



ANALYSYS MASON REPORT

INVESTMENT IN NETWORKS, FACILITIES, AND EQUIPMENT BY CONTENT AND APPLICATION PROVIDERS

DAVID ABECASSIS, ANDREW KLOEDEN, ALEX SLINGER
AND MARINA BONETTI

SEPTEMBER 2014

Contents

1	Executive summary	1
1.1	The Internet relies on a complex and diverse set of networks, facilities, and equipment	1
1.2	Content and Application Providers invest in networks, facilities, and equipment for hosting and data processing, transport and delivery	2
1.3	We estimate that relevant direct and indirect investment by Content and Application Providers and Service Providers exceeds USD30 billion annually	5
1.4	Conclusion	7
2	Introduction	10
3	Content and application providers need networks, facilities, and equipment to operate online	11
3.1	Overview of the Internet	11
3.2	How content and applications are delivered online: a simplified model of the Internet	12
3.3	There is a wide range of activities that Content and Application Providers undertake to deliver their content, all of which require investment	14
3.4	Key players which invest in Internet networks, facilities, and equipment	16
4	Content and Application Providers invest in equipment and networks for hosting and data processing, transport and delivery	18
4.1	Hosting	18
4.2	Transport	23
4.3	Delivery	25
5	Content and Application Providers invest around USD33 billion annually in Internet networks, facilities, and equipment	30
6	Final comments	37

Copyright © 2014. Analysys Mason Limited has produced the information contained herein for Google. The ownership, use and disclosure of this information are subject to the Commercial Terms contained in the contract between Analysys Mason Limited and Google.

Analysys Mason Limited
Bush House, North West Wing
Aldwych
London WC2B 4PJ
UK
Tel: +44 (0)20 7395 9000
Fax: +44 (0)20 7395 9001
london@analysysmason.com
www.analysysmason.com
Registered in England No. 5177472

DISCLAIMER

This report was commissioned and sponsored by Google, and written by Analysys Mason, a global consultancy specialising in telecoms, media and technology.

Analysys Mason is grateful for all inputs received during the research and preparation of the report, from Google, Facebook and the London Internet Exchange.

The analysis contained in this document is the sole responsibility of Analysys Mason and does not necessarily reflect the views of Google or other contributors to the research.

1 Executive summary

1.1 The Internet relies on a complex and diverse set of networks, facilities, and equipment

The Internet is a collection of interconnected networks. It was designed to enable a computer or device connected to one of these networks to access information and services from any computer or device connected to any of the other networks. While the Internet is often abstracted as a ‘cloud’, and may seem somewhat virtual or intangible to its users, it relies on networks, facilities, and equipment including billions of discrete devices connected by millions of miles of cabling, plus a vast array of other equipment.

Investment in these networks, facilities, and equipment is incurred by a wide range of market participants: Internet backbone providers, ‘Internet Access Providers’,¹ ‘Content and Application Providers’ and a range of specialised service providers all invest in the networks that have come together as the Internet.

This report focuses on investment made, worldwide, by Content and Application Providers specifically, as well as investments by other service providers for the use of these Content and Application Providers. In this report, we focus on the networks, facilities, and equipment that support the hosting, transport and delivery of content and applications online. This includes investment from pure online players such as Google, Spotify and Amazon, the online element of multi-platform content providers such as the BBC or the New York Times. These are, broadly, the companies that operate web sites or online services.

Content and Application Providers themselves invest billions of dollars annually in a combination of facilities (such as data centres), fibre networks, servers and routers – a number has grown by 13% between 2011 and 2013. This is perhaps less visible to end users than other investment in R&D, content development, software development and engineering, but forms an essential part of the physical fabric of the Internet. To address the ‘cloud’ analogy, the content and software they develop may be accessible anywhere and anytime, but it needs to be hosted and transported by physical networks, facilities, and equipment.

In addition, the scope of this report also includes investment by third-parties who provide services sold to Content and Application Providers, for example transit and CDN providers. These organisations invest in a range of physical assets to help deliver Internet content from Content and Application Providers to customers; we refer to these market participants as *Service Providers*. They are an essential component of the Internet value chain, and include a broad range of stakeholders. Data centre operators build and operate the physical locations and sometimes servers where content is hosted and processed. Other companies build and operate the Internet backbone

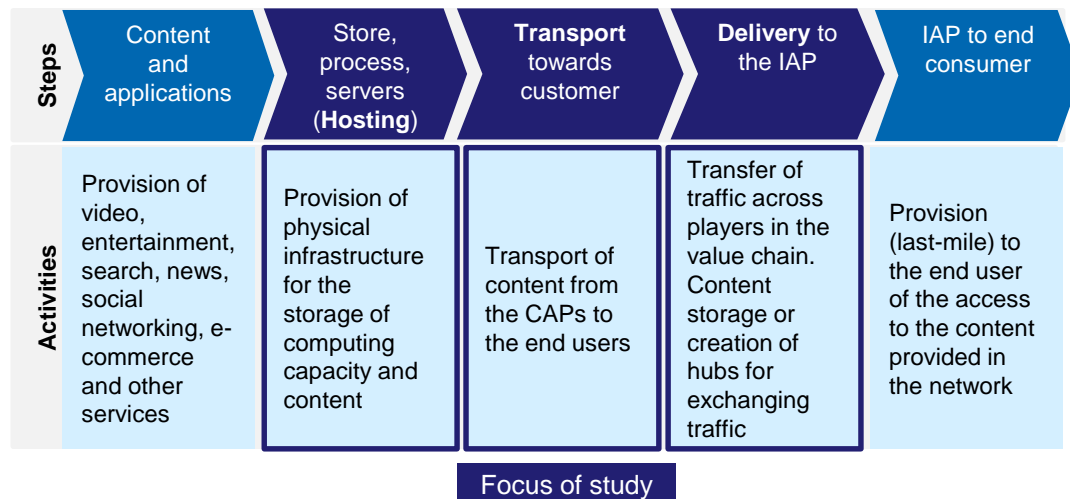
¹ These are companies, typically telecom operators or cable TV companies, that own or operate the “last mile” connection to customer homes and businesses

networks that deliver content from the data centres to the Internet Access Providers. Finally other specialised intermediaries, such as content delivery networks and Internet exchanges points (IXPs), help optimise the delivery of this content.

1.2 Content and Application Providers invest in networks, facilities, and equipment for hosting and data processing, transport and delivery

Content and Application Providers are in the business of delivering content and applications to end users. They have an incentive to ensure that this is delivered with a high quality of experience: high level of service reliability, quick response speeds, high resolution (for images and video) and little or no degradation of the content. To do this, Content and Application Providers must invest in a range of systems, software and networks. For the purpose of this report, we focus on the networks, facilities, and equipment that support the hosting, transport and delivery of content and applications, as illustrated in Figure 1.1 below.

Figure 1.1: Key activities involved at each stage of the Internet value chain [Source: Analysys Mason, 2014]



Hosting

Simplistically, Content and Application Providers need somewhere to store their content. This is typically a storage device located in a large data centre. In addition to this, when a Content and Application Provider receives a request for content from an end user, it needs to process the request. For certain activities (e.g. searching the Internet), this requires a large amount of computing power, provided by servers also located in a data centre. In addition, these data centres house and run a large amount of networking and transport equipment such as routers, switches and cable termination points. As such, they form the ‘nodes’ of the Internet and are an integral part of the network. Figure 1.2 below shows the location of Amazon Web Services’ key data centres, which are located throughout the world.

Figure 1.2: Location of key data centres within the AWS network [Source: Amazon Web Services, 2014]



Transport

Once the Content and Application Provider has decided what content to send, it must be transported, often over long distances, from the hosting location to the Internet Access Provider network to which the customer is connected. This typically involves the use of high capacity fibre optic cables, typically owned and built by Internet backbone providers, who sell capacity to other companies, including Content and Application Providers.

Delivery

Once the content has been carried to the edge of the Internet Access Provider's network, it needs to be handed over to the Internet Access Provider, who then delivers it across the 'middle and last mile' to the end user. This involves physical interconnections between the networks of a 'transit' backbone provider (if used) and the Internet Access Provider, or in some cases directly between the Content and Application Provider and the Internet Access Provider. In addition, Content and Application Providers may try to optimise the efficiency of this delivery by caching the content at the edge of the Internet Access Provider's network, or arranging for a CDN² – this represents a significant investment by Content and Application Providers to improve the efficiency of the transport and delivery networks.

Each of these activities requires significant investment in networks, facilities, and equipment:

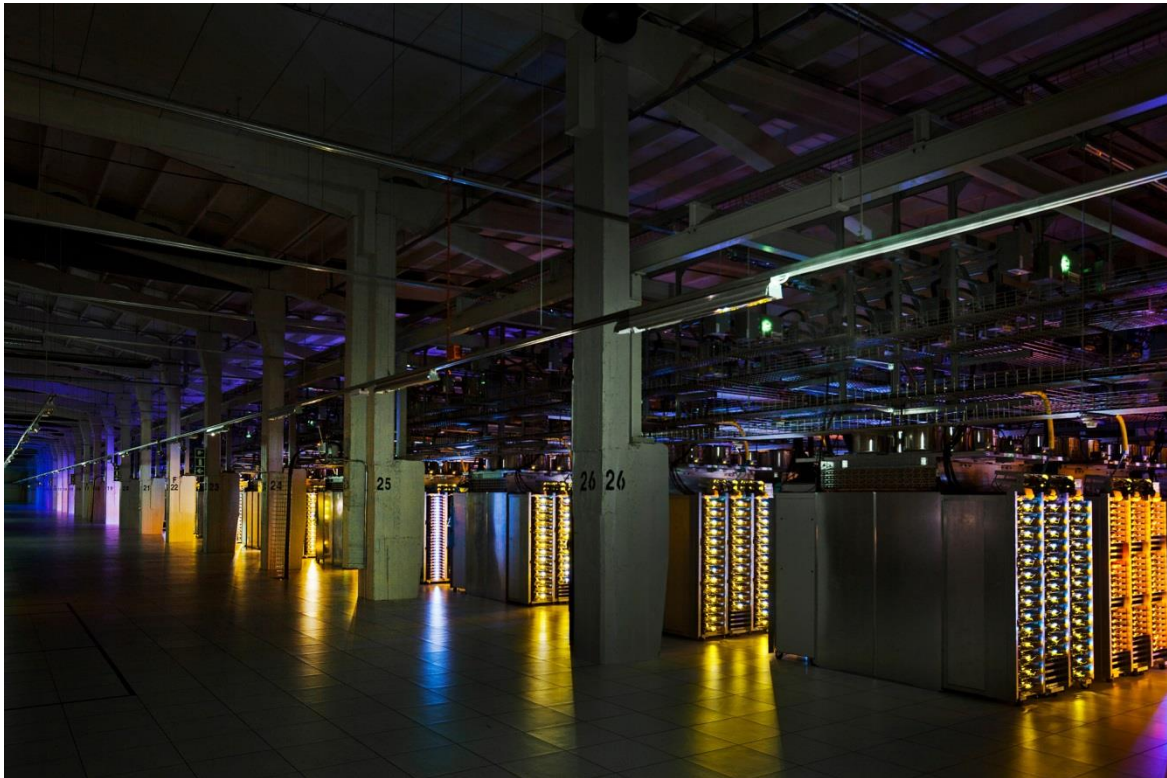
- **Hosting** requires investment in large data centre buildings, with significant electrical power supplies. These buildings house the servers and storage devices that host Internet content.

²

Source: Analysys Mason, Cisco, Informa Telecoms and Media, Google, Microsoft

These servers and storage devices themselves also make up a large proportion of the data centre investment. As these devices generate a lot of heat, data centres need very powerful cooling systems. Finally, they need sophisticated security, monitoring, and other operational systems. Figure 1.3, below, shows the interior of Google's Hamina data centre in Finland, demonstrating the scale of these facilities.

Figure 1.3: Interior of Google's Hamina data centre in Finland, showing racks for the housing of servers and storage devices, and other systems [Source: Google, 2014]



- **Transport** requires investment in large capacity, long distance cables, built either on land (terrestrial cables) or under the sea (submarine cables). Also required is switching and routing equipment to ensure content travels to the correct destination. These cables are expensive to install, involving either large ocean going ships in the case of submarine cables, or expensive civil works in the case of terrestrial cables. These cables are typically owned by Internet backbone providers, who sell capacity to other companies, including Content and Application Providers. Figure 1.4, below, shows a cable-laying ship owned by Alcatel Lucent.

Figure 1.4: The Ile de Batz, a submarine cable laying ship [Source: WIOCC, 2014]



- **Delivery** requires investment in switching equipment in IXPs, routers and servers used in CDNs, and the edge routers that different networks use to interconnect with each other. These investments are largely in electronic equipment. This tends to be of a smaller scale than data centres or transport links. This electronic equipment is typically located in data centre facilities, and connected to transport networks.

1.3 We estimate that relevant direct and indirect investment by Content and Application Providers and Service Providers exceeds USD30 billion annually

The level of investment by Content and Application Providers in the networks, facilities, and equipment of the Internet, or by service providers on their behalf, is significant— between approximately USD28 billion and USD36 billion annually in the last three years (2011-13), with a blended average in the region of USD33 billion per annum.

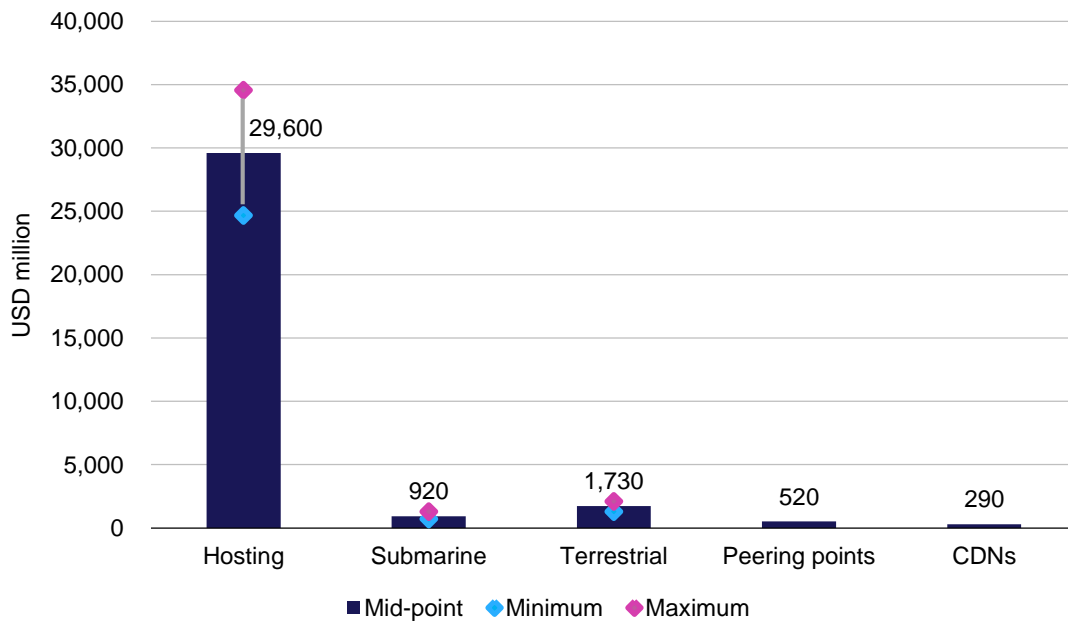
Investment made *directly* by Content and Application Providers is the largest part of this, at around USD25 billion (76% of the total). This includes facilities that the Content and Application Providers invest into directly as part of their capital expenditure, such as Google’s Hamina data centre (shown above). Although the majority of direct investment (USD24 billion annually) is related to hosting, large Content and Application Providers are increasingly investing in physical cable networks (e.g. Facebook in the Asia Pacific Gateway, and Google in the UNITY, South-East Asia Japan Cable and most recently the FASTER cable system).

Indirect investment is that made by service providers (such as internet backbone providers) ‘on behalf of’ Content and Application Providers, by which we mean investments from third parties that are incurred in order to sell to Content and Application Providers. We estimate this at around

USD8 billion per annum, by considering the relative demand from Content and Application Providers vs. other users of service providers' assets (such as submarine cables).

Figure 1.5, below, shows total Content and Application Provider investment by category, averaged over the period 2011-13. Given the inherent uncertainty of estimating global figures, we have put a range on each of the most significant investment categories.

Figure 1.5: Approximate magnitude of investments by Content and Application Providers [Source: Analysys Mason, DCDi, Telegeography, Informa, company data, news reports, peering dB, Comscore, Sandvine, 2014]



This investment is significant, and represents a material proportion of the annual revenues of Content and Application Providers. On average, the largest 3 Content and Applications Providers have invested 9% of their 2011-2013 revenues in networks, facilities, and equipment.³ It is important to note at this stage that this is only part of the financial commitments of Content and Applications Providers in the Internet: investment in R&D, content development and licensing, software development and engineering all form important parts of what they invest in, and this is not captured in this study.

The investment by Content and Application Providers that is considered here is dominated by hosting, which is driven by the growing volume of Internet content that must be hosted and processed – much of it user-generated (e.g. Facebook photos or YouTube videos). Transport investment is also significant, which reflects the scale of global terrestrial and submarine networks and the increasing importance of Content and Application Providers as investors and customers for Internet bandwidth.

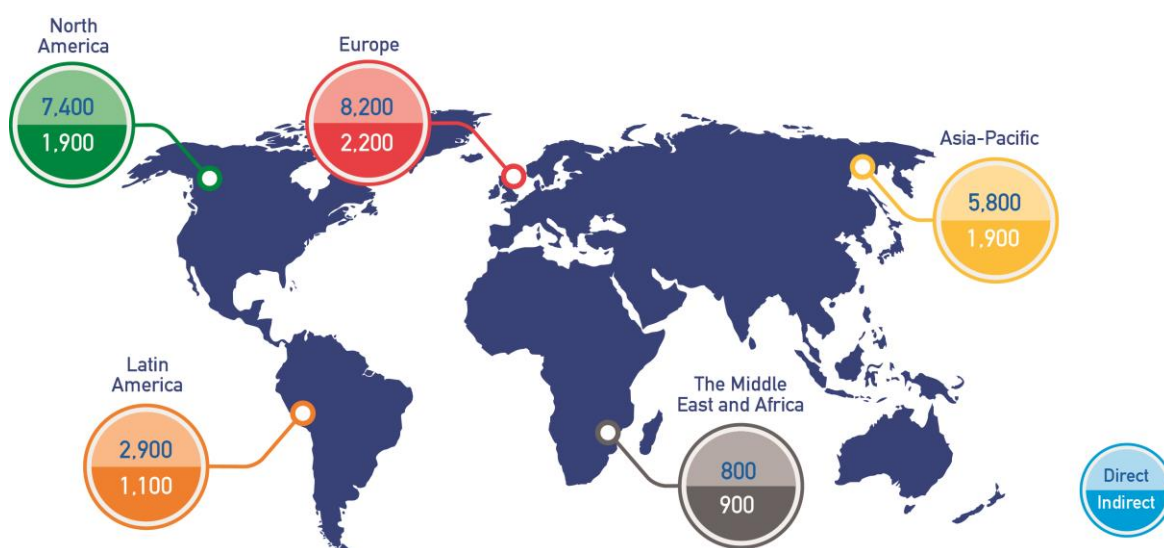
³

These companies are Google, Facebook and Yahoo!

In addition, this investment is growing strongly. Between 2011 and 2013, investment by Content and Application Providers grew by 13% per year. Content and Application Providers are investing significantly to meet the rapidly increasing demand for Internet content from end users.

Finally, we have split the total investment by geographic region. This is illustrated below, in Figure 1.6. Europe appears to be the largest destination for Content and Application Providers' investment. Europe is a hub for Internet traffic as it is the meeting point of many international cables, is home to the world's largest IXPs, and has a large population of Internet users. This is attracting investment by US companies, especially in data centre facilities, as well as investment by local Content and Application providers such as Spotify and the BBC.

Figure 1.6: Regional split of direct and indirect investment⁴ [Source: Analysys Mason, DCDi, Telegeography, Informa, company data, news reports, peering dB, Comscore, Sandvine, 2014]



1.4 Conclusion

Our research demonstrates clearly that the investment in networks, facilities, and equipment by Content and Application Providers, both direct and indirect, is substantial: Content and Application Providers make a significant and on-going contribution to the physical fabric of the Internet.

However, this is only part of the overall investment made by Content and Application Providers in the Internet ecosystem. As noted above, their main business is the provision of attractive content

⁴

Regional investment data is scarcer than global numbers; as such, this regional split is indicative, although the regional breakdowns are more reliable for larger investments (data centres, transport) than for smaller investments (IXPs, CDNs)

and applications to end users, and as such they invest significant amounts of money to produce, maintain, market and distribute content and applications, both in technical and creative activities⁵.

These investments are made by multiple stakeholders, and include for example:

- Video, film, and television production, including scripting and writing, hiring actors, filming and production, editing and other production related activities
- Journalism and news gathering, including writing and photography
- Software and application design, development and testing
- eCommerce systems, including software, as well as other physical investments in warehousing, delivery and fulfilment

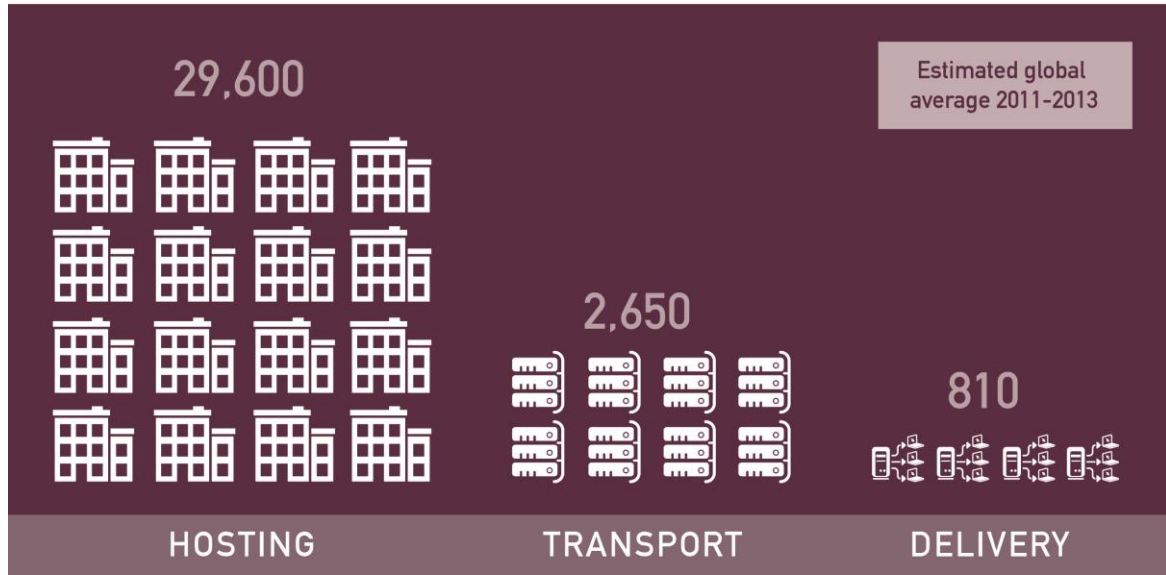
This investment and spending is not captured in the ‘networks, facilities and equipment’ scope of this report, but are relevant contributions by Content and Application Providers to the wealth of content and the quality of experience available online to end users.

⁵

By comparison, network operators tend to invest a greater proportion of their capital expenditure in their network assets. However, some do invest in creative activities and content, especially those that also operate pay TV services. Network operators also invest in retail outlets and mobile handsets

Investment in infrastructure

Content and application providers support around US\$33 billion annual investment in infrastructure worldwide



* ALL NUMBERS ARE IN USDm

Analysys Mason is the leading global telecoms adviser for telecoms, media and technology (TMT).

analysismason.com

2 Introduction

This report explores the investments in networks, facilities, and equipment made by Content and Application Providers – the companies and other entities that operate and distribute services and content over the Internet. It examines the content of this investment, and demonstrates that its overall level is significant.

A Content and Application Provider's core purpose, and the main cost of doing business for many, is related to the intellectual property (the content and applications) that drives consumers to use the Internet. Content and Application Providers invest billions of dollars in developing the video content, news articles, games, platforms and software that make the Internet useable and useful to end users. While not considered directly within this report, these activities obviously form a significant portion of Content and Application Providers investment in the Internet ecosystem.

However, Content and Application providers also invest billions of dollars annually in a combination of physical facilities (such as data centres), fibre networks, servers and routers. This is perhaps less visible to end users than other investment in R&D, content development, software development and engineering, but forms an essential part of the physical fabric of the Internet. The content and software they develop may be accessible anywhere and anytime, but it needs to be hosted and transported by physical networks, facilities and equipment.

This investment is the focus of our report. Our research demonstrates that this investment is substantial and has been increasing in the last few years. Content and Application Providers are therefore large contributors to the physical fabric of the Internet, in addition to the intellectual property they invest in to develop their content and applications.

The structure of this report reflects two aims: to describe, qualitatively, the drivers and nature of Content and Application Providers' investments in networks, facilities, and equipment, and to quantify as much as possible the magnitude of these investments.

- Section 3 discusses why Content and Application providers must invest in networks, facilities, and equipment
- Section 4 discusses these investments made by Content and Application Providers
- Section 5 presents our estimates of the magnitude of these investments
- Section 6 provides a brief conclusion.

3 Content and application providers need networks, facilities, and equipment to operate online

3.1 Overview of the Internet

The Internet is a global network linking billions of connected devices, allowing a connected user to access information and services from other systems which may be physically located anywhere on the planet. To achieve this feat, the Internet is designed as a collection of joined networks (a 'network of networks').

This 'network of networks' structure is a legacy of the transition of the Internet from a defence-sponsored project concerned with resilience to an academic, and eventually mass market phenomenon. The standardisation of the first Internet transmission protocols (TCP/IP) in 1981, which enabled existing local and wide area networks (LANs and WANs) to interconnect easily, is generally considered as the beginning of the Internet. Through the later development of the World Wide Web, the usefulness of the Internet for 'lay users' (in particular consumers) increased dramatically, paving the way for its current popularity.

Over the past 30+ years the Internet has developed from its initial beginnings as a specialist tool, used mostly by universities and large businesses (who already operated LAN/WANs), to a truly universal system used by many in the world on a daily basis. This development has gone hand in hand with an explosion in the range of services, content and applications available for general consumption.

A large part of this growth in services, content and applications is due to innovation and investment in software and in the content itself, particularly creative content. A Content and Application Provider's main business is the creation and delivery of such content and applications to Internet end users. In order to be successful, a Content and Application Provider must be able to both create a demand for its services and be able to supply these services to end users.

This intellectual property (content and services) that users access, consult and consume over the Internet could not exist in an 'infrastructure vacuum': it is enabled and supported by significant investment in networks, facilities, and equipment by all parties involved. It is this investment, by Content and Application Providers in particular, which is the focus of this study.

Investment (both direct and indirect) in networks, facilities, and equipment allows Content and Application Providers to satisfy their users' demand by ensuring a high quality network connecting their services reliably to a global catchment of consumers. For content and applications, high quality relates to ensuring a good end user experience which is based on a high level of service reliability, quick response speeds, high resolution (for images and video) and little or no degradation in the content. Considering the limited barriers to entry for many Internet services,

ensuring a good quality of experience is especially important for Content and Application Providers.

3.2 How content and applications are delivered online: a simplified model of the Internet

In order to understand the workings of the Internet, it is useful to follow the steps of a person using the Internet, for example to access their favourite website, or to watch the trailer for a new film recommended by a friend:

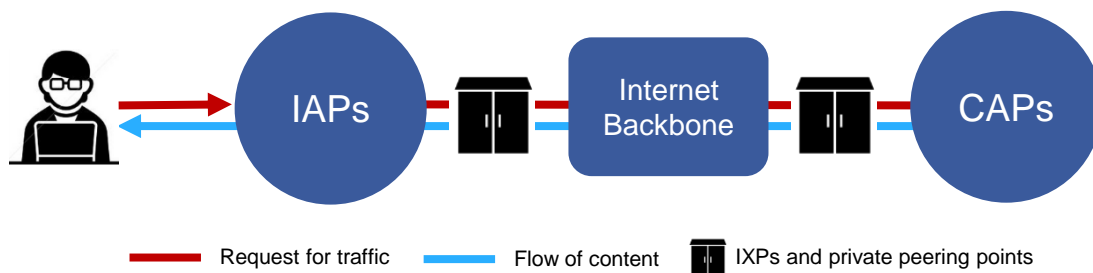
- **Step 1:** Having decided what content they want, a user will generally open a web browser and type the name of the website they want to access in the address bar, click on a link in a search engine or other page, or open a dedicated app. The browser or the app resolves the request by identifying the right IP address to contact,⁶ then sends a request to its default gateway within the end user's Internet Access Provider's network.⁷
- **Step 2:** This request is routed across the Internet Access Provider's network onto an Internet backbone, which provides the 'spine' onto which all other networks are attached and can communicate. These backbones may be operated by Internet Access Providers, Content and Application Providers, or service providers. They may include both terrestrial and submarine portions, depending on the location and routing configurations of the end-users Internet Access Provider's network on the one hand, and of the Content and Application Provider's network on the other hand.
- **Step 3:** Once the request has been carried across to the Content and Application Provider's network, it is processed by the Content and Application Provider's servers and the content is sent back towards the initial end user who requested it, once again through backbone networks, traversing multiple connections, using multiple routers.
- **Step 4:** Once the content reaches the end user's Internet Access Provider, it is finally delivered to the customer.

Although this is a highly simplified view of what happens when the end user first accesses this content from an Internet connected device, it clearly illustrates the fact that content is stored ('hosted') somewhere on the Internet, from where it can be fetched ('processed') upon request so as to be transported across any number of physical links to the network of the end user's Internet Access Providers, where it will be finally delivered to that end user. This is illustrated in Figure 3.1.

⁶ Where the user uses a typed domain address (such as www.google.com), the user's browser will contact a DNS server to find the related Internet Protocol (IP) address.

⁷ For the purpose of this report we use the terminology 'Internet Access Provider' rather than 'Internet Service Provider' to designate the operator that provides Internet access to end-users, ultimately relying on physical infrastructure such as copper-based DSL or fibre-based access networks.

Figure 3.1: Simplified view of the flow of information over the Internet [Source: Analysys Mason, 2014]



Within this simplified model, at the points where networks meet and exchange traffic, there are sometimes specific pieces of infrastructure referred to as *Internet Exchange Points* (IXPs). An IXP is a shared switching and interconnection fabric, typically located in one or more third party data centre facilities. These IXPs enable many different Content and Application Providers, Internet Access Providers and backbones to interconnect in a low cost and convenient manner. This ‘mutualised interconnection point’ enables cost savings and performance improvements that contribute to Internet content being delivered more efficiently to end users.

With the rapid uptake of Internet services by end users and Content and Application Providers, and particularly with the emergence of fast-growing demand for, and supply of, high-quality content (especially video), demands on networks have increased significantly. In order to mitigate the costs associated with the delivery of such content and to improve the experience for end-users, Content and Application Providers increasingly rely on techniques such as *caching* and *preloading* (delivering content to a nearby location during off peak times), sometimes outsourced to service providers called *Content Delivery Networks* (CDNs).

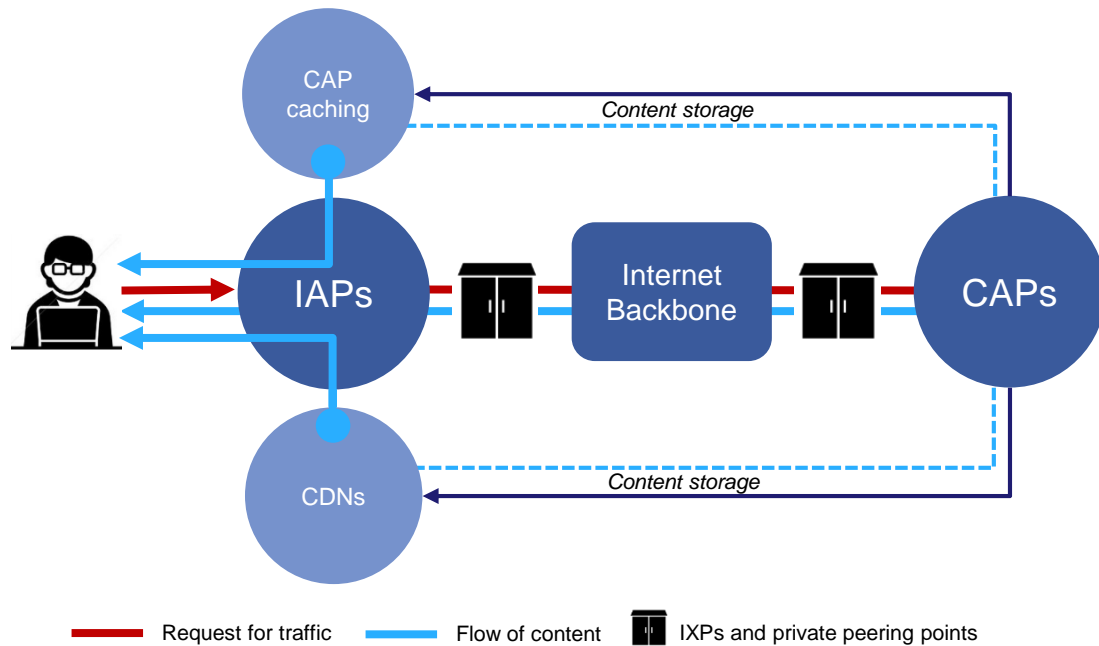
Caching is a process where a Content and Application Provider hosts copies of its content in a number of locations throughout the Internet, to ensure that the content is available close to end users. This minimises the time and network resources to fetch content stored in a central location. Under this model, a Content and Application Provider such as Netflix can host the whole of their content on one platform,⁸ and keep a copy of a relevant subset of content in a hosting facility close to the network of a large Internet Access Provider. This enables the content to be delivered to the customer more quickly, with better throughput and at a lower cost than if it were hosted centrally.

A CDN is, effectively, a set of networked servers and storage facilities that enable efficient caching and delivery of content. CDNs are sometimes an integral part of a Content and Application Provider’s network (e.g. Netflix’s Open Connect), they can be operated by specialised service providers such as Akamai, or they can be part of a broader offering by Internet backbones or even Internet Access Providers. This is illustrated below, in Figure 3.2.

8

In Netflix’s case, the Amazon S3 storage platform (see <http://aws.amazon.com/solutions/case-studies/netflix/>)

Figure 3.2: Simplified view of the flow of information over the Internet using CDNs or caching [Source: Analysys Mason, 2014]

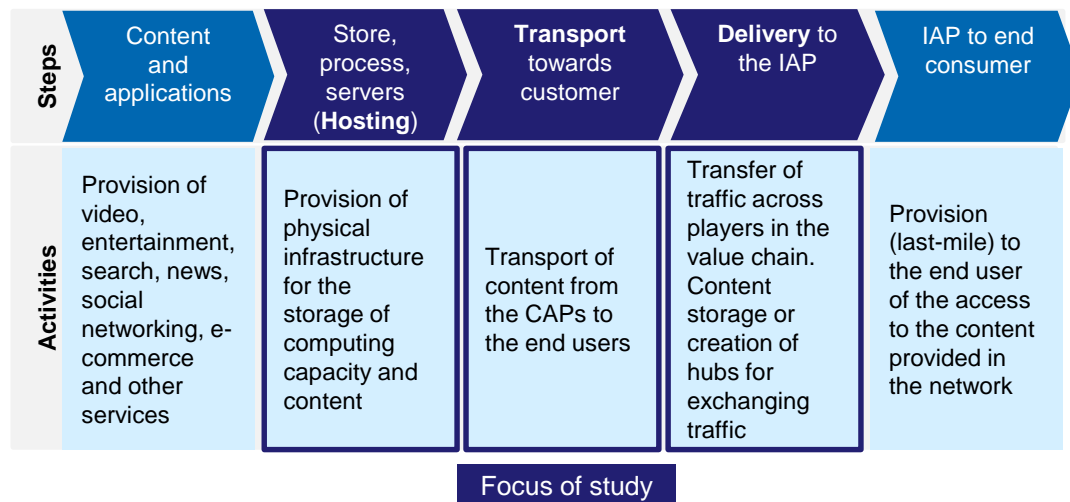


In summary, our simplified representation of how the Internet works involves three stages: content and application data is stored and processed at the ‘**hosting**’ stage, it is carried across the multiple interconnected networks that form the Internet in the ‘**transport**’ stage, and it is delivered to end users as efficiently and cost-effectively in the ‘**delivery**’ stage.

3.3 There is a wide range of activities that Content and Application Providers undertake to deliver their content, all of which require investment

In order for Content and Application Providers to deliver their services to end users with a high quality of experience, there are a number of activities that need to happen. Many of these activities are invisible to end users of the Internet, despite requiring considerable effort and investment. These activities are illustrated below in Figure 3.3, and can be carried out either by Content and Application Providers themselves, or by service providers on their behalf.

Figure 3.3: Key activities involved at each stage of the Internet value chain [Source: Analysys Mason, 2014]

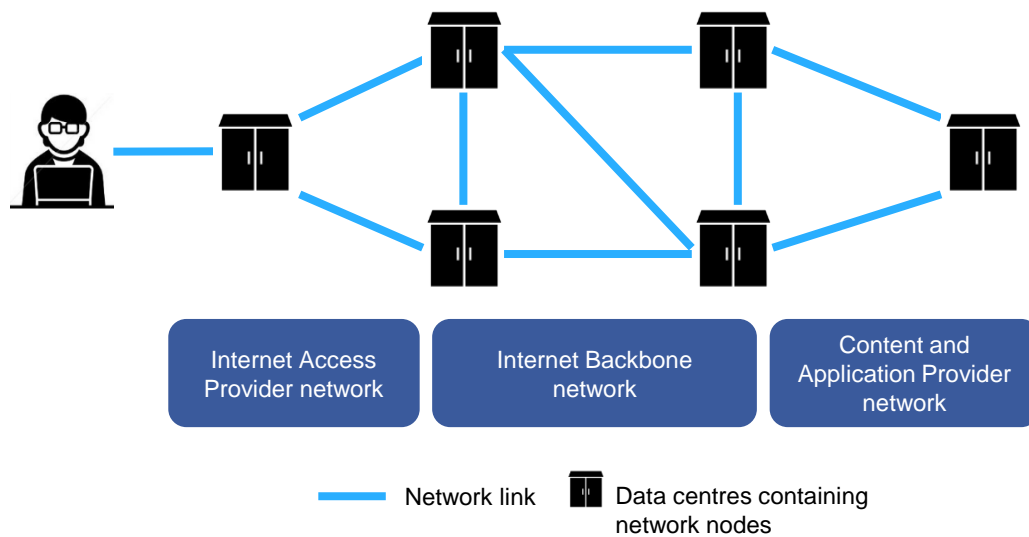


The activities that are most reliant on networks, facilities, and equipment investments by Content and Application Providers are hosting, transport and delivery:

- Hosting:** Simplistically, Content and Application Providers need somewhere to store their content. This is typically a storage device located in a large data centre. In addition to this, when a Content and Application Provider receives a request for content from an end user, it needs to process the request, to decide what content to send where. It also needs to validate that the customer is permitted to receive the content (for example, if it is paid-for content). This may require a large amount of computing power, which is provided by servers, also located in a data centre. Some services, such as content recommendations or programmatic advertising, rely on processing power even further⁹. In addition, the Internet itself can ultimately be seen a network made up of communications links that join network nodes, where traffic is processed and routed. These nodes are located in data centres, which are spread geographically throughout the Internet. As such, hosting and data centres are an integral part of the Internet itself. This is illustrated below in Figure 3.4

⁹ Note that software development and intellectual property regarding any content or services are not within the scope of our analysis. However, the servers and physical equipment required to run them is included

Figure 3.4: The place of data centres in the Internet [Source: Analysys Mason, 2014]



- **Transport:** Once the Content and Application Provider has decided what content to send, it must be transported, often over long distances, from the hosting location to the Internet Access Provider network to which the customer is connected. This typically involves the use of large capacity fibre optic cables.
- **Delivery:** Once the content has been carried to the edge of the Internet Access Provider's network, it needs to be handed over to the Internet Access Provider, who then delivers it across the 'middle and last mile' to the end user. This involves physical interconnections between the networks of a backbone provider (if used) and the Internet Access Provider, or in many cases between the Content and Application Provider and the Internet Access Provider. In addition, Content and Application Providers may try to optimise the efficiency of this delivery, by caching some content at the edge of, or within, the Internet Access Provider's network, or arranging for a CDN to do this for them.

Content and Application Providers, Internet Access Providers and service providers are all involved at various stages of this value chain as explored further in the next section.

3.4 Key players which invest in Internet networks, facilities, and equipment

Each of the steps described above comprises many different processes, and uses different network elements to allow the request and response to travel reliably between the Content and Application Provider and the end user. Investment in these multiple systems and networks is shared between many different stakeholders, from Internet Access Providers to Content and Application Providers through backbone operators and other specialised service providers. These three broad categories of investors are responsible for the vast majority of the investment into, and usage of, physical networks, facilities, and equipment, as detailed in Figure 3.5.

Figure 3.5: Overview of the categories of company active in Internet investments [Source: Analysys Mason, 2014]

	Type of companies	Examples
Content Application Provider (CAP)	Companies that provide end users with Internet content and applications	Google, Facebook, Yahoo!, Microsoft, Amazon, eBay, Netflix, BCC, Spotify, Dailymotion, Axel Springer
Service provider (SP)	Companies that help delivering Internet content, including data centre and backbone providers, IXPs, CDNs	Level 3, Cogent, XO Comms, Tata, Equinix, Akamai, CenturyLink, SunGard, Amazon (AWS), AMS-IX, DE-CIX, LINX
Internet Access provider (IAP)	Companies that provide Internet connectivity for consumers and businesses	NTT, Comcast, AT&T, Deutsche Telekom, Time Warner Cable, Verizon, Orange, KT

Both Content and Application Providers and Internet Access Providers invest directly in their own equipment and networks, while also supporting investment by service providers, through the flow of money in exchange for services they buy from these service providers. This ‘indirect’ investment is effectively incurred by service providers on behalf of Content and Application Providers and Internet Access Providers, sometimes in addition to enterprise customers for private network usage.

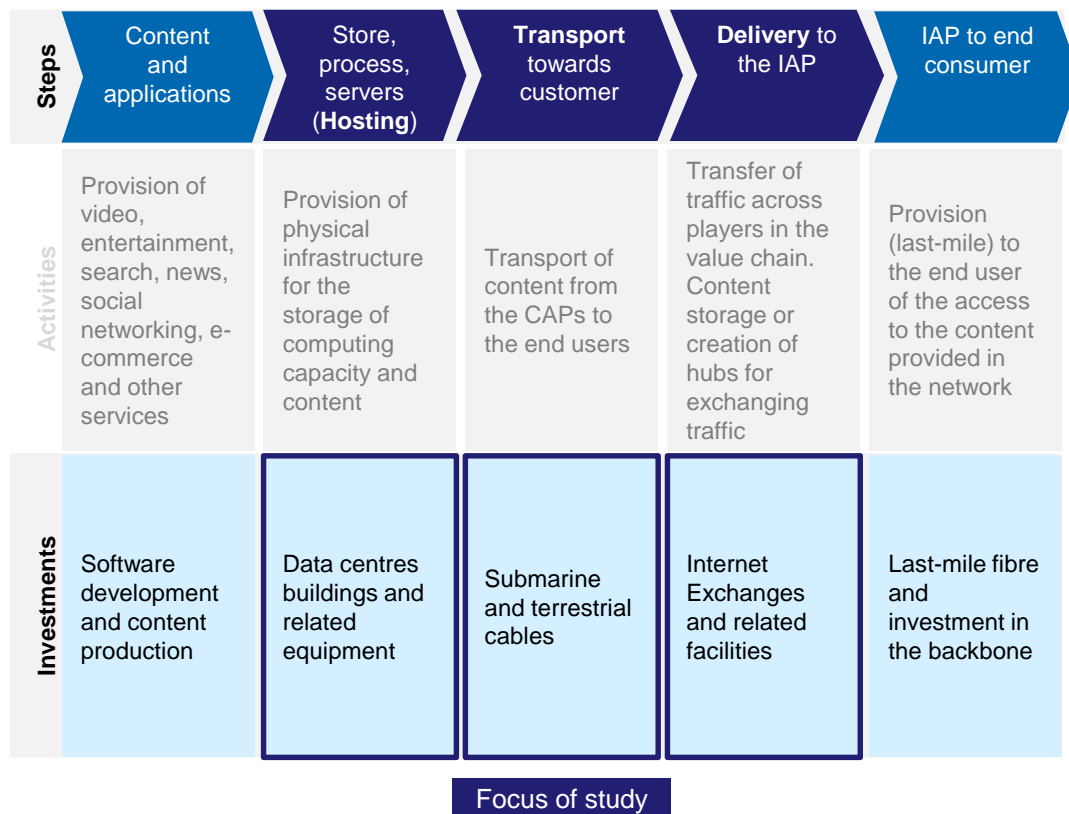
Notably, Internet Access Providers undertake many activities to deliver the content to the end customer. The most important of these is to provide connectivity from homes and businesses to Internet backbones and Content and Application Providers. In addition to this, they typically provide modems to customers, including installation and fault repair services. Internet Access Providers also often pay Internet backbones for IP transit, depending on how extensive their own network is.¹⁰ This payment contributes to the investments made by service providers.

¹⁰ Large Internet Access Providers are often backbone operators themselves, in which case the transit relationship is internal and may not be monetised

4 Content and Application Providers invest in equipment and networks for hosting and data processing, transport and delivery

As discussed in the previous section, Content and Application Providers (and other Internet players) undertake many different activities to get content to end users, much of which is invisible to users of the Internet. These activities require considerable effort on the part of Content and Application Providers and other organisations, and require large investments in physical equipment. These investments, and how they correspond to the activities discussed above, are illustrated in Figure 4.1, below.

Figure 4.1: Investments in networks, facilities, and equipment required at each stage of the Internet value chain [Source: Analysys Mason, 2014]



We describe each area of investment in more detail below.

4.1 Hosting

In order to store and process their content, route their traffic and serve their customers, Content and Application Providers invest in data centres. These are large (sometimes very large) buildings

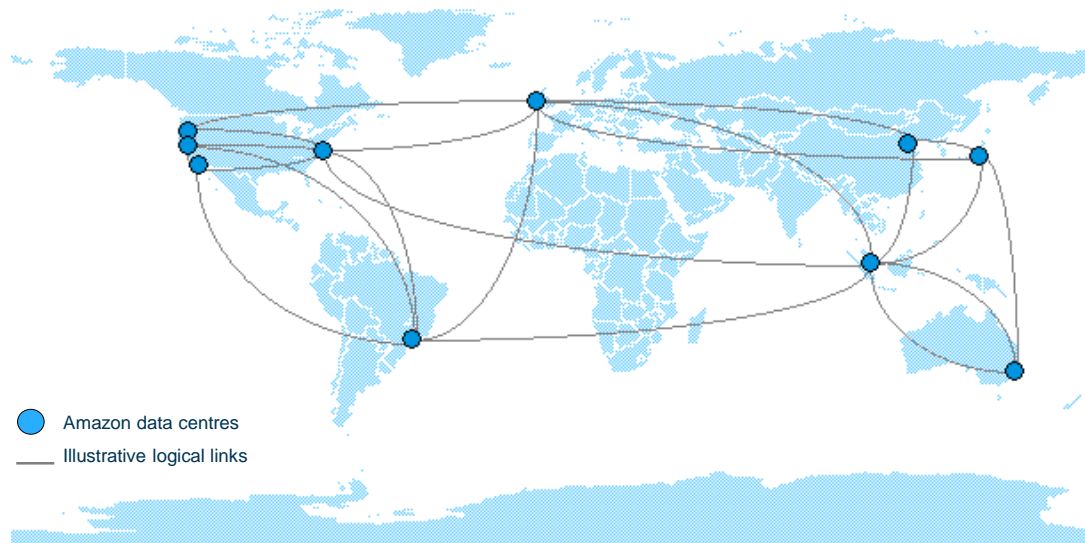
that contain thousands of metal racks, each housing a number of powerful computers (servers) or devices for data storage. These data centres are expensive to deploy, requiring large investments, and expensive to run and maintain. Indeed, they are typically the largest investments made by Content and Application Providers. For example, Google's facility in Hamina, Finland (see photograph in Figure 4.2 below) has been built with approximately USD350 million in investment over time.

Figure 4.2: Interior of Google's Hamina data centre, showing racks for the housing of servers and storage devices, and other systems [Source: Google, 2014]



These data centres are integral parts of the networks that link together to form the Internet. Figure 4.3, below, shows the location of Amazon Web Services' key data centres, which are distributed across the world in a network of their own.

Figure 4.3: Location of key data centres within the AWS network [Source: Amazon Web Services, 2014]



A well-functioning data centre requires investment in a great deal of specialised equipment, including:

- Power connection and distribution
- Cooling equipment
- Servers and storage devices, and racks to house them
- Other operational equipment (e.g. physical security, monitoring and maintenance systems)

Power connections and distribution equipment are a significant cost. Data centres require a very large and very reliable supply of power that is sometimes not even commercially available. For example, a 10 000 square metre data centre like the one pictured above might require a power supply of 10-40 MW. Where commercial power of this magnitude is available, it typically requires a dedicated power connection from the utility, which must be paid for by the data centre operator. This power supply must also be extremely reliable. This requires investment in very large backup generators, battery systems, and redundant external power links. The power supply must then be distributed to racks within the data centre. This requires transformers, power distribution rails and other equipment.

Power makes up such a large proportion of data centre on-going operating costs that companies often build data centres near to renewable energy sources. For example, Facebook has built a data centre in Luleå, in Sweden, near the Arctic Circle. There is an abundant supply of hydro-electricity generation at this location, which lowers power costs and the environment impact of the data centre. Figure 4.4, below shows Facebook's Luleå data centre under construction

Figure 4.4: Facebook's Luleå data centre under construction [Source: © Gunnar Svedenbäck Sweden, 2014]



Because servers and storage devices consume a large amount of power, they generate a lot of heat. In addition, they must be kept cool in order to function effectively. This means that a data centre must have a very efficient and powerful cooling system. These cooling systems are expensive, and consume a great deal of power themselves.¹¹ Figure 4.5, below, shows the liquid-based cooling system at Google's Hamina data centre in Finland.

¹¹ This is another reason for Facebook's choice of Luleå, where average atmospheric temperatures vary between -10C and +15C, as a data centre location

Figure 4.5: Cooling system at Google's Hamina data centre [Source: Google, 2014]



Data centres exist to house servers and storage devices, which themselves sit in rows of metal racks. These racks in turn connect to the data centre's power, cooling and telecoms systems. A single data centre contains tens of thousands of servers or storage devices, in thousands of racks. Servers are typically the largest capital investment item, often comprising up to 50% of the total up-front investment required. Figure 4.6, below shows racks of servers at Google's Oklahoma data centre.

Figure 4.6: Racks of servers at Google's Oklahoma data centre [Source: Google, 2014]



There are a number of other operational systems that data centres need to function. For example, data centres store and process very sensitive data, and are critical facilities for the functioning of Internet services. This means they need sophisticated security systems to control access to the building and monitoring systems to alert the operator when a subsystem needs maintenance or repair. These operational systems require less investment than power, cooling and computing equipment, but nevertheless add to the cost of establishing a data centre.

4.2 Transport

In order to transport content from a Content and Application Provider's data centre to an Internet Access Provider's network (and then on to the end user), investment in long distance transport links is required. These investments are typically made by service providers (in this case, Internet backbone providers) and paid for over time by revenues from Content and Application Providers and Internet Access Providers. These investments are typically made up of large capacity, long distance cables, built either on land (terrestrial cables) or under the sea (submarine cables). Also required is switching and routing equipment to ensure content travels to the correct destination.

Submarine cables are typically used to connect continents, and are often thousands of kilometres in length. A single submarine cable would also normally land in many different countries. For example, the planned SMW-5 cable, which connects Europe and Asia, lands in countries including France, Italy, Egypt, Saudi Arabia, Yemen, Djibouti, Oman, UAE, Sri Lanka, Thailand Malaysia and Singapore. In some regions of the world, the role of submarine cables is regional (e.g. in the

Asia-Pacific region) or even domestic (e.g. in Indonesia or between Peninsular and East Malaysia). To build a submarine cable, investments are needed in:

- The cable itself – typically a bundle of shielded optical fibres inside a thick protective layer. This layer must protect the fibres from the harsh conditions on the sea floor (especially high water pressure and corrosive salt water). Also included inside the protective layer is a copper cable carrying a power supply that is used to power necessary optical and electronic equipment.
- Optical and electronic equipment, including undersea repeaters to boost the signal over long distances, active electronics at each landing point to decode and encode the optical signal, and switching and routing equipment to determine where to send traffic
- The facility in which the cable lands – typically a small data centre in itself that houses the optical and electronic equipment discussed above.
- A specialist ship to lay the cable – typically a large, ocean going ship carrying specialist equipment and machinery. An example is shown below in Figure 4.7, below. This ship was involved in laying the EASSY cable connecting East Africa to Europe.

Figure 4.7: The Ile de Batz, a submarine cable laying ship [Source: WIOCC, 2014]



Terrestrial backbones are similar to submarine, but on land. They are typically high capacity trunk links that connect large network nodes in major cities. They are used for both domestic and international connectivity. They are typically shorter than submarine cables, but are much denser. To build a terrestrial backbone, investments are needed in:

- The cable itself – like a submarine cable, this is a bundle of fibres, with a protective layer. This cable typically does not include a power supply, as relevant electronic and optical equipment is powered from the electricity grid.

- Ducting to house the fibre underground. This is a strong plastic tube through which to run the cable.
- Digging and civil works to lay the cable. This is generally the largest proportion of the cost, and can be very high where the cable must run through urban areas.
- Switching, routing and other electronic equipment to encode the signal and ensure data is sent to the correct destination

As mentioned in the Executive Summary, Content and Application Providers have also invested directly in physical cable networks. Facebook is part of the Asia Pacific Gateway system, and Google is a participant in the UNITY cable (since 2008), South-East Asia Japan Cable (since 2011) and most recently the FASTER cable system (2014).¹²

4.3 Delivery

After content has been transported to a point close to the Internet Access Provider network, it must be delivered to the Internet Access Provider, and then on to the end user. This involves a number of steps:

- Content must be handed over to the Internet Access Provider at a point where its network connects with either a backbone or Content and Application Provider network. This either happens at *private peering point*, where two networks connect with each other in their own facility, or at an *Internet Exchange Point*, a facility which allows many networks to connect with each other in a single, third party, facility. Often private peering points and Internet exchange points are located in the same data centre, but use different interconnection equipment.
- The delivery of content must be optimised, so that the end user experiences a high service quality when consuming the content. This is done by *Content Delivery Networks*. These are either run by service providers on behalf of Content and Application Providers, by Content and Application Providers themselves, to help deliver their own content, or by Internet Access Providers, who charge Content and Application Providers for the service. These are a series of servers and storage facilities, which optimise the delivery of content by hosting it in various locations close to or within large Internet Access Provider networks.¹³

To exchange content and traffic between Internet Access Providers and Content and Application Providers or backbones, a number of investments are needed:

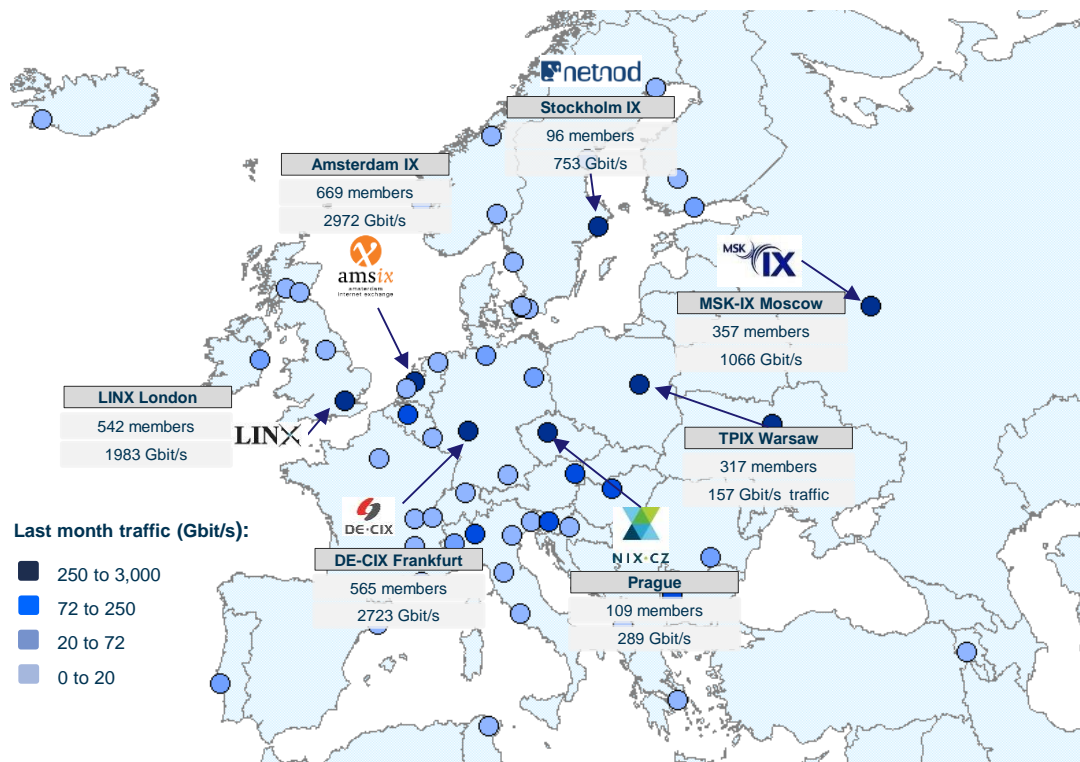
¹² http://www.nec.com/en/press/201408/global_20140811_01.html

¹³ This locally hosted data is typically static Internet content, such as videos, images and web pages, rather than dynamically generated content, customer records or customer data; for example, Netflix operates its own CDN, called OpenConnect, which optimises content caching and delivery in access networks to achieve better quality of experience for end users and mitigate the costs of transit for themselves and for IAPs (see <https://www2.netflix.com/openconnect>)

- At private peering points, each party to the exchange needs switching and routing equipment, interconnected by cabling, that determines which traffic to exchange and where it should be sent.
- At Internet Exchange points, there are two areas of investment. First, the Internet Exchange itself must invest in large capacity switching equipment that its members (Content and Application Providers, backbones and Internet Access Providers) can connect their routers to in order to exchange traffic with each other. Then the members themselves need to invest in routing equipment to determine which traffic to exchange with which other entity connected to the IXP.

The magnitude of these investments behaves in a certain way, based on the economic characteristics of network interconnection. Due to network effects, it makes sense for a potential peer to connect to an IXP which already has many other potential peers as members. This favours larger IXPs, as these already have many potential peering partners. A small IXP with very few peers may be less attractive, since there are few partners for a new member to connect with. The largest IXPs therefore attract most of the members, and most of the traffic. Indeed, the top five IXPs¹⁴ are responsible for approximately 70% of traffic exchanged through IXPs¹⁵. These IXPs are therefore responsible for the lion's share of investment. Figure 4.8 shows the location and size of European IXPs. It can be seen that the traffic of the largest five is significantly larger than the others.

Figure 4.8: Location and size of European IXPs [Source: Euro-IX, 2014]



¹⁴ AMS-IX, DE-CIX, LINX, MSK-IX and NetNod

¹⁵ Source: Euro-IX, Analysys Mason

Finally, CDNs require investment in servers and storage devices that are needed to store content close to the customer and to determine how to balance the storage and delivery of content throughout the network. These servers and storage devices typically reside in data centres near Internet Exchanges.

The use of CDNs has become more important as content (especially video) has become more data-heavy, sensitive to degradations in quality, and bandwidth intensive. Indeed, we estimate that approximately 60%¹⁶ of Internet traffic uses a CDN. Generally, small Content and Application Providers use the services of commercial CDNs (Akamai is by far the largest). Larger Content and Application Providers, such as Google, invest in their own in-house CDNs, as they generate the volume of traffic to justify it. Some Internet Access also operate their own CDNs, for which they charge Content and Application Providers. We estimate that approximately 22% of Internet traffic uses an in-house CDN.¹⁷

¹⁶ Source: Analysys Mason, Cisco, Informa, Microsoft, Google

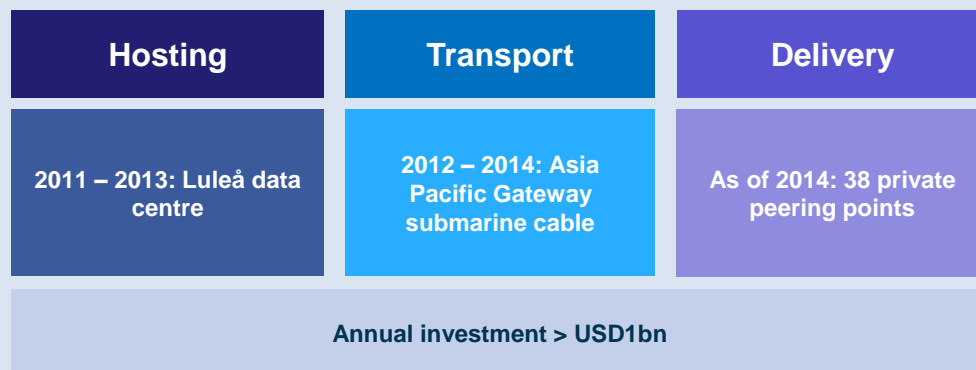
¹⁷ *Ibid.*

Case study: Facebook

Facebook is one of the World's largest Content and Application Providers. It operates a social network used by a reported 1.32 billion users worldwide, notably in developing and middle income markets¹. It invests a substantial amount (approximately USD1 billion every year) in networks, facilities, and equipment, in all three of the categories we have identified – hosting, transport and delivery.

Some examples are illustrated in Figure 4.7, below.

Figure 4.9: Example Facebook investments by category [Source: Analysys Mason, 2014]



In 2011, Facebook broke ground on a new data centre in Luleå, in northern Sweden, just below the Arctic Circle. Facebook has invested USD220m in the construction of the data centre and has begun construction of a second data centre at the site. Luleå was chosen largely for its cold climate, which reduces cooling bills, its abundant hydro-electric power, and its access to competitive fibre connectivity.

In the third quarter of 2014, the Asia Pacific Gateway submarine cable is due to go live. This cable runs between Japan and Malaysia, landing in a number of other Asian countries. It has a capacity of 55 Tbit/s, and is over 10 000 kilometres in length. Facebook is a member of the consortium building the cable. This investment is driven by the substantial growth in Internet traffic, and Facebook usage in Asia, and will allow Facebook to offer services with a lower latency and higher bandwidth across Asia through better control of its transport infrastructure. It will also allow IAPs in Asia to exchange traffic with Facebook at a local interconnection point, rather than pay for trans-Pacific capacity to interconnect in the US.

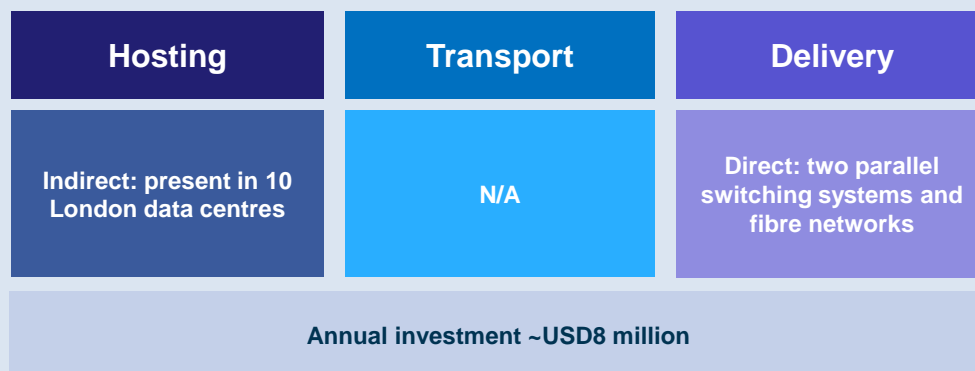
Case study: London Internet Exchange (LINX)

LINX is the world's third largest IXP by traffic. It is a major hub of the global Internet, and plays an important role in the transport and delivery of Internet content within Europe and across the Atlantic. LINX, a not for profit company, was founded in 1994, by five UK ISPs. These ISPs set up an infrastructure to interconnect their networks in an effort to avoid paying expensive trans-Atlantic transit fees, since at the time traffic between their networks was routed via the USA. Since then it has grown to serve 509 Internet companies, exchanging more than 2 Tbit/s of peak traffic.

London is a major global hub for Internet traffic, and LINX is at its heart. As well as being a point of aggregation for traffic flowing between Europe and the USA, it enables Content and Application Providers, Internet Access Providers, and other service providers to directly connect their networks and exchange traffic in locations that are at one of the most important global hubs for internet backbone connectivity. It is used by many of the world's most important Content and Application providers, including Facebook, Amazon and Google, and the BBC in the UK. For example, connectivity via LINX enables the BBC to distribute its iPlayer video content to viewers with low latency, high bandwidth and minimal need for buffering. It does this through the ability to connect directly to key IAPs such as BT, Virgin Media, Sky and Talk Talk, as well as large Internet backbone providers such as Level 3.

To provide this service, LINX has made significant investments in networks, facilities, and equipment, largely in the delivery part of the network, but also indirectly in hosting. This is illustrated below.

Figure 4.10: LINX investment by category [Source: Analysys Mason, 2014]



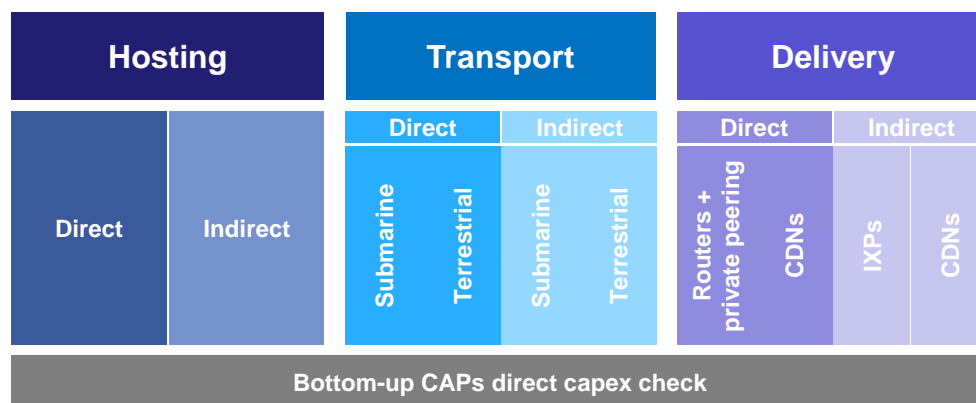
LINX has switching equipment installed in 10 data centres throughout London, allowing any company collocated in those data centres to interconnect with any other. This switching equipment is linked by a network of fibres with full physical redundancy (that is, there are two separate physical fibres for every link). These fibres are leased from Service Providers, and so are indirect investments. The switching equipment is a direct investment made by LINX. The investment required to build and maintain this equipment is significant, and LINX invests approximately USD8 million (GBP4.5 million) per annum on average.

5 Content and Application Providers invest around USD33 billion annually in Internet networks, facilities, and equipment

We have illustrated that there is a wide array of advanced and expensive physical equipment that underpins the operation of the Internet, and that this requires investment, a significant part of which is carried by Content and Application Providers, or by service providers on their behalf. In this section, we quantify the magnitude of this investment over the last three years (2011-13), and in particular, estimate how much of it is undertaken by Content and Application Providers or on their behalf.

Figure 5.1, below, illustrates how we categorise this estimate.

Figure 5.1: Illustration of how we estimate Content and Application Provider investment [Source: Analysys Mason, 2014]



As discussed in the sections above, we split the Internet into three very broad categories (hosting, transport and delivery). Within each of these categories, we include only those investments in networks, facilities, and equipment that are either made by Content and Application Providers, or made on their behalf. We exclude investments in software and services, and investments that are made on behalf of parties other than Content and Application Providers.

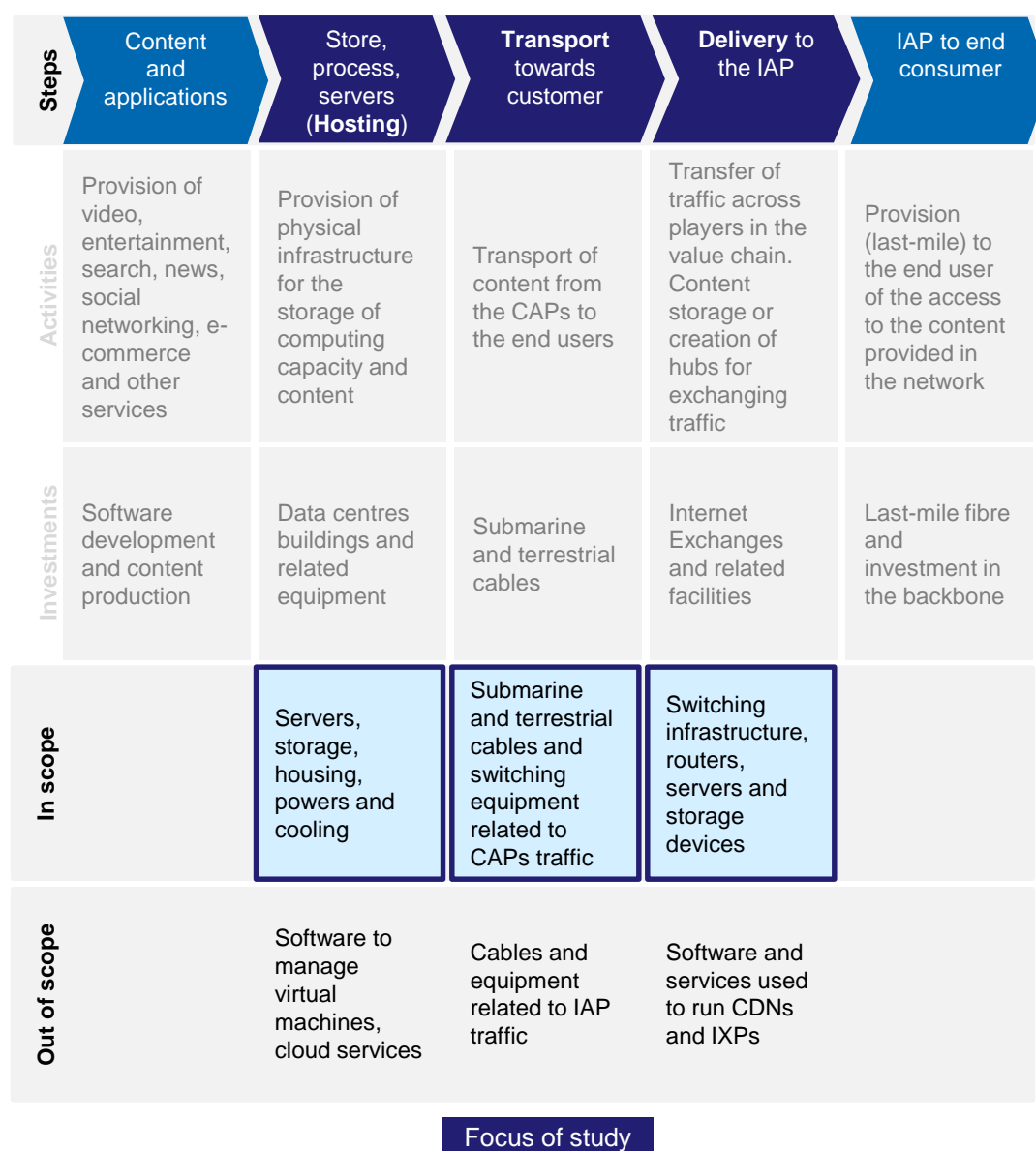
- **Hosting.** Included in hosting investments are the physical components of data centres. This includes the buildings (but not land), power and cooling systems, cabling, security, monitoring and other operational systems. It also includes the servers and storage devices themselves, and the metal racks that house them. It does not include software to run the servers, create and manage virtual machines, or deliver cloud or managed hosting services (but does include the hardware).
- **Transport.** Included in transport investments are the physical cables, fibre, and shielding and investment in laying them (cable ships in the case of submarine cables, trenching and civil works in the case of terrestrial cables). Also included is the cost of active electronics required to operate

the cables and send traffic (switches, routers, optical devices, etc.). This investment is split between that sponsored by Content and Application Providers and that sponsored by Internet Access Providers. Since content is always sent between two places (the Content and Application Provider and the Internet Access Provider), it can be said that both the Content and Application Provider and Internet Access Provider are responsible for the transport of that traffic. As such, we split this investment between the two according to the relative cost they each pay for IP Transit, on average. In this way, we allocate approximately 33% of the investment to Content and Application Providers.

- **Delivery.** Included in delivery are physical investments for IXPs, private peering points and CDNs. For IXPs, this includes the IXP common switches, and the routers of peering members that are connected to this. It does not include any software required to run or manage this equipment, nor does it include the data centre in which the IXP is hosted (this is included in hosting, above). Private peering point investment includes interconnect routers and related equipment such as cabling. Again, it does not include software or data centre space. Finally, CDN investment includes the servers, routers and other physical equipment used in the CDN. It does not include software to run the CDN or data centre space to host the CDN equipment (again, included in hosting, above).

This is illustrated below in Figure 5.2.

Figure 5.2: Investments that are in the scope of this study [Source: Analysys Mason, 2014]

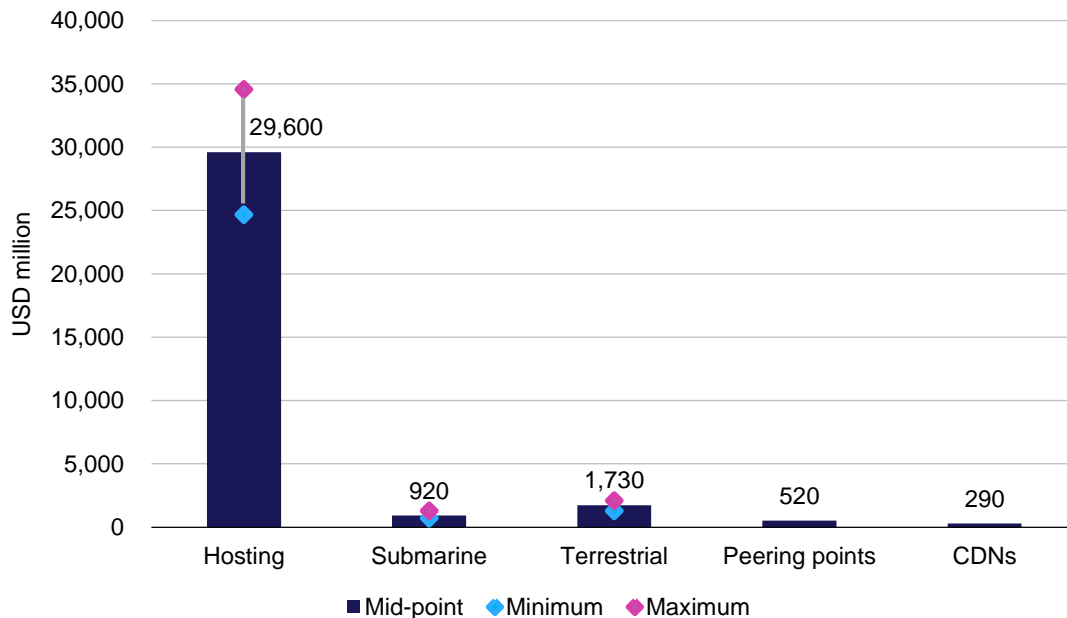


Once we have determined the investment items to include or exclude, we divide the amounts into direct and indirect investments, and further exclude investments made on behalf of enterprises other than Content and Application Providers (such as banks, retailers and other businesses, as well as Internet Access Providers). To do so, we determine the network and equipment usage of these entities relative to that of Content and Application Providers. We use this usage as a proxy for spend and investment, and apply this proportion to the total. This varies by category, depending on data availability. For example, in hosting, public data is available regarding the usage of data centre space by enterprises and Internet Access Providers, and we use this to make the relevant adjustment.

Finally, we calculate our investment estimates by examining capital expenditure over a period of three years (or five years for submarine cables). This enables us to smooth out the volatility due to large investments coming on stream in certain years. This yields an overall level of investment, both direct

and indirect, of approximately **USD33 billion**. Figure 5.3, below sets out our overall view of Content and Application Provider investments. Given the inherent uncertainty of estimating global figures, we have put a range on each of the most significant investment categories.

Figure 5.3: Approximate magnitude of investments by Content and Application Providers [Source: Analysys Mason, DCDi, Telegeography, Informa, company data, news reports, peering dB, Comscore, Sandvine, 2014]



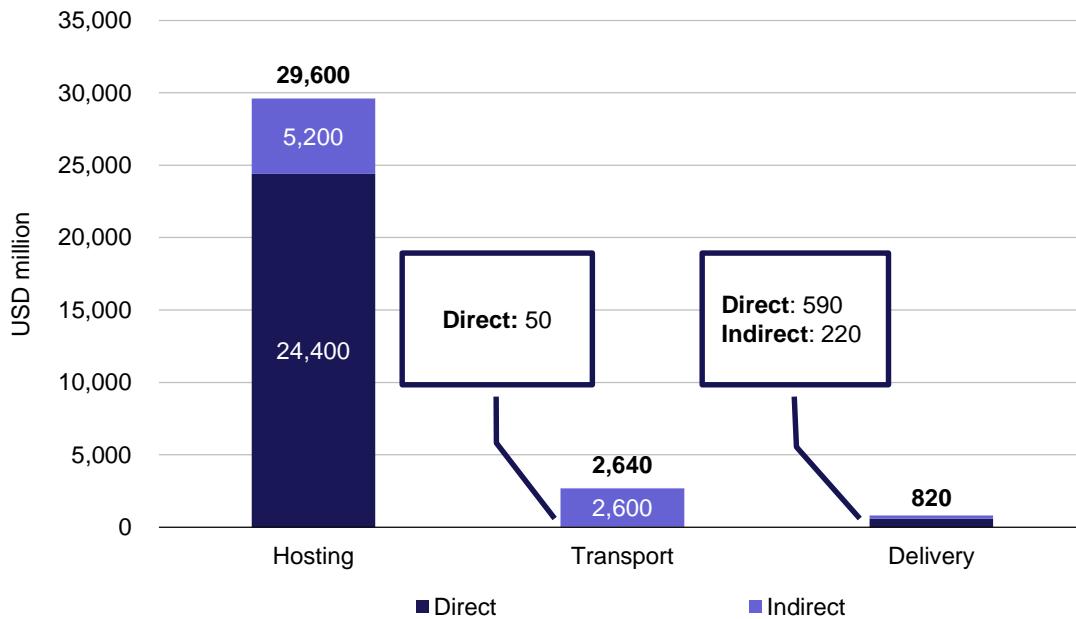
We have validated these numbers by examining the capital expenditure of the largest 13 Content and Application Providers¹⁸. Scaled-up based on traffic, this validation yields a direct annual investment for Content and Application Providers of USD25 billion. The largest three of these companies, on average, invest 9% of their annual revenues in networks, facilities, and equipment.

Hosting is by far the largest category for Content and Application Provider investment. This is unsurprising, given the scale of the computing resources required to serve millions or even billions of Internet customers. Transport is also a significant investment. Again, this is unsurprising, given the large scale and length of Internet backbone links. Finally, delivery is much smaller. This is largely because the equipment we have categorised as delivery is comprised of electronic equipment, such as routers, servers and switches, located at the edge of networks. These are less expensive than hosting or transport investments, as they do not involve large scale construction projects.

A substantial amount of this investment has been made by Content and Application Providers on their own behalf (*direct investment*). This is largely hosting equipment, as this is the main asset in which Content and Application Providers invest their own capital. Transport and delivery investment is largely indirect, reflecting the many large service providers in these parts of the value chain (especially internet backbone providers). This is illustrated below in Figure 5.4.

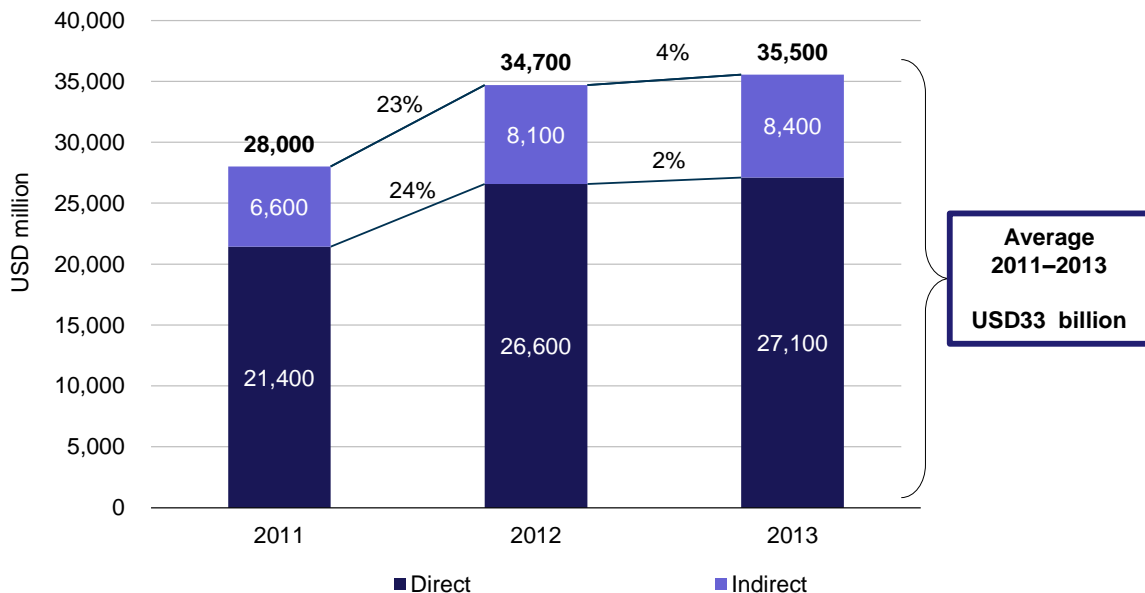
¹⁸ These companies are Google, Facebook, Yahoo!, Microsoft, Tencent, Alibaba, Baidu, Amazon, eBay, Netflix, and Apple

Figure 5.4: Investment by category split into direct and indirect investments [Source: Analysys Mason, DCDi, Telegeography, Informa, company data, news reports, peering dB, Comscore, Sandvine, 2014]



These investments are, unsurprisingly, increasing over time as the Internet and the demand for content grows. Figure 5.5, below, shows the direct investments of Content and Application Providers in all categories over the past three years. It can be seen that this is growing.

Figure 5.5: Content and Application Provider investment over time¹⁹ [Source: Analysys Mason, DCDi, Telegeography, Informa, company data, news reports, peering dB, Comscore, Sandvine, 2014]

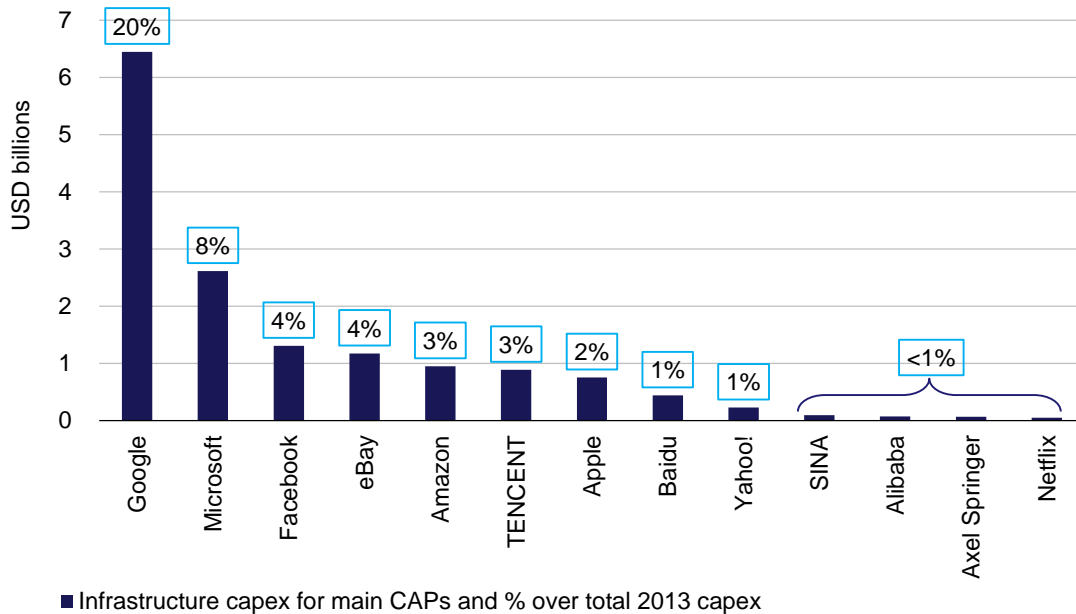


¹⁹

The average investment over three years shown here is different from the sum of the totals presented in figure 4.3. In figure 4.3 the investments in submarine cables and terrestrial cables are averaged over 5 years in order to take into account the higher level of variability of yearly investments noticeable in the transport sector.

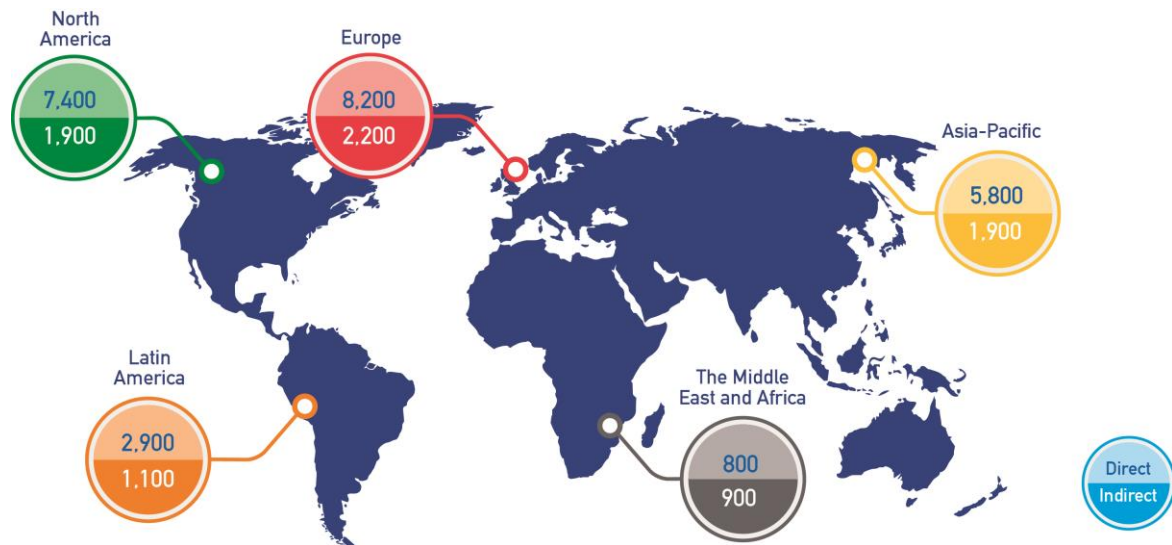
This growth is in large part driven by increases in the capital expenditure of the largest companies. Indeed, investments in networks, facilities, and equipment are heavily concentrated amongst the largest Content and Application Providers. Google alone is responsible for approximately 20% of direct investments. This is illustrated below, in Figure 5.6

Figure 5.6: Concentration of Content and Application Provider direct investments [Source: Analysys Mason, company data, news reports, Comscore, Sandvine, 2014]



Finally, we have split the total investment by geographic region. This is illustrated below, in Figure 5.7.

Figure 5.7: Regional split of direct and indirect investment²⁰ [Source: Analysys Mason, DCDi, Telegeography, Informa, company data, news reports, peering dB, Comscore, Sandvine, 2014]



North America, Europe and Asia are all significant contributors to Internet investment, with Latin America, the Middle East and Africa contributing less. This is unsurprising given the existing concentration of Internet infrastructure in North America and Europe, and the large populations and growth in Internet usage in Asia. Europe appears to be the largest destination for Content and Application Providers' investment. Europe is a hub for Internet traffic as it is the meeting point of many international cables, is home to the world's largest IXPs, and has a large population of end users. This is attracting investment by US companies, especially in data centre facilities, as well as by local Content and Application providers such as Spotify and the BBC.

²⁰ Note that there are fewer available public data on the split of regional investments than global level investments. As such, this regional split should be taken as an indicative estimate of how total investments break down. Numbers are rounded

6 Final comments

The research presented in this report demonstrates clearly, in our view, that the investment in networks, facilities, and equipment by Content and Application Providers, both direct and indirect, is substantial. Content and Application Providers make a significant and on-going contribution to the physical fabric of the Internet.

However, this is only part of the overall investment made by Content and Application Providers in the Internet ecosystem. As noted at the start of this report, their main business is the provision of attractive content and applications to end users, and as such they invest significant amounts of money to produce, maintain, market and distribute content and applications, both in technical and creative activities.

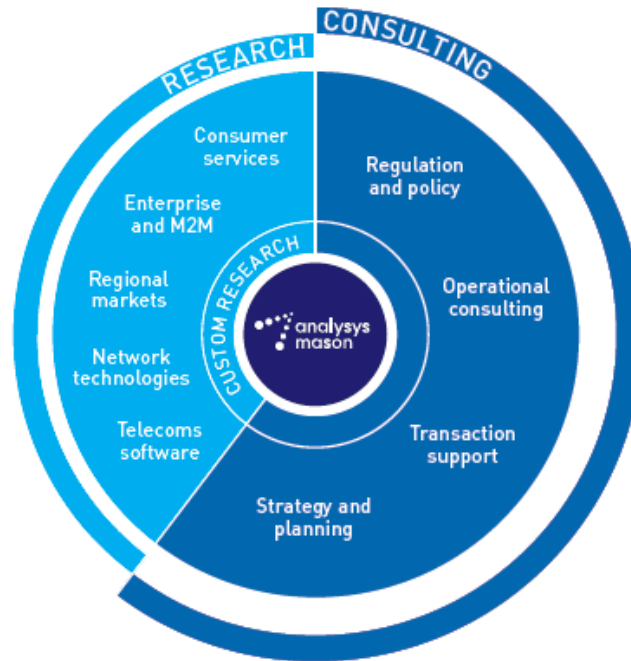
These investments are made by multiple stakeholders, just as physical investments are made by Content and Application Providers, service providers and Internet Access Providers, and include for example:

- Video, film, and television production, including scripting and writing, hiring actors, filming and production, editing and other production related activities
- Journalism and news gathering, including writing and photography
- Software and application design, development and testing
- eCommerce systems, including software, as well as other physical investments in warehousing, delivery and fulfilment

This investment and spending is not captured in the ‘networks and facilities’ scope of this report, but are relevant contributions by Content and Application Providers to the wealth of content and the quality of experience available online to end users.

About Analysys Mason

Analysys Mason is the global specialist adviser on telecoms, media and technology (TMT). Through our global presence and local perspective, we deliver strategy advice, operations support and market intelligence to regulators, operators, financial institutions, vendors and other market players around the world.



Consulting

For 30 years, our consultants have been bringing the benefits of applied intelligence to enable clients to make the most of their opportunities.

- We deliver tangible benefits to clients across the TMT industry: operators, vendors, governments, regulators, service and content providers, financial institutions etc...
- Our sector specialists understand the distinct territorial challenges facing clients, in addition to the wider effects of global forces.
- We are future-focused and help clients understand the challenges and opportunities new technology brings.

Research

Analysys Mason's research service covers consumer and enterprise services, as well as the software, infrastructure and technology underlying those services.

- Our dedicated team of analysts track and forecast the different services accessed by consumers and enterprises.
- We also offer detailed insight into the software, infrastructure and technology delivering those services.
- Clients benefit from regular and timely intelligence and direct access to analysts.