GOOG Exhibit 99.1 Q4 2021 (abc.xyz) https://abc.xyz/investor/static/pdf/2021Q4_alphabet_earnings_release.pdf

Google acquired the currently second most visited website, YouTube.[46] The Chrome web browser was launched by Google in 2008 and currently holds a 58.7%[47] market share in Europe (see Figure 17).

Google entered the mobile industry with the acquisition of the Android OS in 2005, which currently runs on 63.6%[48] of smart devices in Europe and forms a key element of the client side of the internet ecosystem (see Figure 16). The Android OS is, at its core, an open-source platform, open to third party app stores. However, this platform is by and large under Google's control through its control over the pre-installed application store integrated in the OS, namely the Google Play Store and related services.

Typically, devices with an Android operating system are bundled with several pre-installed Google applications, such as the Chrome browser, the Google Play Store, Google Search, Google Maps, Google Voice, Google Docs, Duo (a video call app), Messages, Google Drive, and Gmail. Payments within the Android OS are made available through Google Pay. While the Android system with the Google apps is licensed to Original Equipment Manufacturers (OEMs) of smartphones and tablets, Google also offers the ChromeOS operating system to OEM of laptop computers, thus spreading its reach to other types of end user devices. The different elements offered by Google form a provider-specific ecosystem of applications on the client side, ranging from e-mail through authentication and online payment systems to OSs, cloud services, messaging services and social media, all of which are made accessible to users through a single Google account. Google apps are typically also available and widely used through web browsers and are made native to third party OSs such as iOS. Google is also present in the market for devices, commercialising laptops and mobile phones, although is far from being a leader on it, as most of the devices using ChromeOS are provided by OEMs. Following the acquisition of Fitbit, Alphabet is also active in the market for fitness trackers. On voice assistants, Google is a relevant player with its Google Assistant, which is available on its "Google Home" device, amongst others.

In order to expand the transport capacity between its data centres, Alphabet has invested in submarine cables. Furthermore, Alphabet offers DNS services, both through traditional DNS resolvers and DNS over HTTP (DoH). In the US, Alphabet has expanded into ISP markets with Fibre to the Home (FttH)-deployment through Google Fibre and the Google Fi Mobile Virtual Network Operator (MVNO). With the objective to serve directly its content and applications to users, Alphabet developed hosting solutions which were subsequently made available to third party businesses as a CDN, enterprise cloud computing solutions (Google Cloud Platform), and cloud applications for end-users (Google Docs, Google Drive), as well as cloud gaming (Google Stadia). Alphabet also uses its "Google Global Cache" platform to

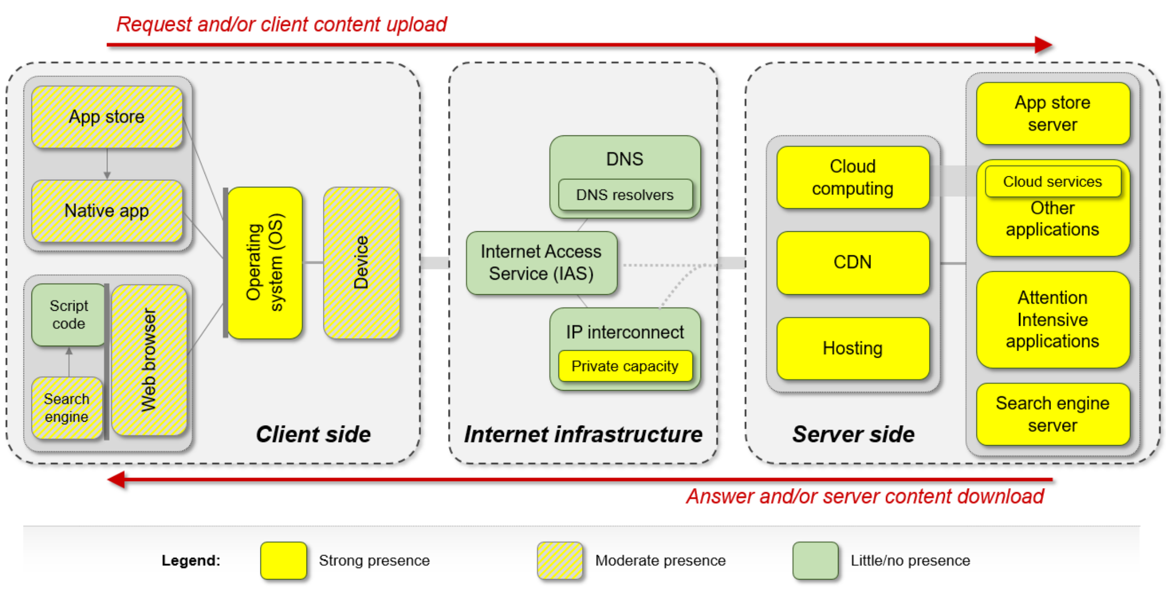
[46] YouTube has over 2 billion unique users each month, which relates to 95% of all internet users. YouTube User Statistics 2022 | Global Media Insight https://www.globalmediainsight.com/blog/youtube-users-statistics/
[47]See https://gs.statcounter.com/browser-market-share/all/europe
[48]See https://gs.statcounter.com/os-market-share/mobile/europe/#monthly-201412-202112

distribute their own content and has established partnerships with telecoms operators in Europe in different areas, such as cloud services, and 5G.

Google is also a market leader in attention intensive applications for content loaded by users through its ownership of YouTube. Furthermore, Google operates key applications used by many users, such as Google Chrome, Search, Gmail, Google Calendar, Google Maps and Google Docs. This position as market leader enables Google to obtain and analyse very large amounts of information from the users of its ecosystem, including information on the way users perform online shopping and comparing products and services, the user's location and movement, the way in which websites are visited and applications are used, the sharing and consumption of content, the way in which users communicate and with whom, etc. The insights gleaned from this user data then allows Google to optimize its existing services and provide new services, thereby reinforcing its position as a market leader in online advertising services through internet-based services, among others.

5.2 Microsoft

Figure 9 – The provider-specific ecosystem of Microsoft



Microsoft was founded in 1975 by Bill Gates and Paul Allen and had success with its OS MS-DOS for the IBM compatible PC from 1980s, and later with the OS enhanced with graphical user interface marketed as Microsoft Windows. Microsoft has grown to an US-based multinational corporation based on its Windows line of OS. Alternatives to the Windows OS, such as macOS and Linux, have minor market shares. Microsoft had an annual total turnover for all market segments of $168 billion in 2021.[49]

Microsoft is the global market leader in desktop OS[50] and a major provider of office application suites through its Microsoft Office product line.[51] Originally, the applications in the Office suite had to be installed manually from discs (CD/DVDs, etc.), but today its app store, Microsoft Store, can be used for software distribution. Microsoft is also providing some hardware products, with its own brand of laptops (Microsoft Surface), but relies on OEM agreements with device manufacturers for other devices using its OS. Furthermore, Microsoft produces game consoles (Xbox) with associated cloud-gaming abilities. On voice assistants, Microsoft has its own virtual assistant (Cortana) that can be used on devices using its OS.

When the internet became commercialised in the 1990s, Microsoft expanded into web products. Their web browser Internet Explorer was launched in 1995 and gained a dominant position in the early 2000s. In 2009, the EC investigated the bundling of Internet Explorer with Windows OS for harming competition. Microsoft then committed to allow competing browsers by letting users choose from a list. Soon after, in the early 2010s, Google Chrome became the most popular browser with a market share of 59% in Europe as of April 2022.[52] Microsoft released its Edge browser in 2015. Regarding search engines, Microsoft launched MSN Search in 1998 and rebranded it to Bing in 2009.

Microsoft entered the mobile market in the 2000s, and when the smartphone industry boomed in the late 2000s, it replaced its Windows Mobile OS with Windows Phone OS. In 2011 Microsoft set an alliance with Nokia, and in 2014 Microsoft acquired Nokia's Devices and Services division and established its subsidiary Microsoft Mobile. However, in 2017 Microsoft announced that it abandoned its mobile business.

Microsoft entered the CDN/cloud computing market in 2008 with its Azure Platform. Azure provides IaaS, PaaS and SaaS. The latter was launched in 2011 and is branded Microsoft 365 (formerly Office 365). With Azure, Microsoft is now able to partner with the telecommunications industry, by providing a large set of services such as virtualised core networks or edge computing. In 2011 Microsoft acquired Skype Technologies, a provider of video conferencing services, and launched its own Skype for Business. Microsoft Teams, an interpersonal communication application widely used in business contexts, was later launched as an integrated communications service to be used together with its Microsoft Office suite. In 2016 Microsoft acquired LinkedIn, a social network predominantly used by business professionals.

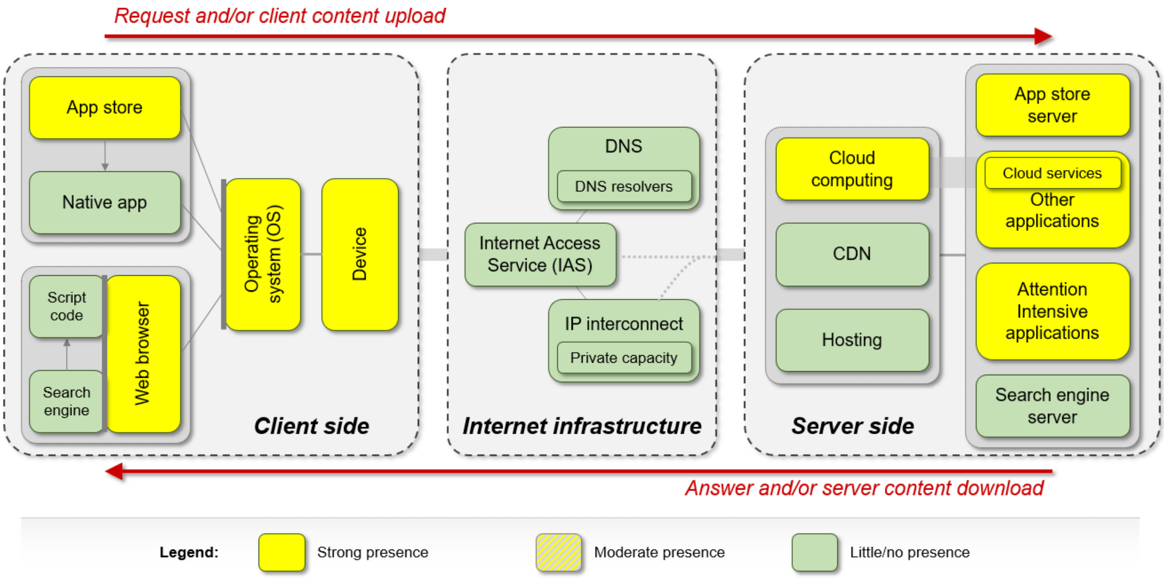
Microsoft provides its own authentication and payment services (e.g. Microsoft Authenticator and Microsoft Pay), which leverages the Microsoft position in the many services provided and reinforces the user attachment to the Microsoft ecosystem. A lot of user data is available to

[49] See https://www.microsoft.com/en-us/investor/earnings/fy-2021-q4/press-release-webcast
[50] See https://gs.statcounter.com/os-market-share/desktop/worldwide
[51] See https://www.datanyze.com/market-share/office-suites--370
[52] See https://gs.statcounter.com/browser-market-share/all/europe

optimise user experience and to reinforce the market position. In summary, the key element is the Windows OS, being the market leader for desktops and laptops, assisted with cloud-based data centres for internet-based applications.

5.3 Apple

Figure 10 – The provider-specific ecosystem of Apple



The US-based multinational company Apple reported a global total net sale of $365.8 billion ($89.3 billion in Europe)[53] over 2021. Initially focusing on computers, this technology company expanded over time to the sale of high-end laptops, audio devices, smartphones, and smart devices. Both hardware and the OS of these products are produced by Apple. In the audio-visual content segment, Apple has been active through Apple Music and more recently through its video streaming platform AppleTV+. On voice assistants, Apple has its own virtual assistant (Siri) that can be used on devices using its OS.

Apple's iPhone and iPad[54] are tied to the operating system iOS/iPadOS, whose functionality can only be expanded through the installation of applications through the Apple App Store exclusively. The installation of alternative app stores or the side-loading of applications is blocked by technical means in the OS. On the iPhone, third party app developers compete with Apple's native applications (e.g. Apple Mail, Safari, Apple Maps), third party browsers are

[53] See 10-28-21 Apple Reports Fourth Quarter Results https://www.apple.com/newsroom/pdfs/FY21_Q4_Consolidated_Financial_Statements.pdf

[54] The iPhone holds a market share of circa 35% in Europe, whereas the iPad's market share is nearly 49%. See https://gs.statcounter.com/os-market-share/mobile/europe https://gs.statcounter.com/os-market-share/tablet/europe

required to operate through Apple's Safari WebKit browser engine, and payments are to be exclusively operated through Apple's payment system. The closed ecosystem of devices, OSs, app stores, and apps which can be operated through Apple's authentication, account and password management, and payment systems allows Apple to optimise compatibility and user experience, and to horizontally expand its user base. Same as for other provider-specific ecosystems, significant amounts of usage data allow Apple to improve their products and services. MacOS, the operating system of iMac and MacBook computers which has an estimated European market share of 16%[55] is more open in comparison to iOS to third party software developers. Like other actors, Apple also provide its own interpersonal communication services for Apple users (Facetime and iMessage). Furthermore, Apple provides the voice assistant Siri, health tracking apps, consumer IoT products and content (e.g. Apple Music).

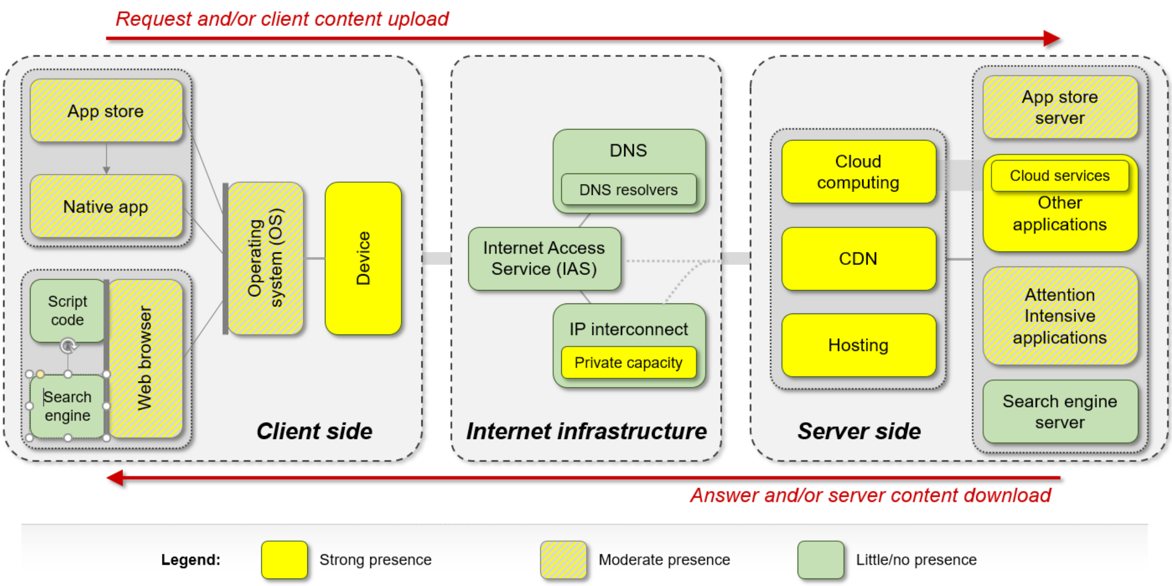
Apple's OSs storage capacity can be expanded with Apple iCloud+ service. The iCloud+ offer includes iCloud Private Relay (IPR), a service similar to VPN that routes web traffic through separate internet relays, which is seen by Apple as a way to enhance browsing privacy. Apple's App Tracking Transparency (ATT) allows its users to review categories of personal data tracked by apps available in the AppStore.[56] Together with IPR, ATT fits in with Apple's effort to market itself as a secure brand in terms of data privacy with a business model not dependent on targeted advertising.

[55] Market share of the European market for desktop and laptop OS, source: https://gs.statcounter.com/os-market-share/desktop/europe

[56] See https://support.apple.com/en-us/HT212614

5.4 Amazon

Figure 11 – The provider-specific ecosystem of Amazon



Amazon is an US-based international technology company providing e-commerce, cloud computing services, consumer electronics and content. Amazon is the largest Internet company in terms of revenues[57] with close to $470 billion in 2021. Most of Amazon revenues are generated through the retail e-commerce activity, followed by third-party seller services, Amazon Web Services (AWSs) cloud services, subscription services including Amazon Prime and advertising services.

Initially founded in 1994 as an online bookstore, Amazon soon expanded its e-commerce service to include other products, such as music and video, consumer electronics, software, toys and video games, finally becoming the leading retail online company in the US[58] and Europe[59] for all kinds of goods. By 2000, Amazon launched Amazon Marketplace, allowing business users to sell their products on Amazon website in a fully integrated manner, including logistics services as well as on-platform advertising and analytics. Additionally, Amazon offers Amazon Mechanical Turk, a crowdsourcing marketplace for discrete tasks to be performed with human labour. Over time, Amazon has diversified its core business model as online marketplace towards other areas.

---

57 See https://www.statista.com/statistics/277123/internet-companies-revenue/
58 Amazon owns 41% market share in the US, as of October 2021, according to statista.com
59 As of April 2021, Amazon appeared as the leading online marketplace in Europe based on number of monthly visits (981 million), according to statista.com

AWSs was launched at the start of the 2000s to provide third-party retailers with tools to build their websites. By 2006, AWSs expanded with the Elastic Compute Cloud (EC2) and Simple Storage Service (S3) products, being one of the first companies to introduce a pay-as-you-go cloud computing model. Nowadays, AWSs portfolio includes an extensive suite of cloud computing services (IaaS, PaaS and SaaS), hosting/CDN and networking services for business customers. With a wide footprint of data centres in the world[60], Amazon is the worldwide market leader of cloud infrastructure service providers, with a 33% market share[61] as of the end of 2021.

Amazon launched its paid subscription service Prime in 2005, to deliver goods purchased through its e-commerce platform in one or two days. Through the years, Amazon Prime has extended its membership benefits to include additional internet-based services, such as streaming of video, music, e-books and gaming. Amazon does not limit itself to distributing content, but also incorporates its own audio-visual content production, as Prime Video also offers the distribution of films and TV series produced by its own subsidiary Amazon Studios. Prime has more than 200 million subscribers worldwide, with presence in 22 countries.[62]

In 2014 Amazon acquired Twitch, one of the leading online video live streaming service mainly focused on video games and eSports. With this product, Amazon expands towards attention-intensive applications market. In addition, in 2020 Amazon entered the cloud-gaming market with its offer "Amazon Luna".

Given the exponential increase of bandwidth demand, same as other Big Tech companies, Amazon has taken a more active role in deploying its own network infrastructure. It prioritizes the rollout of new submarine cables to interconnect their data centres worldwide, and has also launched an ambitious project to build its own satellite network[63] aimed to provide its own IAS to users. In addition, Amazon is leveraging its position as a cloud computing and networking infrastructure provider to expand its services portfolio into the ECSs domain. Products such as AWSs Direct Connect, the launch of services to design and operate mobile access networks (5G Open-RAN) on AWSs cloud infrastructure[64], or the recently announced AWSs Private 5G could potentially compete/partner with ECS operators' offers.

Finally, although Amazon portfolio growth has mainly focused on the server side of the Internet ecosystem, Amazon is also present on the client side through the provision of consumer devices, mainly the Kindle e-reader, Alexa voice assistant, Echo devices and Fire tablets/TV.

[60] In Europe data centres are located in Ireland, Germany, UK, France, Sweden and Italy. Announced expansion to Spain and Switzerland.

[61] See https://www.statista.com/chart/18819/worldwide-market-share-of-leading-cloud-infrastructure-service-providers/#:~:text=According%20to%20estimates%20from%20Synergy,largest%20competitors%2C%20Microsoft%20and%20Google

[62] In Europe, Prime is present in Austria, Belgium, France, Germany, Ireland, Italy, Luxembourg, the Netherlands, Poland, Portugal, Spain, Sweden and UK.

[63] See https://www.aboutamazon.com/news/innovation-at-amazon/amazon-makes-historic-launch-investment-to-advance-project-kuiper

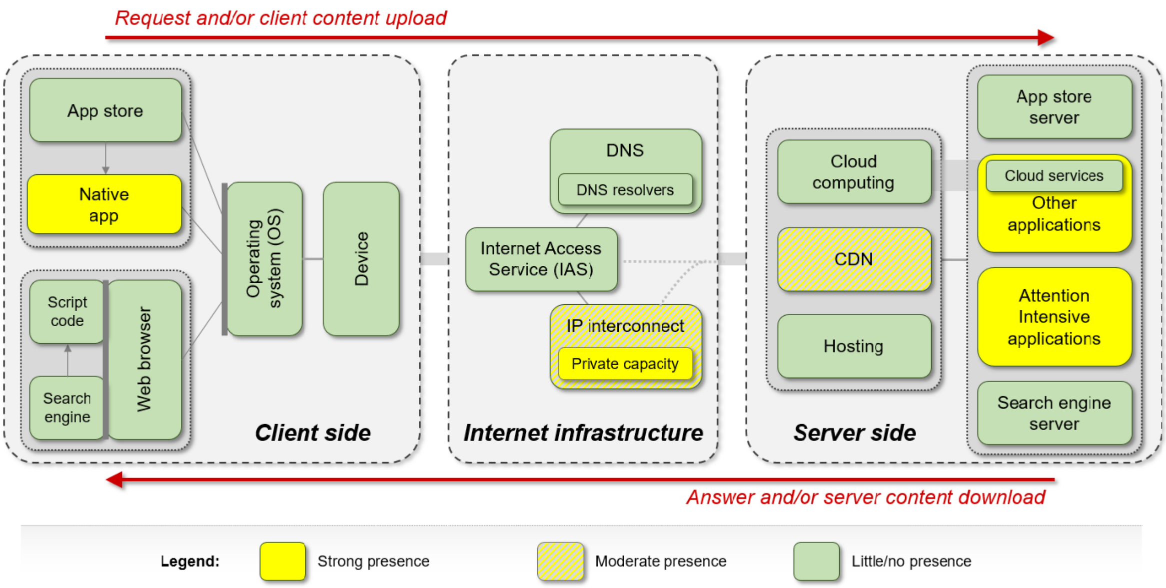
[64] See https://aws.amazon.com/es/blogs/industries/telco-meets-aws-cloud-deploying-dishs-5g-network-in-aws-cloud/

Amazon also developed its own OS (Fire OS), based on the Android Open Source Project, for Echo/Fire devices, and launched its own app store (Amazon Appstore). Its Alexa voice assistant also provides interpersonal messaging services among Amazon users.

Unlike Google, Microsoft or Apple competitors, Amazon's market position is not built around OS, but on its customer base on e-commerce platform. The vast amount of usage data collected through the platform and Prime services portfolio about consumers and business is constantly exploited. New features and tools for buyers and sellers are developed and made available only through the platform, reinforcing leverage effects and loyalty to the Amazon ecosystem. Additionally, the huge hosting capacities of Amazon data centres generate economies of scale and scope, leveraging Amazon's market position in cloud-based services within AWSs portfolio, where the list of (integrated) services has expanded to hundreds of different products (customer service, identity management, databases, Virtual Reality (VR)/ Augmented Reality (AR), IoT, Machine Learning (ML)/AI and more), influencing an increasing number of businesses to migrate their IT and applications to the cloud (e.g. Airbnb, BMW, General Electric, Netflix, Pfizer, Pinterest, SAP or Siemens are users of AWSs).[65]

5.5 Meta

Figure 12 – The provider-specific ecosystem of Meta



Meta is a US-based company focused on providing attention-intensive applications (Facebook, Instagram) and other apps (as WhatsApp) allowing users to share content and

[65] https://aws.amazon.com/solutions/case-studies/

communicate and businesses to advertise based on users' personal data. Facebook counts almost 3 billion monthly active users worldwide (427 million monthly active users in Europe) at the end of 2021.[66] WhatsApp and Instagram count around 2 billion monthly active users each (competitors Telegram and Snapchat each count "only" 550 million monthly active users). This highlights Meta's strong position regarding number-independent interpersonal communication services (analysed in the report under the category "Other applications").

Meta's turnover comes almost entirely (97%) from advertising and has reached $118 billion in 2021 ($29 billion for Europe) with an average increase of around 33% per year for the 2016-2021 period.[67]

Meta owns 21 data centres locations around the world and invests in its own network infrastructure such as submarine cables and terrestrial fibre networks, interconnecting their data centres with their Points of Presence (PoPs)[68]. Meta also deploys cache servers close to end users.

So far, Meta's operations on the client side have remained limited, and rather focused on complementing other ecosystems, such as Google's or Apple's ecosystems on the server side. This could change in the future, given the intense development of VR technologies, and the involvement of Meta in its "Metaverse" project consisting of an immersive 3D social platform and which could require network resources beyond what current networks can provide.

Meta launched in 2007 the Facebook Platform, which allows third-party developers to create their own 'consumer applications' that integrate with Facebook via APIs. But unlike 'traditional' applications running on the operating system on users' devices and providing a standalone service, Facebook's 'applications' are running on top of the social network service.

Given its large user base, Meta collects considerable amount of personal data, which enables Meta to (i) provide users with a personalized and smooth experience, (ii) to strengthen network effects by integrating third-parties applications or by providing services as authentication and payment (iii) to leverage its position to extend its market power to different areas, including advertisement.

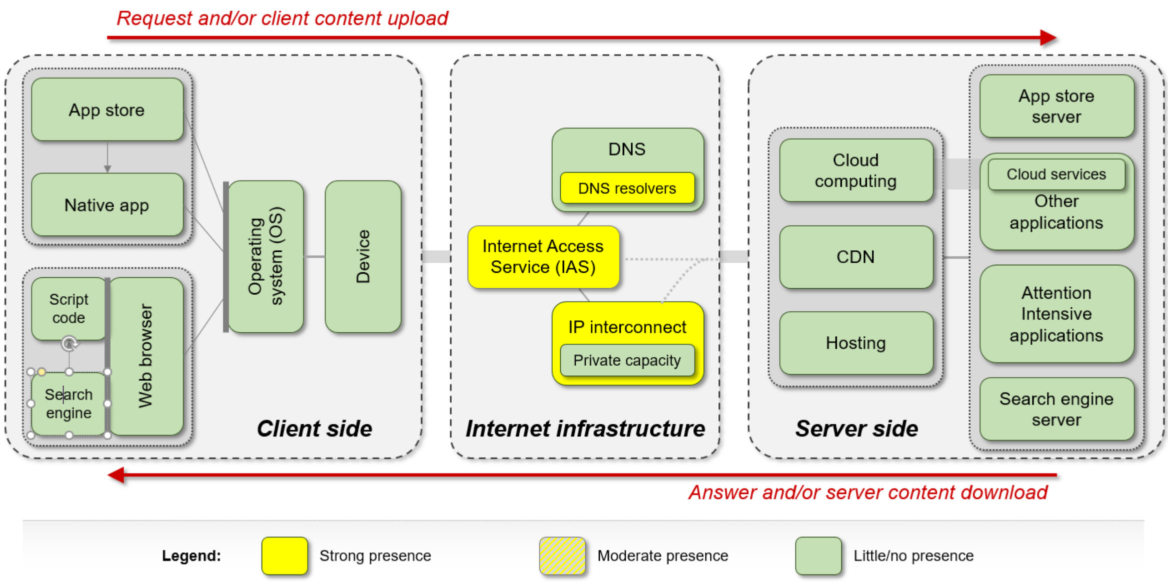
[66]See Meta, Q4 2021 results https://s21.q4cdn.com/399680738/files/doc_financials/2021/q4/Q4-2021_Earnings-Presentation-Final.pdf

[67] https://s21.q4cdn.com/399680738/files/doc_financials/2021/q4/FB-12.31.2021-Exhibit-99.1-Final.pdf

[68] In some cases, the investments are made in collaboration with ISPs which can then use part of the capacity of those infrastructures

5.6 Electronic Communications Service Providers

Figure 13 – The provider-specific ecosystem of ECS providers



Electronic communications service providers have typically a national footprint. However, some operators are providing ECS in many different countries (e.g.: Vodafone, Orange or Telefónica). The largest ones own and operate their own network infrastructure, nationally and also sometimes internationally.

In general, ECS providers are focused on ECSs, providing IAS and some of them (the largest ones with own infrastructure) also providing interconnection for other ISPs and CAPs.

ECS providers are generally not present on the client side, even if some operators supply customer premises equipment (CPE). However, some of them are also present on the other applications layer, providing, for example, apps or content through over-the-top (OTT) pay-TV services, e-mail or IoT services that are many times bundled with IAS services. Others are also partnering with cloud providers or integrate CDN/cloud computing services themselves, but they are not key actors on this element.

ECS providers compete with actors providing OTT interpersonal communications services (voice calls and instant messaging), such as Meta (via WhatsApp, Messenger), and to a lesser degree with other actors for content services, such as TV and video services. Cloud computing providers can partner and/or compete with electronic communications service providers, providing new services combining connectivity with their own cloud services.[69]

5.7 Conclusions

As analysed in this chapter, some of these actors configure a large provider-specific ecosystem around mobile and/or fixed OSs. This is the case for Google (based on Android), Apple (based on macOS/iOS) and Microsoft (based on Windows). Control of the mobile OS allows for also controlling app stores, as it is the case for Apple, where side-loading is not possible, or for Android, where although there are other app stores, Google Play is the dominant one.

Whereas both Google and Microsoft commercialise their own branded devices (e.g. Google Pixel, Microsoft Surface), their OS is also supported in devices from many different suppliers. Apple, on the other hand, restricts the compatibility of its OS to its own devices.

This aspect configures competition dynamics among actors that go beyond basic competition for the individual elements' market. In the context of mobile devices, Google's Android (supported by third party OEMs) is competing with Apple, while in the context of laptops and PCs, the competition is between Microsoft (also supported on third party OEMs) and Apple.

In a simplified view, Google and Microsoft adopt similar strategies, one of them for mobile and the other for PCs, mainly based on opening the use of their OS in third party devices, while Apple is relying on its integration between OSs and devices to compete with Google and Microsoft covering both fixed and mobile use of devices.

These three "provider-specific ecosystems" are competing for users to adopt their ecosystem, but it is important to note that once a consumer selects one of them, usually many other elements provided by that actor are by default used by the consumer, such as the app store or specific applications.

In addition, Google and Microsoft are key actors providing intensively-used applications available on these three OS-based platforms (such as the leading Google search engine and YouTube, the video sharing platform by Google; or Office suite in the case of Microsoft). These actors enjoy the ability to strengthen the position in applications by supporting their own services and applications with a richer set of APIs provided by the OS they control.

The positions of Meta and Amazon are different from Microsoft, Apple and Google, as Meta and Amazon's ecosystems are built around applications and not OSs or devices which are essentially complementary to the previously mentioned actors. The case of Amazon is especially interesting, as Amazon is a key actor on e-retailing and cloud services, but in the

[69] See for example the case of the recent announcement by Amazon on launching AWS Private 5G, a managed service for private cellular networks for enterprises (https://aws.amazon.com/es/private5g/)

last years Amazon has extended its ecosystem to cover also devices (at first e-book readers and now mainly voice assistants, but also tablets), its own OS used for their devices, and to VoD applications, as well as starting to provide services for designing and operating Open RAN and 5G networks through the Amazon cloud infrastructure.

The large internet-based platforms use authentication and payment ancillary facilities, smoothing the user experience and making it more convenient to use applications in the same ecosystem. The use of data collected in one element onto another elements also reinforces this effect. Therefore, in general, the more elements an actor controls and the more ancillary services are provided, the more likely it becomes that consumer inertia sets in, that is, once an end-user has selected a key element (such as the OS), she/he will stick to the corresponding actor for other elements, triggering an ecosystemic effect that leverages the actor's position from one market to another.

In any case, competition among different internet-based platforms is more complex than just provider-specific ecosystems competing among them. As seen in the analysis of this chapter, some elements from one actor can be used and are used in the ecosystem controlled by another actor, as it is the case for Google Search, Chrome, Edge or the Office suite.

ECS providers are a very different type of actor, as they are located at the network layer in between the client and the server side, providing electronic communications services. In general, ECS providers have not extended their reach to elements in the client side nor in the server side. Some of them are providing attention-intensive applications based on pay-TV that are in many occasions bundled with electronic communications services. ECS providers may also provide hosting and CDN services, but at the moment these actors are not key players on these markets. That does not imply that there are no points of friction with other actors, and especially some of the main actors analysed in this chapter.

Many CAPs are deploying their own physical infrastructure, such as CDNs or cloud computing servers, as well as network infrastructure, such as submarine cables, as alternatives or in addition to the infrastructure provided by ECN operators. While in some cases it can also be provided to third parties, the infrastructure deployed by CAPs is often aimed at carrying their own traffic. In this way, they are currently not directly competing, but rather complementing the infrastructure of ECN operators.

6. ANALYSIS OF COMPETITION DYNAMICS

6.1. Introduction

Highly-digitalised technological elements as those involved in the internet ecosystem are typically characterised by high, up-front investment and fixed costs, especially when they rely on physical infrastructures. As the analysis provided below shows, these markets frequently exhibit economies of scale and scope, as well as significant barriers to entry and expansion.

This is typically the case for access and interconnection elements, where ECS pro-competitive regulation in the last two decades has played a very important role in ensuring market entry, effective competition and innovation for the benefit of users.

When it comes to platforms, direct and indirect network effects play the most significant role on competition dynamics. Direct network effects are particularly strong in the case of some attention-intensive applications (e.g. social networks) and other applications like NI-ICS, while indirect network effects can typically be found in the enabling and discovery layer and in the application layer, where OSs, online marketplaces, app stores, search engines and social networking services play a fundamental role in connecting end-users with business users such as, respectively, CAPs, merchants, app developers and online advertisers. Network effects are also reinforced by the key role of data which create feedback loops. For example, the more people use a particular search engine, the more they will provide data to the search engine algorithm about the quality of the search results, e.g. by clicking on certain search results and not others. The search engine can thus provide more precise and relevant search results, eventually attracting new users[70]. This will in turn further inform the algorithms and make the platform's user base and services more attractive for advertisers (using personal data) and business users[71].

In some situations, such as in the case of devices, direct and indirect network effects, coupled with single-homing, significant switching costs and "default bias" towards certain services, as well as pre-installation and pre-configuration, can lock users into a specific service, even though this may have not been their preferred choice under different circumstances. Indeed, as shown in chapter 5, devices might be strongly connected with provider-specific ecosystems encompassing OS and app stores, and as a consequence, changing device provider might not be a convenient option for the user.

Finally, it is important to notice that a particular feature of competition dynamics in the case of platforms is the rivalry to provide the intermediation function in the control of and access to essential content, data or user groups. Thus, if many traditional firms compete mainly *horizontally*[72] platforms tend to compete *vertically.*[73] It means that the competitive process is about controlling access to crucial nodes, such as essential content, and data or other type of users.[74] In this setting, rivalry does not necessarily involve offering similar services, but it entails the provision of "alternative routes" to reach a given content, a set of data or a user group. Therefore, each platform tries to gain an "intermediation" position and works for "disintermediating" the position of a rival platform. For example, web browsers can

---

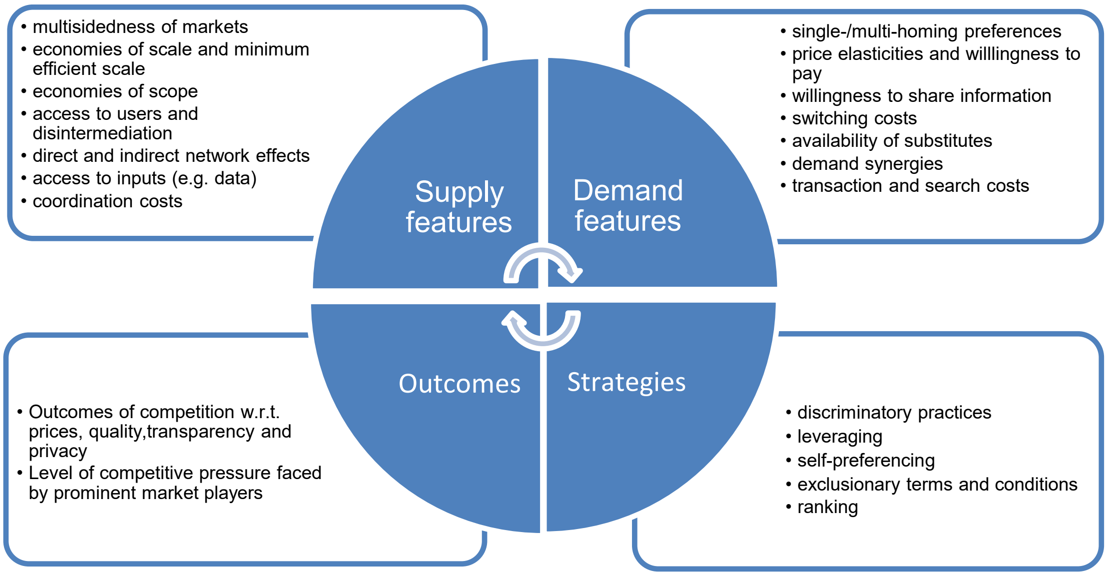
[70] User feedback loop
[71] Monetisation feedback loop
[72] I.e. by offering similar products and services at more competitive price or with a higher quality
[73] Digital Gatekeepers: assessing exclusionary conducts, De Bijl P. and van Gorp N., commissioned by the Dutch Minister of Economic Affairs and Climate, October 2019
https://www.researchgate.net/publication/349684657_Digital_gatekeepers_assessing_exclusionary_conduct
[74] E.g. end-users for business users

theoretically provide an alternative option to access services and content and thus "disintermediate" app stores.

In this report, the level of competition dynamics in the internet ecosystem is assessed for each of the elements according to 1) whether the element market is concentrated and 2) the existence of barriers to entry or expansion (either technical, legal or resulting from economic features), as well as 3) the strategies and behaviours (e.g. disintermediation, envelopment, refusal to interoperate, discrimination, etc.) of the players affecting inter-platform[75] and/or intra-platform[76] competition.

These aspects of competition dynamics of the internet ecosystem may be aggregated into supply and demand market features, strategies implemented by the main players and resulting outcomes (see Figure 14).

Figure 14 – Competition dynamics assessment



6.2 Analysis of the elements

6.2.1 Enabling and discovery layer elements

As explained in chapter 3, the enabling and discovery layer markets include OSs, web browsers, app stores, and search engines elements. The enabling and discovery layer allow

[75] Among direct competitors
[76] Between the provider and its business users

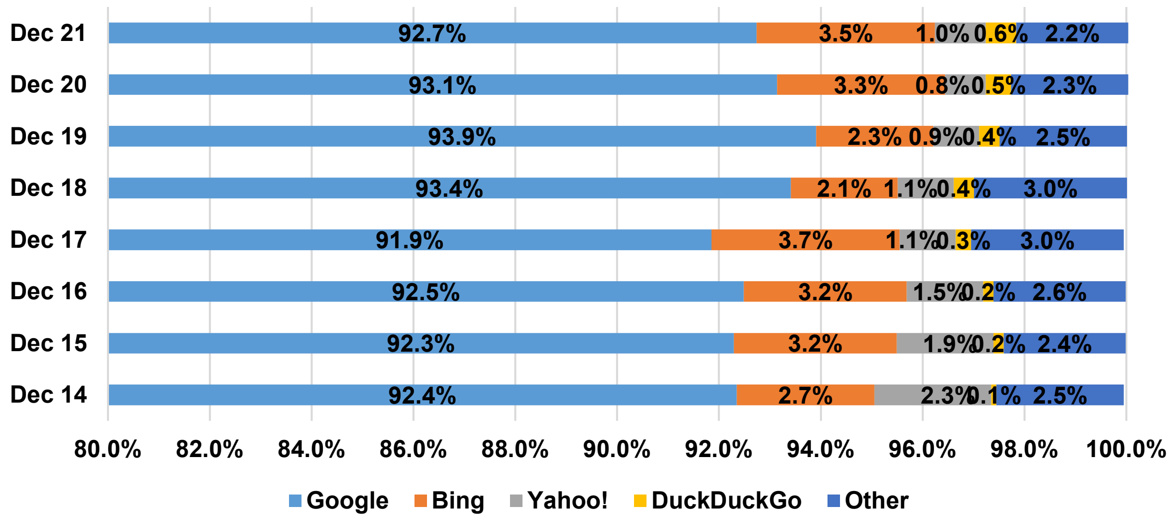
users to interact with the broad internet ecosystem in order to create, offer and access new applications, content and services.

All elements listed above are crucial in the internet ecosystem regarding competition dynamics. Indeed, on the one hand OSs and web browsers are powerful enabling tools, as they manage/control the access to some functionalities that may be critical for the correct functioning of the device, battery management, the allocation of resources and computing power to applications and influence Quality of Service (QoS) (e.g. how quickly content can be downloaded).

On the other hand, OS providers can make strategic decisions that may have a significant effect on compatibility and interoperability, eventually by preventing or enabling some applications to run on a certain device. Web browsers are also important, as they set the quality parameters that affect the webpages performance, and the way web apps perform. This enabling function of OSs and web browsers also implies a “selective” or “nudging” power, as they can steer users towards some application or services. Even beyond these elements, nudging can be exerted by other discovery elements. App stores and online search engines, for instance, may do so through their primary function, which is to display and rank specific content to the users.

All enabling and discovery elements described above correspond to markets with a high degree of concentration. As an example, the market for search engines presents the highest concentration level, as it is dominated by Google with a market share of 92.7% in Europe (see Figure 15), followed by the mobile OS element, where Android leads the way with a market share in Europe of 63.6% and iOS represents 35.7% of the market (see Figure 16). A high market concentration level is typically derived from high barriers to market entry. These barriers are even higher when the existing players are also vertically integrated. The business strategies of the app developers also contribute to the high concentration at the upstream level of the internet ecosystem (e.g. app stores, OSs), as they have to be present in the main app stores, in order to reach sufficient scale (i.e. of achieving a significant volume of users).

Figure 15 – Search Engine market share Europe, December 2014- December 2021[77]



One of the most important features of the enabling and discovery elements is the presence of significant indirect network effects.[78,79] Competing in the OS market necessarily implies to build sufficient scale for the multi-sided product to be profitable, attracting app developers to make their apps and drivers available, by offering a trusted platform that allow them to attract a sufficient user base. Moreover, there are significant costs of adapting and updating an app to run on several OSs, which requires app developers to focus on the largest platforms, reinforcing the position of these largest platforms in the market. In addition to that, switching OS is very difficult for users and developers. Indeed, it entails significant switching costs, effort and time investment in transferring data and applications to new devices (provided that this is possible) as well as learning costs. These considerations certainly explain the strong position of largest OSs, such as Google Android and Apple iOS in smartphones, and Microsoft Windows in desktops/laptops. At the same time, users and developers also benefit from easy access to each other over these OSs, realising network effects. The leadership that the two main players have in the smartphone OS market makes it difficult for other players to enter and/or expand their position in this market. For example, even Microsoft, despite being the dominant OS provider in desktops/laptops retaining with a 76% market share on a global basis[80], finally exited the smartphone OS market.

---

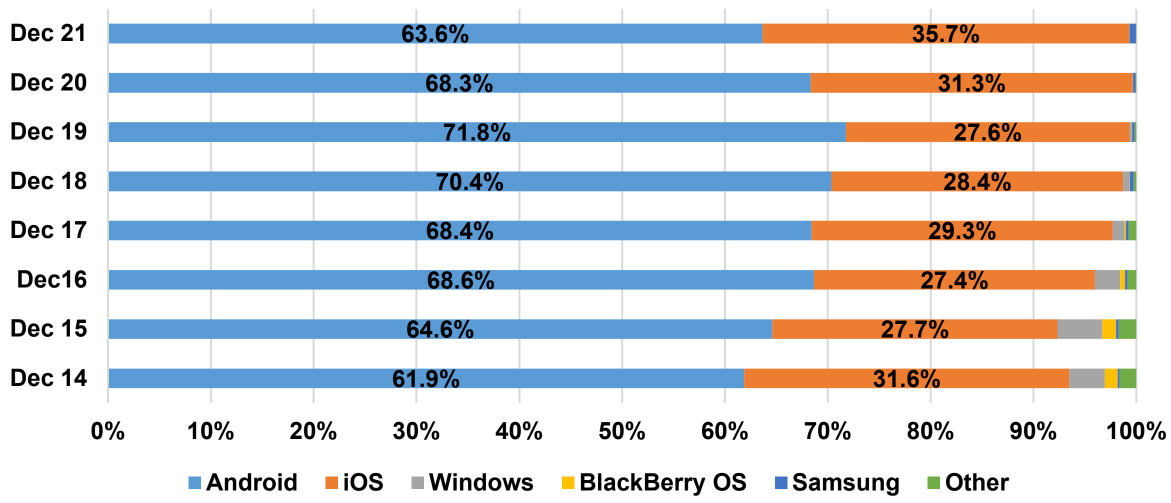
[77] Source: https://gs.statcounter.com/search-engine-market-share/all/europe/#monthly-201412-202112

[78] Market study into mobile app stores, ACM, April 2019 https://www.acm.nl/sites/default/files/documents/market-study-into-mobile-app-stores.pdf

[79] Jan Krämer, Richard Feasey, “Device Neutrality, openness, non-discrimination and transparency on mobile devices for general internet access”, CERRE, June 2021 https://cerre.eu/publications/mobile-devices-net-neutrality-internet-access/?nowprocket=1

[80] See https://gs.statcounter.com/os-market-share/desktop/worldwide

Figure 16 – Mobile OS market share Europe, December 2014-December 2021[81]



As far as the mobile device market is concerned, market concentration in OSs has also a deep impact on app stores' markets concentration. Indeed, mobile OSs either do not allow non-proprietary app store to be installed – as in the case of iOS – or, even if alternative app stores are permitted, those are rarely used.[82] As a result, the Google Play Store and the Apple App Store are the biggest platforms for app distribution worldwide, with almost 143 billion of combined downloaded mobile apps in 2020, on a total number of 230 billion worldwide downloads of mobile applications.[83] In this context, lack of access of independent software app developers to integrated app stores can eliminate or limit competition in the downstream market for those apps. This effect can be fostered when large app stores are able to charge developers with supra-competitive commissions for distributing their content.[84] In addition to that, dominant app stores can negatively impact inter- and intra-platform competition by refusing access to data collected or not granting access to data on fair terms.

In the market for desktop and laptop OSs, concentration and vertical integration can also significantly limit the competitive process by creating entry barriers for competing services. As an example, Microsoft is able to leverage its strong position in desktop OS and productivity software markets (e.g. Office Suite) to cloud services, especially in SaaS and PaaS segments.

---

[81] See https://gs.statcounter.com/os-market-share/mobile/europe/#monthly-201412-202112

[82] As an example, in 2016 Google Play Store accounted for more than 90% of apps downloaded on Android devices in the EEA, even if Android allows the installation of other app stores. See the factsheet "*Antitrust: Commission sends Statement of Objections to Google on Android operating system and applications*", available at https://ec.europa.eu/commission/presscorner/detail/it/MEMO_16_1484 .

[83] See App stores - Statistics & Facts | Statista

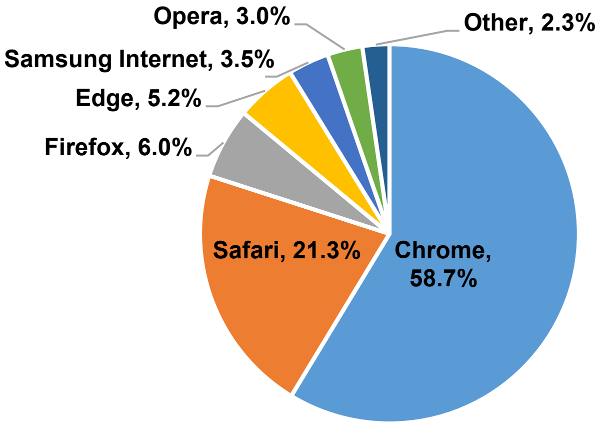
[84] See the press release IP/21/2061 " Antitrust: Commission sends Statement of Objections to Apple on App Store rules for music streaming providers", available at https://ec.europa.eu/commission/presscorner/detail/en/ip_21_2061

From a competitive point of view, provider-specific ecosystems integrating app store providers, OS providers and device manufacturers often bind software developers to provide user-friendly services that allow end-users to seamlessly switch between devices while using the service. They do so by retaining a common standard of security and privacy rules, which – while it can have positive outcomes if the standards are high – may also create a barrier to the development of new apps/content and even compromise entry into the market.

Side-loading[85] could facilitate the market dynamics through the promotion of app developers' access to users. This would indeed allow to "disintermediate" the role of the software application stores, enabling users to install apps from outside the integrated app store offered by the main OSs. However, integrated device manufacturers often argue that the side-loading practice is potentially harmful to users, because they may inadvertently install malicious or buggy software that endangers the security and integrity of the device and may compromise the privacy of users.[86] It is however important to stress that side-loading has been the most common manner of installing applications and software on desktop OSs till recently, and that anti-virus and anti-spam software can limit the negative effects of malicious content.

As far as web browsers are concerned, competition issues should be assessed mainly through the analysis of pre-installation practices and default settings. Normally, in mobile markets users tend to use apps that are pre-installed in the device, and therefore are heavily dependent on the OS and/or device providers. That is one of the key reasons why the web browsers market is rather concentrated for mobile use, as in Europe Google's Chrome (59% market share) and Apple's Safari (21%) are the main operators.

Figure 17 – Web browser market share in Europe, 2021[87]



[85] The possibility to install software on a device from other sources than the "official" software application store compatible with the device.
[86] CERRE's Report on Device neutrality (June 2021), Ibid Footnote 79
[87] See https://gs.statcounter.com/browser-market-share/all/europe

Web browsers can compete with apps on some services, as they allow users to access some applications on the open web, enabling them to avoid their internet experience from being entirely intermediated by apps. This possibility is granted by the fact that, as explained in subchapter 2.3, CAPs can choose to convey content through the "native application approach" or the "web application approach". Therefore, if users want to access content via "native apps", they must use the API provided by the OS. On the contrary, "web apps" and "progressive apps" are openly accessible via web browsers, whose API is standardised by the W3C and applicable to all OSs. However, web apps and progressive apps performance is generally lower than those of native applications. Moreover, web browsers functionalities might be limited strategically, as in the case of Apple's browse engine WebKit that holds back performance and viability of web apps.[88]

As an example of this, in its 2021 market study interim report on Mobile ecosystem, the Competition and Markets Authority (CMA) states that[89] "*the competitive constraint from web apps on the download of native apps through the App Store and Play Store is likely to be limited at present"*.[90] Moreover, according to CMA, several app developers indicated that web applications are not currently a viable alternative to native applications, mainly due to a gap in functionality. This seems to be the case especially for Apple's ecosystem, "*which undermines the incentive for developers to invest in web apps across both ecosystems"*.[91]

Finally, in the specific case of algorithm-based services such as search engines, competitively strong providers enjoying data-driven network effects, are in the position to rank in a discriminatory way input values inserted by users and influence the search index and data used for the algorithm. Additionally, there may be lack of transparency regarding outputs such as search results: for example, the rationale of the ranking (and the corresponding "bias") may not be clearly understood by the users, and the terms and conditions of the service for users may be difficult to find and/or understand.

6.2.2 Devices

Access to content and services is growingly mediated by continuously evolving "smart" devices (e.g. smartphones, smart TV, smart speakers and other IoT devices), that in turn are often integrated with applications (e.g. voice assistants with search functionalities[92]).

---

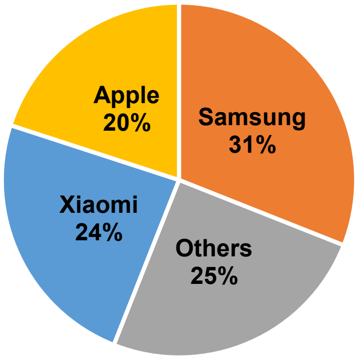
[88] See CERRE Report (Ibid footnote79), page 19 and CMA " Mobile ecosystems market study - interim report", par. 4.132.
[89] CMA "Market study interim report on Mobile ecosystems", par. 4.143, December 2021.
[90] Indeed, according to data provided by Google in their response to CMA's statement of scope: "*Google estimates that in the UK, progressive web app icons were installed by users on the screens of their Android devices via Chrome a total of [5–5.5] million times in 2019 (compared to [4–4.5] million in 2020). This is compared to the installation of [1.5–2] billion native apps from the Play Store for the UK in 2019".* CMA, "Market study interim report on Mobile ecosystems", par. 4.141, December 2021.
[91] CMA, "Market study interim report on Mobile ecosystems", §4.142, December 2021
[92] Voice assistants can be seen as an integrated interface between the enabling and discovery layer and the devices layer.

From an economic point of view, device hardware markets are characterised by transnational economies of scale and scope. These markets are in general competitive, even if there are different levels of concentration among the several types of devices included in this element.

In the European smartphone market, Samsung leads the way, followed by Xiaomi and Apple (see Figure 18). In regard to the computer vendor market, it was relatively concentrated in 2021 with Lenovo and HP serving almost half of the market worldwide (see Figure 19).

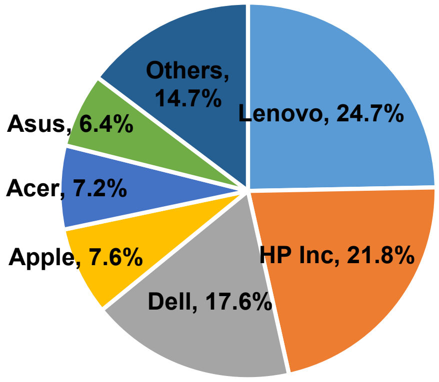
In the *embedded-SIM* (eSIM) market, major players in the global market include Gemalto, Giesecke+Devrient GmbH, STMicroelectronics and Infineon Technologies.[93] As far as devices which enable fixed access to the internet (e.g. routers) are concerned, there are several major players (e.g. ASUS, Netgear, D-Link, Huawei, Xiaomi), but few of them currently dominate the global market.[94]

Figure 18 – Smartphone market shares in Europe, Q2 2021[95, 96, 97]



[93] See https://www.mordorintelligence.com/industry-reports/embedded-sim-market
[94] See https://www.mordorintelligence.com/industry-reports/wireless-router-market
[95] See https://www.statista.com/statistics/1232278/samsung-smartphone-market-share-in-europe/
[96] See https://www.statista.com/statistics/1232282/xiaomi-smartphone-market-share-in-europe/
[97] See https://www.statista.com/statistics/1232268/apple-smartphone-market-share-in-europe/

Figure 19 – Personal computers vendor market share worldwide 2021[98]



Several OEMs are horizontally integrated, being active in multiple devices markets.[99] Additionally, some device manufacturers are sometimes vertically integrated, providing other services on the internet ecosystem, like OS, app-stores and/or search engines. Such integrations give devices manufacturers a certain degree of market power, potentially resulting in a “termination monopoly”. ”.[100] This may generate high entry costs for competitors (e.g. when provider-specific ecosystems provide functionalities which rely on the interplay of several devices) or business users (e.g. content providers relying on access to functionalities of a voice assistant), that may be even higher when negotiating with device manufacturers that are integrated into a provider-specific ecosystem, because the manufacturer tends to have a lower bargaining power. In addition, as far as end-users are concerned, the integration into a provider-specific ecosystem may create lock-in effects and also reduce transparency, as users may be unaware of potential restrictions of access to some elements of the internet ecosystem (e.g. applications). These lock-in effects may also come from restrictions of data portability, resulting in a lower willingness to change devices, especially when these are integrated in a provider-specific ecosystem encompassing services in the discovery layer (particularly the OS).

Additionally, OEMs may restrict competition by favouring their own products and services, implementing tying/bundling strategies and/or combining data from users.

In some cases, although not vertically integrated, devices are tied to other elements (e.g. OS), for example through commercial agreements (e.g. carrier partner agreement) or exclusive partnerships (e.g. pre-installation agreements). This “envelopment strategy” by OEMs may create barriers to entry for new competitors, even if the users might appreciate having software

[98] See https://www.statista.com/statistics/267018/global-market-share-held-by-pc-vendors/

[99] For instance, many smartphones manufacturers are also manufacturing smartwatches, smart TVs, smart-home devices and voice assistants

[100] Ibid footnote 4 and 79

pre-installed. However, in the absence of that kind of agreements, the OEMs may limit the device, e.g. several features may be blocked or not work properly or even may have to be configured manually (e.g. MMS, Mobile Hotspot, VoLTE deployment, 5G access, VoWiFi). This may impact competition on electronic communications markets in prejudice of smaller operators that do not have commercial agreements with an OEM. Eventually, there are other discriminatory practices by OEMs, such as privileging, restricting or prohibiting access to certain networks, OS, system functionalities, compatibility with other devices, and/or applications that can restrict competition.

Furthermore, OEMs could resort to the exclusive use of eSIM (as opposed to physical SIM cards) in smartphones and/or other connected devices and activating agreements exclusively with a subset of electronic communications service providers, thereby restricting the possible subscription profiles that can be provisioned on the eSIM (e.g. eSIMs in smartwatches). This could pose a threat to competition in the relevant electronic communications market and, also to users' choice to change providers, and to number portability, which may result in consequences akin to those resulting from SIM-locking practices. [101]

6.2.3 Internet Access Service

The IAS market is characterised by economies of scale and scope, capacity constraints and sunk costs, resulting typically in asymmetric conditions among providers. Nevertheless, the IAS market is nowadays mostly dynamic, thanks, among other factors, to the regulation that has been imposed, in most countries, in order to ensure a more diversified offer at lower prices to the users. In any case, there remain differences among Member States related to the competitive specificities of each market (e.g. the number of players).

Notwithstanding, IAS competition may be affected differently depending on the type of infrastructure considered.

In fixed networks, there are high barriers to entry, due to high investment costs necessary for rolling out a network. In this context, new entrants mainly use regulated or commercial wholesale access, including passive infrastructures, to enter into the IAS market. In many countries, wholesale access has also been essential to improve the national coverage for alternative operators, mainly in areas that are not profitable to cover.

In mobile networks, there are four main ways for market entry: i) spectrum assignment combined with network rollout, ii) network rollout combined with network sharing[102], iii) MVNO agreements (which might be regulated – for example through access obligations in mobile

---

[101] For further information on eSIMs, please consider the WIC report "*Strategies to promote Over-the-air provisioning*" (November 2021), available at https://www.comreg.ie/media/2021/11/ComReg-21114a.pdf.

[102] BoR (11) 26, BEREC-RSPG report on infrastructure and spectrum sharing in mobile/wireless networks, 03.06. 2011.
https://berec.europa.eu/eng/document_register/subject_matter/berec/reports/224-berec-rspg-report-on-infrastructure-and-spectrum-sharing-in-mobilewireless-networks

licenses – or concluded on a commercial basis), or iv) network design, software development for network equipment and/or network supervision (all those tasks can be handled by a single third party, i.e. potentially a new entrant for the open Radio Access Network (RAN) architecture[103]).[104]

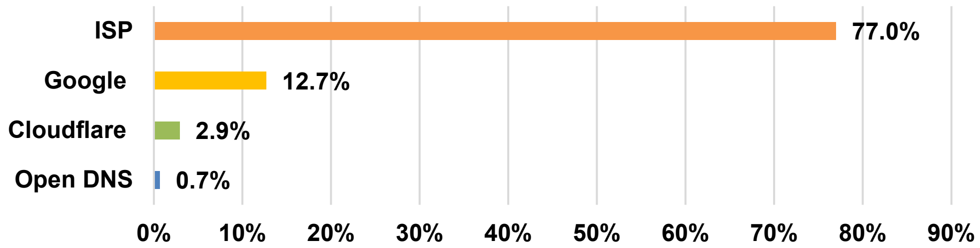
In the last ten years, there has been a trend towards bundled offers with fixed and mobile services, also including other services, which may have increased switching barriers[105], and thereby created lock-in effects[106]. These dynamics make it more difficult for new market entrants to compete in the convergent market and to win new customers.

6.2.4 Domain Name System

Currently there seems to be a relevant level of competition among DNS resolver providers. Users are requesting name translation for a "default DNS resolver", which is usually run by the ISP providing the IAS. Today, encrypted DNS is introduced to some extent, for example using a protocol called DoH. This may typically be provided if the web browser sends encrypted DNS request towards a DNS resolver (DoH resolver) which can be run by the provider of the web browser, such as Google or Mozilla, as well as other DNS providers.

As shown in Figure 20, Google and Cloudflare are among the top open DNS resolvers worldwide, and also large ISPs serving their own users are in the list.

Figure 20 – DNS resolver usage shares in the EU in January 2022[107]



[103] Open RAN is an architecture allowing multi-vendor RAN equipment to interoperate and which consists of standardized open network interfaces, defined in 3GPP, O-RAN Alliance, IEEE, and other standard developing organizations and industry, see https://www.3gpp.org/news-events/2150-open_ran

[104] With the arrival of 5G and 5G applications, new business models have emerged as MNOs need to continue searching for cost-efficient options to expand and densify their network. For further details see BoR (21) 160, Report on the diversification of the 5G ecosystem, 09.12.2021 https://berec.europa.eu/eng/document_register/subject_matter/berec/reports/10130-report-on-the-diversification-of-the-5g-ecosystem and BoR (20) 223, Guide to the BEREC 5G Radar, 10.12.2020 https://berec.europa.eu/eng/document_register/subject_matter/berec/others/9721-guide-to-the-berec-5g-radar-and-5g-radar

[105] Notwithstanding, switching barriers for consumers are lower in the mobile market compared to the fixed market, partially due to regulation, such as number portability.

[106] It is worth mentioning that Article 107 EECC addresses some of the issues related to bundled offers.

[107] "Open DNS" is a provider of DNS resolver. Source: The ISP Column, DNS4EU, Huston G., February 2022 https://www.potaroo.net/ispcol/2022-02/dns4eu.html

Switching costs are generally rather low, as users can choose their DNS provider, irrespective of their use of associated services. However, they are likely to keep their default DNS resolver. Usage of DNS resolver is usually depending on the pre-set DNS resolver of the router, web browser or OS.[108]

It is worth mentioning that users can easily configure an alternative DNS resolver, however the impact of default settings should not be underestimated and in practice, because of pre-configuration, the market outcome is highly dependent on strategies of actors in other layers (namely from ISPs, OS, OEMs, etc.). At the same time the existing competitiveness might also contribute to the quality of DNS resolver with respect to privacy, speed, etc.

The marginal cost of providing an additional user with DNS services is close to zero and tends to decline, indicating economies of scale. There are also economies of scope with services providing additional cybersecurity or privacy to users.

Notwithstanding, the diversification of value-added services to DNS and their protocols could lead to higher barriers to entry. Large providers relying less on multi-stakeholder processes on definition, introduction and usage of related standards may also be able to pre-set DNS services of many devices and applications, making use of the large user base.[109]

In addition, it is important to note that a DNS resolver may technically block any address between certain users (as it is already done in cases of attacks, fraud and copyright issues). Thus, a company active in both DNS resolver and in downstream markets has the ability and may have the incentive to block addresses of competitors, although this does not seem to materialise due to competitive pressure, and in the case of DNS provided by ISPs to their customers, the regulation on Open Internet applies.

6.2.5 IP Interconnection

For the time being, transit and interconnection players do not seem to pose major difficulties to competition. Nevertheless, other large players, such as CAPs, are increasingly entering the IP interconnection market, investing in dedicated capacity, when economies of scale and scope justify a "make" rather than "buy" strategy. Bypassing transit providers may affect competition. As mentioned in chapter 5, CAPs like Google or Meta are investing in backbone submarine cable infrastructures.[110] This trend has taken greater prominence in the last 3-4

[108] Some Devices, e.g. TV-Sticks and game consoles may also set certain DNS by default.

[109] As the article referred to in the previous footnote points out: "Dominant players can create their own namespace that does not require ICANN's multi-stakeholder processes and market leaders would have the power to preconfigure their resolvers on billions of devices or applications, creating an additional incentive for users to switch to a particular service, but also raising the market barriers to entry".

[110] "*In fact Google, Facebook, Amazon and Microsoft owned or leased more than half of the undersea bandwidth in 2018. Currently, Google alone owns six active submarine cables, and plans to have eight more ready within two years*." Internet health report, April 2019 Source: https://internethealthreport.org/2019/the-new-investors-in-underwater-sea-cables/.

years. On the other hand, smaller players typically cannot benefit from sufficient economies of scale and scope, thereby making it more reasonable for them to use shared capacity from third party intermediaries, such as commercial CDNs or internet exchange points.

Additionally, competition concerns may arise from restrictive peering policies that ISPs impose on small CAPs and hosting providers. To the extent that large ISP and CAP players are not present at internet exchanges (or only with low capacity), smaller players might end up being forced to use transit which leads to a lower control of data traffic and possibly a lower quality of service and experience, or to accept paid peering policies of ISPs instead of settlement free peering.[111] As a result, the element could be getting more 'closed', making it harder for smaller CAPs to grow.

Given the vertical integration strategies of large CAPs[112], these players in many cases interconnect directly with the ISPs access networks without any involvement of transit networks. These CAPs place their caching servers into the access networks. This strategy of bringing content closer to the users induces competitive pressure on transit backbones.[113]

6.2.6 Hosting, CDN and cloud computing (IaaS and PaaS)

In this report hosting, CDN, IaaS and PaaS are grouped separately from SaaS, which is treated below within other apps. While hosting, CDN, IaaS and PaaS cover many different types of services with different purposes, users have greater control regarding the design of services, for example regarding OS, storage capacities and interfaces. SaaS on the other hand provides integrated applications to users. Figure 21 shows that SaaS has the highest relevance regarding revenues among IaaS, PaaS and SaaS. Aside from the differences of the services on each specific layer, SaaS and PaaS services are often bundled with the underlying infrastructure (IaaS).

The above-mentioned elements can be grouped as IT (outsourcing) services in general, with dividing lines between them being sometimes blurry. There are some big providers of colocation services (in multi-tenant data centres), for example Equinix and Digital Realty[114],

---

"Trans- Atlantic content providers has around 58% investments share of CAPEX on new submarine cables in the period from 2015-2019 and plans future investments around 85% of CAPEX in the period 2020-2023 while Trans-Pacific content providers has around 12% investments share of CAPEX on new submarine cables in the period from 2015-2019 and plans future investments around 70% of CAPEX in the period 2020-2023". Source: https://blog.telegeography.com/submarine-cable-growth-fashions-from-yesteryear

[111] Marktstudie IP interconnectie ACM, 2021, p. 41 https://www.acm.nl/sites/default/files/documents/marktstudie-ip-interconnectie-2021.pdf

[112] E.g. investment in backbone networks, in-house CDNs, etc.

[113] BoR (17) 184, BEREC Report on IP-Interconnection practices in the Context of Net Neutrality, 05.10.2017. https://berec.europa.eu/eng/document_register/subject_matter/berec/reports/7299-berec-report-on-ip-interconnection-practices-in-the-context-of-net-neutrality

[114] Global colocation data center market share 2021 | Statista

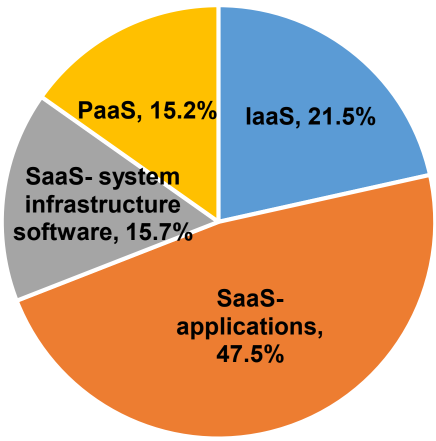
that provide these services together with network services that benefit from economies of scale and scope.

Cloud computing is another way to outsource IT resources, in the sense that the hardware (racks and servers) is owned by cloud providers instead of the clients. Sharing the infrastructure leads to extra efficiencies and additional economies of scale for hyperscalers.

Local hosting can be provided independently, but lower latency may require additional geographic distribution.

The market for commercial CDNs seems to be quite concentrated. The ranking of the major CDN providers can vary depending on the way market shares are measured[115], but in general few players dominate a large majority of the market[116]. While significant investment is necessary to reach the geographical coverage needed to host QoS-sensitive applications and content efficiently, there is a strong tendency towards the deployment of in-house CDNs[117] and market entry can be observed (e.g. recent entrants such as Fastly, Cloudflare and large cloud platforms offering CDN services such as Amazon Cloudfront or Google Media CDN).

Figure 21 – Worldwide Public Cloud Service Market Share, 2H 2020[118]



Also, in terms of IaaS, market entry requires a significant level of investment that is not easily replicable (geographical repartition and size of data centres is critical for the attractiveness of

[115] See ENISA, "Short paper on the security and operation of content delivery networks", 2022 – *available under request*

[116] According to ENISA, there are different ways to look at the market share of a CDN. CDN providers can be ranked according to the number of websites served from the "top 10 million" list. With this approach, Cloudflare would have over 80% market share. The International Data Corporation (IDC) also identifies a concentrated market around few CDN providers (Akamai is leading this list, followed by Amazon CloudFront, Cloudflare and Alibaba). See ENISA, ibid footnote 115

[117] Thus making such CAPs less dependent on commercial CDN providers

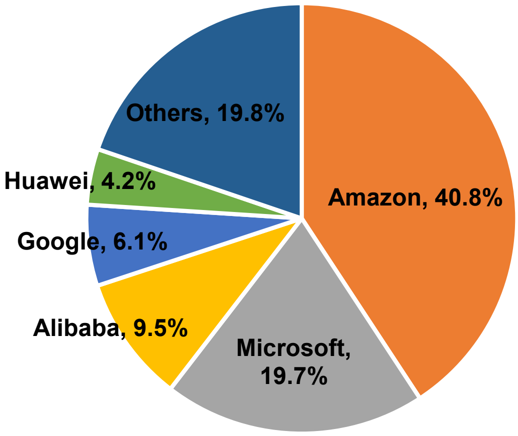
[118] See "IDC Worldwide Semiannual Public Cloud Services Tracker, 2H2020"

the offer) and the market for cloud computing services shows strong economies of scale and scope.

Figure 22 shows that there is a high degree of concentration for IaaS public cloud services. This can be due to or affected by several factors:

- Switching barriers give early movers a significant advantage (egress fees, technical differences between services generate switching costs);
- A significant customer base makes infrastructure owners more attractive for the integration of new third-party software services;
- Big companies active on the IaaS market are also leveraging on other (layers of the) cloud service market(s), namely software and services that can complement their offer of cloud computing services (bundled offers and one-stop shop);
- Big companies can also leverage the software and services layers of the cloud services on the infrastructure, by bundling these services with the infrastructure of the (cloud) service provider;
- Bigger market players often attract new customers through free-tier offers as entry-level products, which are only profitable in relation with significant scales or cross-sale of products.

Figure 22 – Worldwide IaaS Public Cloud Services Market Share 2020[119]



[119] See Worldwide IaaS Public Cloud Services Market – Gartner, June 2020

Although it could be beneficial for the sustainability of smaller players, there seem to be some technical and financial barriers that make it difficult to set up multi-cloud services[120] (e.g. resilience, cost control, better provisioning).

The increasing relevance of the Big Tech in cloud services indicates that their role is extending from the provision of content and intermediation services to significant investment in infrastructure and in the design and quality of various software.

6.2.7 Attention-intensive applications

The relevance of social networks and video-sharing platforms for access to news and information is confirmed by the fact that, for example, Facebook (Meta) and YouTube are also seen by online newspapers as important channels for delivery of their editorial content.[121] Other applications that provide access to premium content in live streaming or VoD, such as Netflix, HBO, Disney+ or Amazon Prime Video do not show this same feature. They are analysed separately in subchapter 6.2.8.

Attention-intensive application markets, that are mainly based on an advertising-funded business model, are very concentrated around two players, in terms of size, usage and aggregation capacity: Facebook (Meta)[122] and YouTube (Google/Alphabet).[123] Their prominent place as intermediaries between the users and the content, their scale and reach, through a large user base, and therefore ownership of large amounts of data on individual and business users, give them a major competitive advantage in the online advertising market.

---

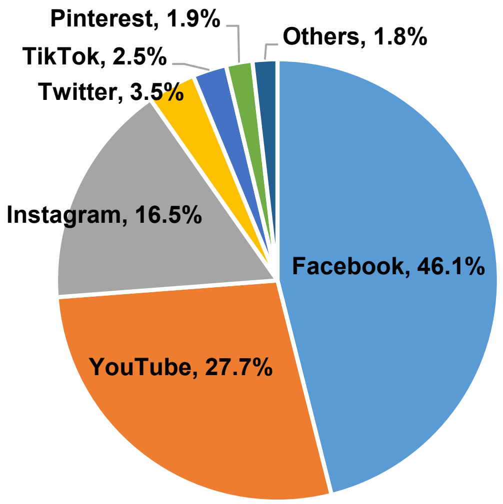
[120] Multi-cloud services refer to services provided by more than one cloud vendor.

[121] See CMA *Online platforms and digital advertising market study*, and specifically Appendix S on the relationship between large digital platforms and publishers, available at https://assets.publishing.service.gov.uk/media/5efb22fbd3bf7f768fdcdfae/Appendix_S__the_relationship_between_large_digital_platforms_and_publishers.pdf

[122] Facebook reached 78% social media market share in Europe in May 2021
See: https://gs.statcounter.com/social-media-stats/all/europe/#monthly-201412-202112)

[123] According to Online Video Sharing report published by the European Audiovisual Observatory in 2018 (https://rm.coe.int/online-video-sharing/16808b2e16), YouTube reached 74% global online video platforms market share.

Figure 23 – The main social media platforms used by European consumers[124]



These platforms have strong economies of scale and scope, and direct and indirect network effects, favoured by the high collective[125] switching costs, which may hinder the emergence or growth of rival platforms, negatively impacting competition dynamics. Direct and indirect network effects by favouring dominant platforms may affect the degree of competition, since they create lock-in effects, even though multi-homing is possible (e.g. use of several social networks). There is also evidence of strong consumer inertia[126], particularly in social networks, making platform switching low/rare.

Several concerns may also arise with respect to the lack of transparency, access to data and APIs, as well as discriminatory conducts, which are very similar to those conducts identified in the discovery layer.

---

[124] BoR (21) 89, Analysing EU consumer perceptions and behaviour on digital platform's for communications, PPMi, commisioned by BEREC, 10.06.2021. https://berec.europa.eu/en/document-categories/berec/reports/analysing-eu-consumer-perceptions-and-behaviour-on-digital-platforms-for-communication-analysis-report According to this survey there are different preferences among age groups with regard to specific social networks services: the use of Facebook as a user's main social networking site is more used by older groups (46 – 75), while Instagram is mostly used by younger groups (16 – 35). YouTube is used by all age groups, although more prominently among youngest users (16 – 25).

[125] Users can *individually* easily register and use an alternative social network or video sharing platform, so *individual* switching costs may appear to be low. However, because of strong network effects, they would have no incentive to switch unless other users do it too. The need for coordinated switching makes *collective* switching costs high.

[126] According to the findings of the BEREC commissioned study BEREC BoR (21) 89 Ibid footnote 124, entitled "Analysing EU consumer perceptions and behaviour on digital platforms for communication", "*there is strong evidence among consumers of inertia, brand identification and emotional attachment to applications. In terms of pull factors, to successfully attract consumers to different services, new applications would have to replicate many of the factors that consumers currently seek and receive via other services – free-of-charge use, ease and convenience, and having friends and family who use the same service.*". "

6.2.8 Other applications

Other applications are relevant in influencing the ways end-users access premium content (e.g. live streaming and VoD content providers), choose and consume physical goods (e.g. e-commerce), store and process information (e.g. the SaaS segment of the cloud services industry) or communicate with friends and businesses (e.g. NI-ICS), but they seem to be less influential in shaping the way end-users access internet content or applications overall.

6.2.8.1 Live streaming and VoD content providers

Platforms providing access to live events or to VoD content are characterised by high fixed costs, as the acquisition of media rights for live broadcasting of important sport events or for most popular TV series and movies, especially those produced by the so-called “Hollywood Majors”, is very expensive. For this reason, many relevant platforms active in this market have a global scope (e.g.: Netflix, Prime Video, Sky etc.), in order to be able to distribute such content to the highest possible number of users.[127]

6.2.8.2 Number-independent interpersonal communication services (NI-ICS)

NI-ICS includes for example instant messengers, video conferencing and email services. Instant messengers generally provide functionalities whereby users can communicate via text messaging, voice or video calls with other users of this service.[128] Users’ identifiers used in instant messengers are generally proprietary to the provider offering the service, or can use E.164 numbering resources merely as an identifier (i.e. not to connect or enable communication with other number-based ICS).[129] On the other hand, email services provide users with a unique email address that can be reached by all email users, regardless of the address provider.

High collective switching costs and network effects (increasing efficiencies of few providers or standards) may hinder the emergence or growth of rival messengers. Although multi-homing is possible (e.g. use of several instant messaging services) and used by consumers at a certain extent, direct network effects in combination with closed de facto standards favour dominant instant messaging services. There is also evidence of strong consumer inertia resulting in low switching.[130] This situation may also lead to the imposition of terms and

---

[127] For a comprehensive assessment of premium content industry and its impact on ECS market, see BoR (18) 35 BEREC Report on the impact of premium content on ECS markets and the effect of devices on the open use of the Internet, available at https://berec.europa.eu/eng/document_register/subject_matter/berec/reports/8013-berec-report-on-the-impact-of-premium-content-on-ecs-markets-and-the-effect-of-devices-on-the-open-use-of-the-internet.

[128] As defined in Article 2(7) of the EECC, NI-ICS are interpersonal communication services that “do not connect with publicly assigned numbering resources, namely, a number or numbers in national or international numbering plans, or which does not enable communication with a number or numbers in national or international numbering plans”.

[129] NI-ICS cannot connect or enable communication with other number-based ICS.

[130] Ibid footnote 124, p. 76.

conditions, low incentives for innovation or general quality deterioration (e.g. concerning privacy or security).

A key feature of messaging applications is its usage for communication within larger groups of users. Switching group communications to another service requires coordination among all participants, instead of only between two users as it is the case of one-to-one communication. The significant (non-monetary) costs that this coordination entails makes switching nearly impossible in practice.

Moreover, the BEREC study on consumer perceptions and behaviour on digital platforms for communications shows that "regardless of their main applications, most (respondents) would fall back on to using WhatsApp if their main application (other than WhatsApp) stopped working for a short or long period of time. EU consumers prefer using the same application for communication in various situations, not only compared with other applications, but also with other means of communication. Nonetheless, multi-homing on platforms that provide interpersonal communication services is prevalent among EU consumers, who use different platforms to communicate with different social circles and the survey results show that the number of messenger applications used by a single consumer depends somewhat on their demographic characteristics – in particular, age. Rates of usage vary quite markedly between European countries, which can be grouped into WhatsApp vs. Facebook Messenger-dominated markets."[131] The most important motivations for using messenger applications are also that they are free of monetary charge, easy and convenient to use, and that the service is also used by friends and family members.[132]

The high reach and frequency of access to the service enable providers to leverage their user base to other services. WeChat is an example for the development of an ecosystem around messengers, providing not only communication features, but also platform services for e-commerce, payment, delivery, transportation and social networks.[133] In general, the business models of NI-ICS providers are very diverse and may also include direct payments from consumers to the provider (e.g. the messenger Threema is provided in exchange for a one-time monetary fee). Messengers may become more integrated into ecosystems, e.g. as communication channel for businesses as "WhatsApp Business" shows, and the line to other services might blur. On the other hand, providers may collaborate with device manufacturers (e.g. on pre-installed apps).

The market for email services generally seems less prone to switching costs and tipping, since interoperability of communication based on open standards exists and direct network effects can be realised by new entrants. However, effective switching may be low due to high synergies with other services of ecosystems (e.g. identification or cloud services). Moreover, for end-users the process to port emails from one provider to another can seem complex or

[131] Ibid footnote 124, Page 24 et seq.
[132] Ibid footnote 124, Page 47.
[133] For an overview on the history of WeChat see https://www.techinasia.com/history-of-wechat

even not safe, making it sometimes difficult for small entrants to effectively provide or expand competing services[134]. Nevertheless, bottlenecks of communication between end-users and businesses are less likely.

6.2.8.3 Software as a Service (SaaS)

SaaS services are often provided bundled with IaaS and desktop OSs. This strong integration might make switching very difficult for consumers, as IaaS are often provided with high and non-transparent egress fees.[135] Moreover, there might be difficulties of switching between non-integrated SaaS providers due to lack of technical interoperability[136] resulting in lock-in effects. However, open standards are promoted in order to facilitate switching. In terms of revenues, SaaS represents more than half of the public cloud services market.[137] The provision of "productivity software" (e.g. office suites) together with widely used desktop OSs may bring advantages for the provider when bundling these with cloud services (e.g. as SaaS). Thus, vertically integrated service providers would theoretically be able to leverage other markets and profit from scale economies. For example, AWS profited from first-mover advantages from offering IaaS first, and introduced PaaS and SaaS later. Microsoft leveraged its dominance with Windows and the Office suite to introduce a range of complementary SaaS (e.g. Office 365), to PaaS and IaaS (e.g. Azure) offerings. Google competes by offering advanced machine learning and data analytics applications. Additionally, there are dependencies of customers on the services of a few large cloud service providers, since the switching costs are high. For competitors providing cloud services, it may be hard to compete with the level and speed of innovation of these three companies.

6.2.8.4 e-Commerce

High indirect network effects (between sellers and buyers), economies of scale and scope and switching costs to buyers[138] and sellers usually characterise e-commerce platform markets. Data (for example aggregated sales data, behavioural data on interactions, feedback data, etc.) generated by buyers and sellers can be used for optimising own services or own retail products. Dominant e-commerce platforms may additionally provide, when vertically integrated, services of storage, logistics or delivery themselves, increasing barriers to entry

---

134 In the case of e-mail services provided by ISPs together with the internet access service, Article 115 and Annex VI EECC specify the obligation for ISP providers regarding e-mail forwarding or access to e-mails after termination of the contract with a provider of an internet access service.
135 When data is retrieved from the cloud, cloud providers tend to charge large fees.
136 US House of Representatives (October 2020), investigation of competition in digital markets – Majority staff report and recommendations. Subcommittee on antitrust, commercial and administrative law of the committee on the judiciary, https://judiciary.house.gov/uploadedfiles/competition_in_digital_markets.pdf
137 According to "IDC Worldwide Semiannual Public Cloud Services Tracker, 2H20", SaaS – applications represents 47.5%, SaaS - system infrastructure software represents 15.7%, IaaS represents 21.5% and PaaS represents 15.2%.See Figure 21
138 Switching an E-Commerce platform may require e.g. the set-up of an additional account or additional delivery fees in cases where delivery is otherwise included in upfront subscriptions.

and expansion for competitors trying to replicate service quality to buyers or sellers. The provision of such integrated services may also result in increased dependence of sellers on such services and may further decrease their inclination to switch to another platform. Furthermore, sellers on these platforms may face a lack of transparency regarding the ranking practices of these platforms, which may result in higher prices for sponsored ranking.

Some providers of e-commerce platforms exercise control over whole platform ecosystems that require competitors to enter multiple markets, irrespective of how innovative and efficient they may be in single markets. As a result of the weak competitive pressure experienced by these large players, the likelihood increases that these markets do not function well – or may soon fail to function well – and thus do not deliver the best outcome for end-users or businesses in terms of prices, quality, choice and innovation. This could also affect the markets which these platforms serve.

6.2.9 IoT

Consumer IoT and industrial IoT are considered distinct sectors with specific characteristics. One of the specificities of consumer IoT is that the type of data collected by smart devices typically includes personal data. While IoT services and products are currently provided by a variety of large and small players, there is a trend towards concentration with Big Tech companies merging or acquiring other smaller companies.[139] In the consumer IoT sector, vertical integration by the Big Tech companies, such as Google, Amazon and Apple, constitutes a high barrier to entry or expansion for other players, as highlighted in the sector enquiry on IoT launched by the EC in 2021.[140] This is essentially due to the fact that the Big Tech companies have their own provider-specific ecosystems, within and beyond the consumer IoT sector. This may lead to discriminatory practices, such as pre-installation, default-setting and prominent placement of their services on IoT devices, as well as bundling or tying different types of software, technology and applications. In addition, these companies own large amounts of data which allow them not only to improve their products and services, but also to enter adjacent markets, further raising barriers to entry or expansion for their competitors.

Moreover, these companies own and control proprietary technology. This has an impact on IoT interoperability, as they independently determine the technical requirements and certification processes to achieve interoperability. The lack of interoperability and common standards among the different components of an IoT ecosystem may represent a further barrier to competition, since it tends to create user lock-in. For some IoT users an assessment

---

[139] See https://www.mordorintelligence.com/industry-reports/internet-of-things-moving-towards-a-smarter-tomorrow-market-industry.

[140] According to the "Final report – sector inquiry into consumer Internet of Things", EC, January 2022 https://ec.europa.eu/competition-policy/system/files/2022-01/internet-of-things_final_report_2022_en.pdf the consumer IoT sector encompasses services, devices and technologies that support the interaction of consumers with connected devices which collect and exchange data over the internet

of the security and integrity of IoT devices and networks may be difficult, resulting in less competition and innovation regarding these features.

Difficulties in switching related to physical SIM cards, may also impact competition. On the contrary, eSIMs, not only may improve provisioning and switching processes, but also contribute to lower costs, enhancing competition among existing players and new entrants.[141] However, as discussed further above in subchapter 6.2.2, the competitive dynamics of eSIMs are not necessarily straightforward.

In regard to competition dynamics in the IoT market, there may also be potential issues related to permanent roaming agreements. Potential issues could arise with regard to the charges established in the wholesale agreements as the Roam Like At Home (RLAH) principle in the Roaming Regulation is not meant to be applicable for permanent roaming. This could lead to potential barriers to entry for new providers of M2M connectivity services in the European Economic Area (EEA).[142] However, as expressed in the BEREC wholesale roaming guidelines[143], in practice the IoT/M2M market is constantly growing. BEREC is dedicating a report about M2M and permanent roaming for the work program of 2023. In addition, the Roaming Regulation expects MNOs to accept reasonable requests from providers of M2M connectivity services for wholesale roaming agreements which explicitly allow permanent roaming for M2M communications.

Finally, there may be issues related to the scarcity of some numbering resources and identifiers used for IoT services in public and non-public networks (e.g. E.164 numbers, E.212 Mobile Country Code and Mobile Network Code (MCC+MNC), IPv4 addresses) which may also affect competition dynamics. This is particularly relevant considering that it is estimated that there will be a significant increase in IoT devices in the coming years.[144]

---

[141] Strategies to promote Over-the-air provisioning, WIK-Consult, commissioned by ComReg, November 2021 https://www.comreg.ie/media/2021/11/ComReg-21114a.pdf

[142] BoR (20) 131, BEREC input on EC's request for the preparation of the legislative proposal for the new roaming regulations, 30.06.2020. https://berec.europa.eu/eng/document_register/subject_matter/berec/opinions/9373-berec-input-on-ec-request-for-the-preparation-of-the-legislative-proposal-for-the-new-roaming-regulations

[143] BoR (22) 55, Draft BEREC Guidelines on the application of Article 3 of Regulation (EU) 2022/612 of 6 April 2022 on roaming on public communications networks within the Union (Wholesale Roaming Guidelines), 24.05.2022. Available at https://www.berec.europa.eu/sites/default/files/files/document_register_store/2022/5/BoR%20%2822%29%2055%20Draft_IR_Wholesale_Guidelines.pdf

[144] See https://iot-analytics.com

7. ANALYSIS OF OPENNESS

7.1. Introduction

In this chapter the challenges to openness will be discussed by assessing how each element in the internet ecosystem impacts both the ability of users to access and distribute information and content, without unlawful interference or discrimination, and the ability to innovate.

Openness within the internet ecosystem in terms of internet access is regulated under the OI Regulation for the IAS element and for adjacent services when offered together with the IAS (e.g. default DNS resolvers).[145] Openness within the IAS element might therefore provide a benchmark for assessing how openness may look like in other parts of the internet ecosystem and what possible challenges there might be. The parallel can more easily be drawn with those network elements that have a routing/forwarding function similar to the IAS. For some other elements with different types of functions (e.g. a more editorial role) the analysis requires a broader understanding of openness. Several elements in the internet ecosystem may influence the way internet-based services are provided, commercially and technically. This deserves to be analysed since there may be an impact on the incentives to innovate. These functional differences will therefore be taken into consideration as well as the competition dynamics within the different elements where needed.

7.2. Analysis of the elements

7.2.1 Enabling and discovery layer elements

Undertakings providing elements such as OSs, web browsers, search engines and app stores constitute (almost) unavoidable gateways to access the internet, content and applications. Due to the central role of those elements, blockages, alterations, restrictions, interferences, degradations or discriminations in the way users (i.e. consumers and business users) access and use those elements may have an important impact on their freedom of choice, due to the control potentially exerted by the providers of those elements.[146]

Providers of OSs are in a position to discriminate between business users or end-users, by:

- Prohibiting or inhibiting the installation of the OS on certain hardware;

---

[145] BoR (20) 112, BEREC Guidelines on the Implementation of the Open Internet Regulation, 11.06.2020, paragraph 78a.
https://www.berec.europa.eu/en/document-categories/berec/regulatory-best-practices/guidelines/berec-guidelines-on-the-implementation-of-the-open-internet-regulation

[146] See CERRE's Report (Ibid footnote 79), Page 6: "*The exercise of 'gatekeeper control'* […] *can apply at many different layers*". The reasoning in this rapport applies specifically to devices. However, it can be extended to other elements.

- Privileging, restricting or prohibiting access to certain networks (mobile, ad-hoc or infrastructure networks), or network protocols (e.g. VoWiFi, VoLTE, etc.);
- Reserving or privileging system resources (e.g. battery, memory, computing power, (data) storage, APIs) for specific apps;
- Software at a higher level may either be privileged in its access permissions, or prohibited, inhibited or restricted at higher layers to from such access to certain hardware components (e.g. sensors, chips, camera, microphone, screen).

These practices may directly or indirectly affect openness, by restricting the users' access to certain hardware and/or software.

Undertakings providing web browsers may block, alter, restrict, interfere with, degrade or discriminate between websites, also with regard to access to certain functionalities available on devices; however, where end-users are aware of those impediments, switching web browsers is generally rather easy for them, which attenuates the impact on openness (unless the browser and the OS are tied, or the default installation of the browser makes the user unaware of alternatives).

Undertakings providing search engines and app stores may unduly block or discriminate, content, services and applications. In the case of app stores, providers can deny the access of apps to the store; in the case of search engines, providers can decide not to show specific search results. In both cases, the hierarchy of ranking and recommendations can be a controversial topic for their users, and determinant for the capacity of the users to innovate successfully.

Furthermore, dominant providers of search engines, web browsers and OS may exert pressure to influence the way standards are adopted and implemented. Developers of applications or websites tend to adapt their services and applications to the incumbent's specifications services, giving incumbents the possibility to influence the evolution of standards which are, in principle, elaborated upon and implemented openly. This may strengthen the control incumbents have on the internet ecosystem or further increase the dependency of developers on these dominant providers.

The consequence of the impact undertakings may have on openness and innovation is also strengthened by the fact that most of the services concerned are often provided bundled into a provider-specific ecosystem. As shown in the section on actors in the Internet ecosystem (chapter 5), some actors control several fundamental elements used by their users (e.g. Google provides a search engine, a web browser, an OS and an app store; Apple provides a web browser, an OS and an app store).

7.2.1.1 Innovation in web architecture and app architecture

In an overarching analysis of the OS and the web browser elements, it is important to explore the question of openness in the context of competition between native apps and web-based content on smartphones (for the technical background of this discussion, see subchapter 2.3), especially in a context of growing smartphone usage compared to other means of access to the internet. Users' behaviour is often described as prone to favour apps over web content. It is however important to analyse whether this trend is due to the ease of use, or whether some hardware functions may not be accessible to web-based services, resulting in developers being nudged towards creating native apps.

The choice between the two architectures, native apps and web-based, has several implications. In case of the web architecture, developers are free to develop and deploy their services, which can then be downloaded and accessed by users. The only prerequisite is that the code is implemented according to the specifications of the standards organisation W3C. There is no need for approval before the service can be run. This is applicable for any web browser, which works as a bridge between the different OSs since the code does not need to be adapted for specific OSs. This can be referred to as "the open web" and is one of the foundations for the engine of innovation within the internet. If implemented in an open manner by OS providers and browsers, the web architecture offers the possibility for developers to offer applications according to the specification of the standard, and with some predictability as standards are developed in an open manner (users can monitor and participate in the development of standards). Regarding incentives to innovate, the web architecture provides a global, open platform for provision of internet-based services, where virtually any user can access the service according to the specification of the standard.

In case of native apps, developers need to conceive their service according to the specification of the OS provider of the processing platform where they want to run the service. Those specifications can strongly influence the look and feel of the content, but also the type of content provided (as OS providers curate the offers on their app stores and prohibit certain types of apps, an intermediation practice that has no equivalent on the web-based architecture). Furthermore, the service deployment has higher transaction costs to allow the service to reach its customers than the web architecture, as elaborated above, since offering applications on several OSs require adaptation to different specifications. Finally, when deploying the service, developers will typically need approval from the provider of the app store, and in many cases, they also need to pay a service fee to the provider (including revenue sharing schemes concerning the purchase of the app and in-app transactions). Such steps may reduce the level of openness of the OS as a platform for provision of internet-based services and may stifle innovation when compared to the "open web" architecture.

That said, there are also upsides to the native app architecture, which the developers take into account. In particular, in the mobile market where native apps have become the preferred way of accessing internet-based services, possibly because of their user-friendliness and smooth processing, providing services over the web may be a disadvantage. Developers of native apps can also benefit from scalable and easy access to advertising or ancillary services of identification or payment. Furthermore, the approval process of native apps, while potentially less open, may provide better security protection for users.

7.2.2 Devices

When referring to devices, openness can be influenced in several ways.

First, in a more straightforward sense, the users' experience of openness will be affected, when their freedom of choice of the terminal equipment is impaired. In general, the current European framework enables freedom of choice of the terminal, but there are some exceptions. In the past, users used to be confined to exclusivities in the sales of certain manufacturers or ISPs. Nowadays, users can be confined to obligatory equipment in certain cases, for example, if an ISP has technically justified that some CPE is part of its network. This might be the case for routers provided by the ISP within the provision of IAS in some national jurisdictions. This may negatively impact innovation as the market for this type of CPE becomes limited to the equipment chosen by ISPs, making market entry difficult. Also, the users' choice of the terminal can be impaired on devices using the eSIM standard: users of eSIM-only devices may not be able to choose an IAS from every possible ISP, as there might be some ISPs that do not offer eSIM-based connectivity services, or ISPs that had been precluded by the OEM from offering their subscription profile on their specific device. This is a very sensitive threat to openness. In addition, restricting the use of classic SIM cards in specific terminal equipment may compromise the ability of users to use a terminal equipment of their choice and consequently prejudice innovation.

Secondly, users can be impacted by practices on the device itself. Those practices are generally found at the software layer of the device, as very often a device comes tied-in with a specific OS (with very limited possibility to change it, or even none at all in some cases) and specific firmware. In certain cases, the OS is not a stand-alone product. Users can be confronted with the impossibility to switch the OS of their hardware (or through complicated manipulations such as unlocking firmware), and providers of alternative OSs have difficulties to distribute their products on the most available handsets on the market. Handset manufacturers often engage in exclusivity deals with major OSs, and alternative OSs have no official access to some essential firmware that enables the functioning of the hardware and all its specific components. Hence, users (among them, developers) might be restricted in the way they access the device's resources. For example, basic functionalities of the device may be available only to specific apps (e.g. NFC chip); there may also be limits to access to other resources, such as battery charge, memory space and CPU. This can be seen as a limit to software innovation at the device level. As mentioned in section 6.2.2, some limitations (e.g. blocking, malfunctioning) in devices' functionalities (e.g. MMS, Mobile Hotspot, VoLTE deployment, 5G access, VoWiFi) may result from commercial restrictions, when device manufacturers condition the correct functioning of the device to the signature of a 'carrier partner agreement', thus reducing users' choice. Other restrictions and limitations could also be introduced into the device, for instance port blocking, which may also impact users' choice.

It is important to note that also in this element, additional openness issues may arise in the case where devices are integrated into a provider-specific ecosystem, for instance by locking users into the manufacturer's environment and restricting their choice, or at least enticing them to stay in the same environment to benefit from cross-device services and better interoperability of devices. These lock-in effects into provider-specific ecosystems may prevent competitors from investing into and developing new innovative products, thus affecting openness. In addition, the collection and use of personal data by devices integrated into an ecosystem may limit users' choices, as users do not have perception of nor control over the use of their (sensitive) data by other business areas, such as health and insurance.[147] The data collection is even more relevant when there is vertical integration, as the combination of data from different sources within the ecosystem can be used not only to improve existing products, but also to create new ones, enhancing innovation from the integrated provider (but at the same time making it harder for others to replicate). Notwithstanding, it can also be used to extend the ecosystem itself and leverage the power to other adjacent markets, which may impact innovation and competition.

7.2.3 Internet Access Service

The IAS plays a substantial role in the internet ecosystem as it is a gateway between end-users and business users such as CAPs. By exerting technical control over the internet access, providers of IAS have the ability to influence an important part of the network layer. However, users are safeguarded by the OI Regulation, as this regulation prevents restrictions or limitations to access not only to the services, content and applications over the IAS, but also to the provision of the internet-based services. For that reason, under the OI regulation, ISPs are prohibited from discriminating between internet traffic, applications, protocols, or providers of internet-based services (practices that might have existed before the OI Regulation came into force).

Therefore, there is no need for users to ask their ISP for any kind of permission to run the services of their choice, and no need for developers to ask regarding their provision of their services, which is referred to as "innovation without permission".[148] These measures have contributed, in a general manner, to safeguarding the users' choice and innovation, and consequently to ensuring the openness of the internet.

7.2.4 Domain Name Service

The DNS is an important element within the internet ecosystem and the way that the DNS was designed to function[149] allows in principle the DNS to contribute to a high level of openness within the internet ecosystem. The default DNS resolver offered by the ISP falls under the scope of the OI Regulation, as such when the DNS resolver is offered in combination with the IAS to users. The ability to restrict openness (e.g. blocking of websites or filtering of content)

[147] In the Google/Fitbit merger, this concern was considered in the commitments agreed by Google.

[148] This relates to the end-to-end principle of the internet, where services are implemented in the endpoints connected to the internet infrastructure, without any need to adapt the infrastructure. This is opposed to Public Switched Telephone Network (PSTN) where service implementation depended on the network provider updating the PSTN infrastructure.

[149] i.e. answering a query in the same way, independent of who and how the query is put forward

through the DNS resolver is therefore limited, due to the strict conditions set out in the OI Regulation (e.g. court order).

However, additional DNS resolvers that are offered by providers other than ISPs do not have to adhere to these strict conditions and therefore can restrict openness in a way that would not be allowed for ISPs. One example is that non-ISP DNS providers might have the incentive to differentiate the way they deal with DNS queries for addresses hosted by competing providers, for example by increasing the DNS lookup time.[150] Another example is error traffic monetisation, where the DNS provider redirects a user whose query fails to a web server on which advertisements and search results are presented to users who mistyped a website's address in their browser.[151] This type of practices might be detected if the DNS stub resolver were to verify the integrity of the DNS response using DNSSEC validation.

On the other hand, the availability of DNS-resolvers of providers other than ISPs, through the offering of public and open DNS resolvers, can also have a positive impact on openness aspects and convenience for users, by increasing users' choice. Providers of DNS resolvers respond to the users' needs, which can boost innovation by providers adapting the way their DNS resolvers works. For example, a DNS-resolver provider can focus on end-users that chose their DNS-resolver based on the level of privacy that is promised or business-users that may be looking for a DNS-resolver that offers a high level of security.

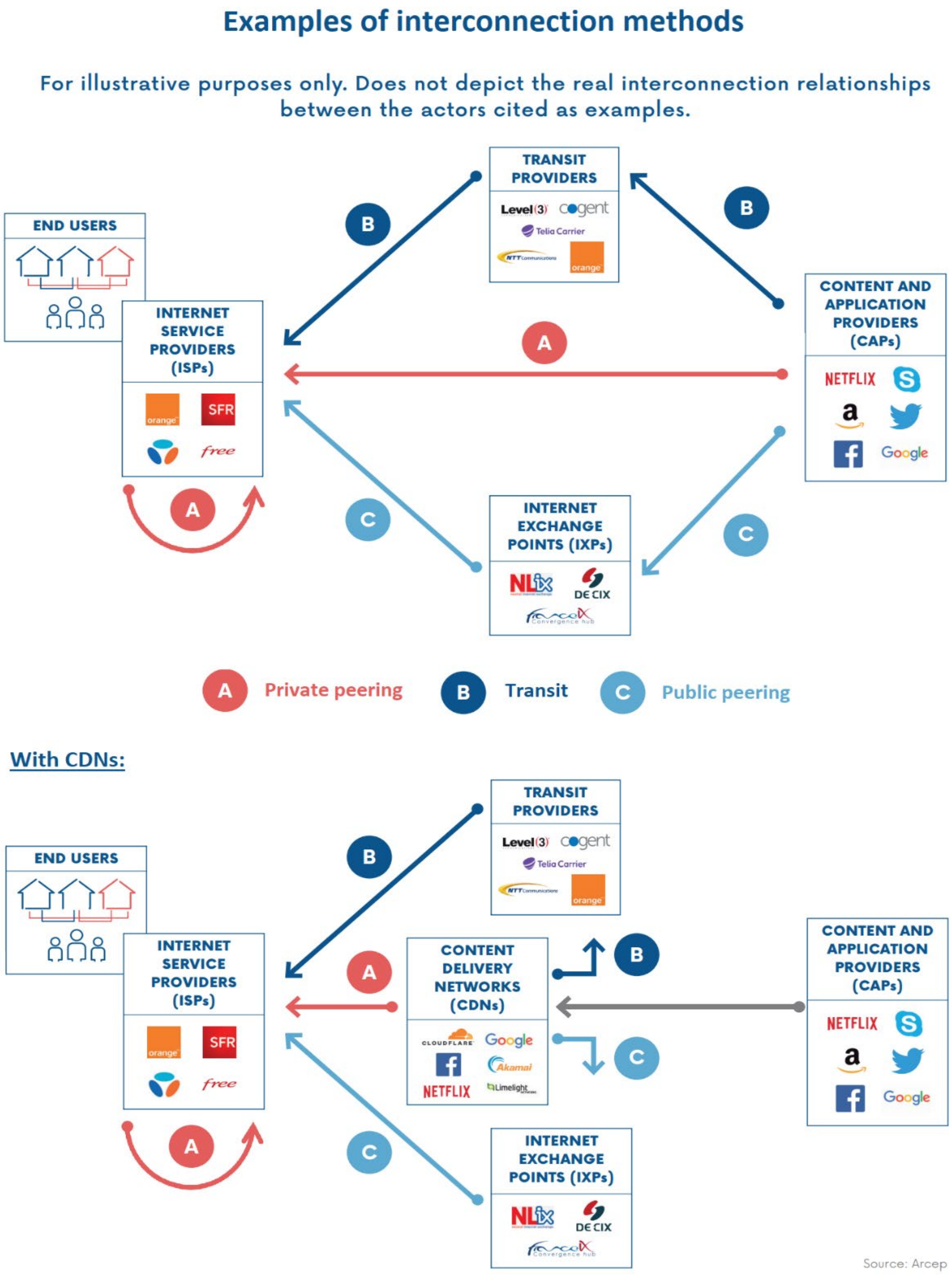
7.2.5 IP Interconnection

Even though the IP interconnection practices of ISPs are generally outside the scope of the OI Regulation and largely unregulated, issues at this level may have a significant impact on the users' internet experience.

ISPs and other players may choose different strategies to interconnect their networks with the rest of the internet (see Figure 24): pay a transit provider (point B in Figure 24), peer at an internet exchange point (alias public peering, point C in the figure) and/or engage in a direct peering with another market player (point A in the figure). Larger CAPs might use dedicated private capacity (such as investing in submarine cables and larger delivery networks) to interconnect their own data centers and other networks. Whether there will be a peering agreement between networks will depend on several factors like the nature of the agreement (e.g. paid settlements), the customer base of the ISP, the imbalance of the traffic volume between the two players, etc. The degree of the user's control of quality and price of the interconnection varies a lot, which ultimately impacts the way in which openness is experienced.

150 https://blog.powerdns.com/2019/12/03/doh-anti-competitive-and-network-neutrality-aspects/
151 https://www.icsi.berkeley.edu/pubs/networking/redirectingdnsforads11.pdf

Figure 24 – Models of interconnection with the rest of the internet



In case networks do not meet the requirements for settlement-free peering set out in an ISP's peering policies, they have to resort to transit or paid peering. For example, smaller networks may not have enough traffic volume or their interconnection links may not meet the capacity required to qualify for settlement-free peering (according to the terms of their counterpart, as most players set specific thresholds in volume or reciprocity levels to peer).

On the other hand, large CAPs may "generate" a large traffic volume (e.g. due to video streaming requested by users) so that the required traffic ratios cannot be met. However, as indicated in subchapter 6.2.5, they may generate sufficient scale making it a viable strategy to vertically integrate forward and to interconnect directly with ISPs. Thus, different CAPs may avail of different interconnection strategies. Whether this boils down to a (relative) competitive disadvantage in terms of openness for smaller CAPs inter alia depends on the competitiveness of transit services, the availability of using public internet exchanges and also the qualitative properties of the interconnection services (as peering has certain advantages in terms of quality compared to transit). The complexity of the IP-interconnection ecosystem also reflects that different players (CAPs, ISPs) apply different strategies (use of peering, transit, direct interconnection, CDNs, "make or buy", etc.).

While IAS providers (all other things being equal) have an incentive to exploit their termination monopoly, which may lead to obstacles for CAPs when providing internet-based services (cost of interconnection, sufficiency of interconnection-capacity for QoS-sensitive applications), bigger CAPs can leverage the attractiveness of their content for users (as a sort of must-have for ISPs). If the market settles on a suboptimal situation, several users (end-users but also producers of content) are impaired in their experience of openness.

Despite this incentive structure for the respective players, it should be noted that there is a mutual interdependence between CAPs and ISPs. On the one hand, CAPs are interested in providing their content to as many users as possible. This requires high-performance networks. Otherwise, their content will not reach the user or not be delivered at the required quality level. On the other hand, the value of a network for users increases in parallel with the quantity and quality of content it can give access to. But the actual experience shows that the market is affected by the differences in bargaining power.

Typically, users will not know which interconnection modalities are deployed when they use applications or services. For example, they hardly can assess the quality of the interconnection service their IAS provider relies on. Users can assess whether the quality of their internet experience is rather good or bad, but it may be extremely difficult for such a user to assess whether e.g. quality issues when streaming videos are caused by an IAS provider's net neutrality violations or result from IP interconnection disputes. As BEREC concluded in its IP interconnection report 2017[152], in case of congestion issues "it remains a challenge to clearly identify its exact location across the internet ecosystem and even more who is responsible for the problem" which is due to the fact that IP interconnection issues involve complex relationships as well as economical and/or strategical considerations of the providers.

Users may benefit in terms of quality where CAPs apply strategies to bring content closer to the users, e.g. by vertically integrating (i.e. CAPs investing in own backbones or CDNs) and directly interconnecting with the ISPs' access networks, or investing in cache servers (on-net

[152] BEREC (17) 184 BEREC Report on IP-Interconnection practices in the Context of Net Neutrality", 05.10.2017. https://berec.europa.eu/eng/document_register/subject_matter/berec/reports/7299-berec-report-on-ip-interconnection-practices-in-the-context-of-net-neutrality, conclusions f)

CDNs) within the ISPs core network. Such strategies are also subject to complex negotiations between CAPs and ISPs.

Since large CAPs increasingly use dedicated, private capacity functioning as a backbone in parallel to the shared internet infrastructure, this may lead to a situation where small CAPs are not able to provide the same quality of service to their internet-based services. Users expect a relatively fast response of their services, otherwise they switch to faster services.[153] This leads to problems for innovative start-ups that compete with large CAPs that are able to invest in dedicated capacity and run faster services.

7.2.6 Hosting, CDN and cloud computing (IaaS and PaaS)

Hosting, CDN and cloud computing providers[154] are not regulated under the OI Regulation. However, that does not mean that these providers cannot impact openness for the internet ecosystem. BEREC has identified a couple of ways by which providers within this element can potentially impact the level of openness within the internet ecosystem and, more generally, influence user experience.

Hosting service providers in theory can differentiate between CAPs by the conditions they set for access, or they can differentiate through the contracts they offer to CAPs depending on their size. However, the likelihood of this type of practices occurring or being able to modify the users experience is limited due to the availability of many independent hosting providers. CAPs are therefore able to choose from a wide range of hosting service providers and switch in case modification of users' experience or differentiated treatment of content occurs, although switching costs vary, for example depending on the integration of hosting with other services.

As far as CDNs are concerned, these services are crucial for ensuring a high-quality distribution of content (especially audio-visual content) to end-users. For example, the quality of live streaming of sport events is heavily dependent on the availability of good CDN services. This might become relevant for end users experience in case of integration or partnership between CDNs, CAPs and ISPs.[155]

---

[153] Don't Let a Slow Website Kill Your Bottom Line, Forbes, https://www.forbes.com/sites/rogerdooley/2012/12/04/fast-sites/#14be9e3353cf

[154] An exception are providers of public ECS over cloud infrastructure (cloud communications providers), which fall under the scope of the OI Regulation.

[155] As an example, AGCOM adopted a "Recommendation" (Decision 206/21/CONS) whose goal was to prevent network congestion during the live-streaming of football games provided by a CAP and, in general, to avoid quality degradation of Internet access services for all users and, at the same time, to ensure economic and technical sustainability of network developments. The CAP was recommended to provide to ISPs caches of its own CDN and to collaborate with ISPs in order to define more efficient technical solutions for ensuring a high-quality live streaming distribution to all end users.

With regards to cloud services, three types of cloud services (i.e. IaaS, PaaS and SaaS) can be distinguished and this subchapter focuses on IaaS and PaaS services. The extent to which cloud computing services can affect the level of openness and differ depending on the type of service.

As an example, as more CAPs are using cloud computing services, this could undermine the decentralised design of the internet and widespread outages can lead to content and services not being available for users. Outages, for example of AWS in 2021, resulted in multiple websites being down for hours or not working properly for users.[156] These outages do not only point to potential robustness issues, but also indicate the potential ability for cloud computing services to affect the level of openness, if these robustness issues become systematic.

The market for cloud computing services (namely, IaaS and PaaS) is characterised by strong economies of scale and scope and a high degree of concentration. Openness issues can potentially occur if the IaaS/PaaS cloud computing provider would prohibit some type of information being distributed, and the business user would be unable to switch the cloud computing provider, or to provide the information through an alternative channel, due to switching barriers (technical and financial) and/or contractual obligations.

Because of the high level of concentration, the dependency on a limited number of cloud computing providers amplifies the risk that this group of providers can pose to openness within the internet ecosystem. It may also be challenging for small business users to innovate and scale up internet-based service provisioning with replicated storage and processing in competition with large business users which control their own CDNs and cloud computing facilities.

These types of openness challenges are more likely to occur for PaaS (and SaaS) than for IaaS. IaaS services give business users more control over their data and, due to relatively homogeneous services, it is easier to switch (see chapter 6) when an IaaS provider would decide to take measures that would restrict openness. With PaaS it is more difficult to switch, because a business user not only depends on the infrastructure of the cloud provider but also on customized (possibly bundled and integrated) services that are only able to run (efficiently) on a specific cloud environment or platform.

The proposed Data Act[157] aims to remove the existing barriers to switching between cloud providers and shows that there is a growing awareness of the current issues.

---

[156] https://www.theguardian.com/technology/2021/dec/07/amazon-web-services-outage-hits-sites-and-apps-such-as-imdb-and-tinder

[157] COM (2022) 68: Proposal for a Regulation of the European Parliament and of the Council REGULATION OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL on harmonised rules on fair access to and use of data (Data Act);), https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52022PC0068.

7.2.7 Attention-intensive applications

Attention-intensive applications rely on content which is often provided by users. By representing a gateway to specific content, services or other users, these applications can directly impact CAPs and users' choice. This is especially true for the two main types of attention-intensive applications that are social networks and video-sharing platforms. By the means of the network effect that supports them, they have become indispensable technical and commercial intermediaries for CAPs and users, and as such they may have the incentive to impose their formats, protocols and editorial policies, shaping the way content is provided to the user and how innovation can take place.

This aspect may be of particular importance where users remain locked into the attention-intensive applications, e.g. due to network effects, or the impossibility to port their data. Indeed, they tend to apply an "open early, closed late" strategy: once a critical mass of users is reached, attention-intensive apps may control access to their users in order to lock them in and exclude rivals.[158] This may give attention-intensive app the possibility to block, alter, restrict, interfere with, degrade or discriminate between content, services or other users.

The integration of some of these applications with other layers of the ecosystem, such as the app store, the OS and specific CDNs and cloud computing services, enhances their character as essential technical or commercial intermediaries that are not easy for CAPs and users to bypass. As such these applications can have a huge impact on the capacity of others to innovate.

7.2.8 Other applications

Other applications can also show signs of market dominance leaving little space for new market entrants to innovate and produce new internet-based services or for users to communicate in the way they want over the internet, even though these applications generally do not appear in principle as critical technical or commercial intermediaries to users.

In addition to that, some services that qualify as NI-ICS can rely on network effects that makes their market position not easily contestable. When end-to-end connectivity is endangered,

[158] *Cf.* S. A. Sher, B. T. Tennis, "Exploiting others' investments in Open Standards", Competition Policy International, 09.2016: "*In particular, the original developer of a technology that becomes a unilateral de facto standard can employ an 'open early, closed late' strategy to induce industry reliance on the technology and then later exploit that reliance to create lock-in and exclude rivals.*"; C. Shapiro, testimony before the Antitrust Modernization Commission, Exclusionary Conduct page 15, 09.09.2005.

there might be a need for service interoperability in order to provide a service continuity for users across platforms[159], a case that is envisaged in the EECC.[160]

Similarly, other applications like e-commerce platforms or cloud services may show signs of market concentration, with dominant platforms likely to shape the way users can use this type of applications to produce or offer their services or innovate. In this respect, legislative acts like the P2B Regulation (for the e-commerce platforms in particular) and the DMA are positive first steps towards a level playing field, addressing the asymmetry of bargaining power between users and such platforms.

7.2.9 IoT

The IoT represents a variation of the internet ecosystem, as the concerned devices, OSs, apps, manufacturers, services providers and internet access providers may be different than what is used for the publicly available IAS ecosystem. Hence, the problems detected on other elements of the internet ecosystem in this report are often also valid for the IoT environment, but several other IoT-specific issues are added.

Several openness issues encountered by IoT users are linked to the particular market structure of IoT services. As mentioned in chapter 6, it is common that IoT services are provided in a way that integrates the manufacturer of the device, the access service provider and the provision of software IoT services embedded on the device. This integration can generate several switching and lock-in issues:

- Switching an access service provider may require a hardware modification of the IoT device (e.g. the physical replacement of a SIM card or module). The cost of doing so (especially when combined to the management of a large fleet of devices, which might be dispatched geographically) might be a disincentive for an IoT user to switch to another access service provider, thus generating the “lock-in” effect. This may also restrain users’ choice and act as a disincentive for the development of innovative competing products, because it deters users from switching to alternative products.
- The lack of device interoperability, especially due to the creation of proprietary IoT ecosystems, can also lead to users becoming locked-in into a specific ecosystem, limiting their choices. This may also negatively affect users’ willingness to buy certain types of IoT products and services. Therefore, the absence of interoperability may also represent a barrier to innovation, as it tends to limit the ability of competitors to create

[159] BNetzA published a study on that topic, analysing the demand for interoperability on the user side, compared to multi-homing and low switching costs: https://www.bundesnetzagentur.de/DE/Sachgebiete/Digitalisierung/Onlinekomm/diskussionspapier_IOP.pdf?__blob=publicationFile&v=2

[160] See provisions in article 61(2) of the European Electronic Communications Code (https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32018L1972)

new products. The lack of common standards additionally represents an obstacle to IoT interoperability.

On the other hand, integration allows providers and users to benefit for example from:[161]

- Efficiency gained through easy compatibility between the components of the (eco-) system (e.g. between different IoT devices) to increase quality, for example coherent technological advances across multiple components.
- Efficiency gained through quick introduction of new functionalities and protocols by coordination efforts of the (eco-)system owner without having the drawback of being limited by standardization.
- Efficiency gained through little or no incentive of the (eco-)system to sell low-quality components as this would decrease the customer base.

An array of openness issues can arise from the design of IoT devices themselves: poorly designed and configured IoT devices may have negative consequences for the networking resources they connect to and the broader internet. This could be alleviated by open and widely adopted IoT standards that could help avoid the proliferation of devices that may affect in negative ways the internet. Similarly, poorly secured IoT devices that are connected to the internet can serve as entry points for cyber-attacks and, therefore, can potentially affect the security and resilience of the internet, as well as the experience of their end-users.

Another type of problem encountered by business-users and providers of IoT services is linked to numbering and addressing issues: the scarcity of numbering resources and identifiers (including e.g. E.164 numbers, E.212 MCC+MNC, IPv4 addresses) may result in different conditions of accessibility, entry and expansion for different manufacturers of connected devices within public networks. In a similar way, the absence of a unified naming system has generated a great heterogeneity in identifier naming conventions and provisioning structure. This raises concerns regarding the communication between objects that use different identifier naming conventions. According to Afnic[162], a naming service based on the DNS could be applied to the IoT ecosystem, to harmonize IoT identifiers at the international level, improving interoperability and security of communications[163], but this has yet to be adopted by the organization.

[161] CMA and Autorité de la concurrence (2014): The economics of open and closed systems, p. 27-30. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/387718/The_economics_of_open_and_closed_systems.pdf

[162] Association française pour le nommage Internet en coopération

[163] https://www.afnic.fr/wp-media/uploads/2021/01/ADN_AFNIC_DossierThematique_DNS_EN_WEB_02.pdf and https://www.afnic.fr/wp-media/uploads/2021/01/DNS-The-naming-service-for-IoT-AN-AFNIC-PERSPECTIVE.pdf.

8. FUTURE WORK

The analysis in this report provides a starting point to identify different areas of work where BEREC can contribute over the next years. The internet ecosystem is composed of heterogeneous yet interrelated elements and there are a large number of different areas which may require further analysis. Some of these areas are closely related to ECS, while others may not be directly within BEREC's regulatory realm, but BEREC and its members have experience in regulating electronic communications markets which can be valuable.

A first area for future work is at the intersection between ECS services and other elements of the internet ecosystem. In this context, BEREC considers that further work on the dynamics of competition and collaboration between the traditional ECN/ECS providers and other actors – in particular providing internet-based services and platforms such the Big Tech companies – is of special interest.

For instance, the Big Tech companies have traditionally provided services on the client and server sides of the internet ecosystem, and not generally on the internet infrastructure-related side. However, in recent years, they have invested increasingly in telecommunications infrastructures and have been providing additional services related to the network and ECS markets. Some examples include virtualised network services, content delivery networks (CDN), cloud computing with increasing ubiquity, the deployment of extensive international networks (e.g. submarine cables), as well as trends towards the provision of IAS. As a result, nowadays Big Tech companies are present across practically all the elements, or they can enjoy a significant presence in a relevant part of the elements in the internet ecosystem and can often leverage their position among different services and products e.g. by partnering with ECN and ECS providers, but also directly competing with them. Moreover, Big Tech companies may unilaterally implement some practices (e.g. redirecting traffic to their own servers from the user's device) which deserve to be further assessed.

The increasing investment by the Big Tech companies in infrastructures (such as submarine cables and satellite networks for interconnecting their data centres) is another area where BEREC could investigate in the future, given the impact on the competitive landscape for IP interconnection and ECSs in general. In this line, cloud and edge computing services, as well as their interaction with ECSs is also an area of interest, as it is important to understand how cloud computing providers are competing and collaborating with traditional ECN and ECS providers in the provision of new innovative services. In this context, facilitating switching, interoperability and or data portability are key, just like facilitating IAS switching and number portability are key in the traditional markets for ECSs.

In the same line, future work could also address issues such as the evolution of CDNs and cloud computing, as well as the effect of this evolution on the internet architecture and interconnection agreements. An additional issue for future work in relation to the architecture of the internet is the evolution from the "web" architecture (i.e. providing services according to

World Wide Web standards, typically through a web page) to the “app” architecture for CAPs, and its implications for governance, competition dynamics and openness.

In addition, the evolution of the internet interconnection architecture also appears to be a relevant topic for further analysis. This report highlights the bargaining asymmetries between smaller players (ISPs or CAPs) and big players. Moreover, the potential impact of interconnection architectures on openness should also be considered at a time when new internet-based services, which are sensitive to quality of service or data-intensive, are being developed and are therefore affected by an interconnection that is too restricted.[164]

Another relevant area where BEREC considers that further work could be done is related to user devices and their corresponding OS, as potential restrictions for competition, switching, interoperability, portability, etc. deserve to be analysed. This work need not be limited to only traditional terminal equipment, such as mobile phones or tablets, but could also include smart displays and speakers (and the corresponding virtual assistants), smart TVs and IoT devices. This also includes aspects such as the increasing use of eSIMs and its implications. In a more general scope, BEREC considers that ensuring the ability for users to provide and access the content and applications of their choice, not only in terms of the openness of their IAS, but across the whole internet ecosystem, is key for European society. This key issue would deserve further analysis for the elements in the internet ecosystem which are beyond the scope of the OI regulation.

Moreover, this current study on the landscape of the internet ecosystem may be complemented in the future by further assessing the environmental aspects of the services and products provided within the internet ecosystem. This potential future work would be in line with BEREC’s recent work on sustainability.

Finally, BEREC will continue collaborating with the EU institutions, both for the implementation of the DMA as well as any other regulatory instrument for elements in the internet ecosystem. BEREC keeps on monitoring and analysing the evolutions of the markets and the impact and effects of the practices implemented by the gatekeepers, especially those which may not be addressed by the current legal initiatives.

[164] BEREC touched upon this topic in two previous reports: BoR (12) 130, BEREC Report on An assessment of IP interconnection in the context of Net Neutrality, 06.12. 2012. https://berec.europa.eu/eng/document_register/subject_matter/berec/reports/1130-an-assessment-of-ip-interconnection-in-the-context-of-net-neutrality and BoR (17) 184 Ibid footnote 113

9. CONCLUSIONS

ECS and ECNs are part of a vast internet ecosystem which allows users and society as a whole to benefit from the extraordinary potential of a large variety of services provided via the internet. Like any other ecosystem, the internet is composed of many interrelated elements that affect each other.

This report presents a broad analysis aimed at understanding how users' internet experience is affected by the different elements of the ecosystem and how the interactions among them may have an impact on BEREC's and/or NRAs' regulatory intervention.

The main findings of the report are summarised here below.

First of all, the most relevant actors for the client and server sides of the internet ecosystem are Google/Alphabet, Apple, Meta, Amazon and Microsoft. ECN/ECS providers are mainly focused on providing IAS and infrastructure elements, thus supporting the communication between the client and server side, or between users. Additionally, ECN/ECS providers may make OTT video content (pay TV) available to end-users, in competition or cooperation with CAP, and/or by providing their own OTT interpersonal communications services. On the other hand, the Big Tech companies facilitate provider-specific ecosystems, by providing internet-based services and platforms related to a significant variety of different elements (from applications to internet access network). Such provider-specific ecosystems may be built around OS (e.g. Google, Apple and Microsoft) or around some key applications (e.g. Meta and Amazon). Each provider-specific ecosystem consists of a different combination of elements. For instance, Apple produces devices running its own OS, which is solely compatible with Apple's own application store and web browser engine; Google's or Microsoft's services/products are tightly integrated, such as through a singular identification service for access to multiple services, and common user interface elements.

Secondly, the Big Tech companies have traditionally provided services on the client and server sides of the internet ecosystem, and generally not on the internet infrastructure-related elements. However, in recent years, they have invested increasingly in telecommunications infrastructures and have been providing additional services related to the network and ECS markets. Some typical examples include virtualised network services, CDN, cloud computing with increasing ubiquity, the deployment of extensive international networks (e.g. submarine cables), as well as trends towards the provision of IAS. As a result, nowadays Big Tech companies are present across practically all the elements, or they can enjoy a significant presence in a relevant part of the elements in the internet ecosystem and can often leverage their position among different services and products, e.g. partnering with ECN and ECS providers, but also directly competing with them. Moreover, the Big Tech companies may unilaterally implement some practices (e.g. redirecting traffic to their own servers from the device) which deserve to be further assessed.

Thirdly, the way in which the provision of an internet-based service is implemented has technical, economic and behavioural implications which need to be taken into account. For example, there are two architectures which can be used to access or provide online content and services: native applications[165] and/or web applications[166]. Native applications are based on APIs set by the providers of the OS, while websites and web applications are based on common standards implemented by the web browser, and web pages/script code can run in any web browser. Since the market for mobile OSs is currently almost exclusively dominated by Google and Apple, the app software infrastructure is provided by two parallel provider-specific ecosystems. While CAPs may choose to use both architectures (native and web), they are subject to the choices taken by the two main mobile OS providers concerning technical formats, editorial choices and business models. This could have significant impacts in terms of openness, i.e. the potential of the internet to provide an open, easy-to-access and common infrastructure where non-proprietary, free software, contents and applications potentially governed by open communities, such as the internet protocols (i.e. TCP/IP), would enable the preservation and/or development of some digital services as common goods.

Fourthly, the analysis of the competition dynamics of the internet ecosystem's elements shows that there are several issues and potential bottlenecks especially concerning CDNs, cloud computing, enabling and discovery elements, devices, attention-intensive applications, e-commerce, instant messaging and the IoT.

Commercial CDN and cloud markets are largely concentrated and significant investments are required to have the necessary geographical coverage and capillarity. The infrastructure of cloud computing services (IaaS) also relies on large investments, due to the existence of very significant economies of scale in this market where large companies can leverage their power on other parts of the ecosystem.

With regards to devices, many original equipment manufacturers are horizontally and/or vertically integrated, often enjoying a termination monopoly[167]. The integration into a provider-specific ecosystem (e.g. Apple) creates lock-in effects and may also result in lack of transparency and potential restrictions on data portability. Other bottlenecks may arise from self-preferencing, commercial agreements, exclusive partnerships or discriminatory practices restricting competition (e.g. Google).

Enabling and discovery elements (OSs, web browsers, app stores and search engines elements) are characterised by very strong direct and indirect network effects. These elements are key to the openness of the internet ecosystem, as they allow users to interact with the whole internet ecosystem to create, offer and access new applications, content and services. The structural barriers to entry and expansion on these elements are reinforced by vertical

---

[165] A native application is a piece of software developed to run on a specific underlying platform or operating system.
[166] By accessing the World Wide Web
[167] A termination monopoly refers to the power exerted by a provider when its users are in ex-post dependency on a specific service/product. For instance, users dependency on services belonging to the same ecosystem can limit the conditions of access to or usage of competing products or services. By buying a specific device, users are not only often obliged to use the corresponding OS, but also the software application store and applications developed for this OS. Since users usually do not have the possibility to use other services/products provided by competitors, the provider can exert a de facto monopoly. The term is also mentioned by CERRE's Report on Device neutrality (June 2021) Ibid footnote 79

integration into provider-specific ecosystems, high switching costs for users, and significant costs of adapting and updating apps to run on several OSs.

Concentration of the OS market has a strong impact on the market for application stores, as users rarely use alternative app stores (when available). Furthermore, in case of lack of access for independent application developers to integrated application stores, competition in the downstream market for those apps can be hindered or eliminated.

Web browsers are also rather concentrated, especially in the mobile markets, as users tend to choose and use apps that are pre-installed on the device, and are therefore heavily dependent on the OS and/or device providers. Online search is also a very concentrated market, and largely dominated by a single provider (Google). Attention-intensive applications (social networking and video-sharing platform services) are concentrated around two players (Meta and Google) and several concerns may also arise on issues such as lack of transparency, access to data and discriminatory conducts.

In the IoT market, despite the apparently high number of players, some big and vertically integrated companies, such as Google, Amazon and Apple, play an important role. By having their own provider-specific ecosystems and by controlling proprietary technology, these companies have the ability and may have the incentive to adopt discriminatory practices (e.g. pre-installation, default-settings, tying), limiting interoperability and creating lock-in effects.

Finally, the analysis for most of the internet ecosystem elements generally shows that, in addition to significant network effects, consumer inertia is strong, resulting in low switching and thus reinforcing strong market positions/concentration. Examples of this include Google in search engines, Google and Apple in the mobile segment of the enabling and discovery layer, Meta in the attention-intensive elements and instant messaging, Microsoft in the desktop/laptop OS and SaaS layers, Amazon in cloud computing IaaS and PaaS, and in e-commerce. The business models for these large providers rely in many cases on extensive data collection, analysis and monetisation. Concerning cloud services, the European Commission's proposal for a Data Act aims to facilitate switching and data portability. In its high-level opinion on this proposal[168], BEREC strongly welcomes the provisions to facilitate switching between data processing services, and considers that the reduction and eventual removal of switching charges will lead to increased competition in the data processing services market.

This report highlights how the internet experience for users is affected by many different elements, such as devices, OSs, and application stores. These elements are not directly within NRAs' and BEREC's regulatory realm, but can still have an impact on ECN and ECSs – which are subject to NRAs' monitoring and regulation.

[168] BoR (22) 118, BEREC High-Level Opinion on the European Commission's proposal for a Data Act, 15.07.2022. https://berec.europa.eu/en/document-categories/berec/opinions/berec-high-level-opinion-on-the-ecs-proposal-for-a-data-act

The analysis also shows that some elements of the internet ecosystem are largely dominated by few players organised in provider-specific ecosystems. While such companies were initially providing services/products complementary to telecom operators, their entry into the ECN and ECS markets and the impact on the current regulatory framework deserves to be further addressed. Moreover, the analysis of the evolution of CDN and IP interconnection markets also appears to be crucial and closely connected with ECN/ECS markets.

Together with BEREC's previous work on the regulation of digital gatekeepers[169], this report shows how a small number of digital platforms have reached a position allowing them to shape and potentially restrict both the competition dynamics on different elements of the internet ecosystem and the relative openness under which content, services and information can be accessed and shared.

In line with BEREC's strategic priority to support competitive, sustainable and open digital markets, and with the role that BEREC will play within the High-Level Group for the enforcement of the Digital Markets Act, BEREC keeps on monitoring and analysing the evolutions in the internet ecosystem, particularly in markets that are significantly impacted by those practices of the gatekeepers which may not be addressed by the current legislative initiatives.

[169] BoR (21) 130, BEREC Report on the outcome of the public consultation on the Draft BEREC Report on the ex- ante regulation of digital gatekeepers, 30.09.2021. https://berec.europa.eu/eng/document_register/subject_matter/berec/reports/10042-berec-report-on-the-outcome-of-the-public-consultation-on-the-draft-berec-report-on-the-ex-ante-regulation-of-digital-gatekeepers;
BoR (21) 85, BEREC Report on the interplay between the EECC and the EC's proposal for a Digital Markets Act concerning number-independent interpersonal communication services, 10.06.2021. https://berec.europa.eu/eng/document_register/subject_matter/berec/reports/9966-berec-report-on-the-interplay-between-the-eecc-and-the-ec8217s-proposal-for-a-digital-markets-act-concerning-number-independent-interpersonal-communication-services;
BoR (21) 93, BEREC proposal on the set-up of an Advisory Board in the context of the Digital Markets Act, 10.06.2021.
https://berec.europa.eu/eng/document_register/subject_matter/berec/others/9963-berec-proposal-on-the-set-up-of-an-advisory-board-in-the-context-of-the-digital-markets-act;
BoR (21) 94, BEREC proposal on remedies-tailoring and structured participation processes for stakeholders in the context of the Digital Markets Act, 10.06.2021. https://berec.europa.eu/eng/document_register/subject_matter/berec/others/9964-berec-proposal-on-remedies-tailoring-and-structured-participation-processes-for-stakeholders-in-the-context-of-the-digital-markets-act;
BoR (20) 138, BEREC Response to the Public Consultations on the Digital Services Act Package and the New Competition Tool, 07.09.2020.
https://berec.europa.eu/en/document-categories/berec/others/berec-response-to-the-public-consultations-on-the-digital-services-act-package-and-the-new-competition-tool

ANNEX 1: List of abbreviations

AI	Artificial Intelligence
API	Application Programming Interface
ATT	App Tracking Transparency
AR	Augmented Reality
AWS	Amazon Web Service
BEREC	Body of European Regulators for Electronic Communications
Big Tech companies	Alphabet, Apple, Meta, Amazon and Microsoft
B2B	Business to business
B2G	Business to government
CAP	Content and Application Provider
CDN	Content Delivery Network
CMA	Competition and Markets Authority
CPE	Customer Premises Equipment
DNS	Domain Name System
DMA	Digital Market Act
DoH	DNS over HTTPS
DSA	Digital Service Act
EC	European Commission
ECS	Electronic Communications Services
ECN	Electronic Communications Networks
EC2	Elastic Compute Cloud
EEA	European Economic Area
EECC	European Electronic Communications Code
eSIM	embedded SIM
FTTH	Fibre to the Home

GDPR	General Data Protection Regulation
IAS	Internet Access Service
IaaS	Infrastructure as a Service
ICANN	Internet Corporation for Assigned Names and Numbers
IoT	Internet of Things
IP	Internet Protocol
IPR	iCloud Private Relay
ISP	Internet Service Provider
IT	Internet Technology
MEC	Mobile Edge Computing
MNC	Mobile Network Code
MNO	Mobile Network Operator
ML	Machine Learning
MVNO	Mobile Virtual Network Operator
M2M	Machine-to-machine
NI-ICS	Number-Independent Interpersonal Communication Services
NFC	Near Field Communication
NRA	National Regulatory Authority
OEM	Original Equipment Manufacturer
OI	Open Internet
OTT	Over the Top
OS	Operating System
P2B	Platform to Business
PaaS	Platform as a Service
PC	Personal Computer
QoS	Quality of Service

RAN	Radio Access Network
SaaS	Software as a Service
SIM	Subscriber Identity Module
SMS	Short Message Service
S3	Simple Storage Service
VoD	Video on Demand
VoLTE	Voice over Long-Term Evolution
VPN	Virtual Private Network
VR	Virtual Reality
VSP	Video Sharing Platforms
Wi-Fi	Wireless Fidelity
WWW	World Wide Web
W3C	World Wide Web Consortium

ANNEX 2: List of figures and tables