Analyzing the Interconnection Strategies of Content Providers

Manuel Palacin, Alex Bikfalvi, and Miquel Oliver

Networking Technology and Strategies (NeTS) Research Group,
Universitat Pompeu Fabra (UPF)
{manuel.palacin,miquel.oliver}@upf.edu,alex.bikfalvi@midokura.com

Abstract. The analysis of the interconnection status-quo between content providers (CPs) and access ISPs is essential to better understand the evolution of the Internet topology. In the last years we have witnessed an increase in the Internet traffic, especially multimedia content, which has driven both CPs and access ISPs to rethink their interconnections. Content delivery models, such as employing CDNs or establishing peering agreements, force tier-1s to reinvent themselves. These changes raise the question of what are the interconnection differences between global and regional CPs. To this end, we collected an extensive data set that allows us to evaluate the connectivity between a set of access ISPs and the most popular CPs for a specific market. Our results confirm that global CPs have a strong presence near or within the access ISPs, while revealing that smaller or regional CPs orient themselves toward more affordable interconnection models, such as using CDNs services of tier-1s or hosting providers.

1 Introduction

The Internet topology is continuously evolving and in the last years we have witnessed a spectacular increase in the consumption of multimedia content [14] shifting the traditional roles of most of the Internet players. The needs for having faster delivery pipes, together with the irruption of content delivery and cache mechanisms, have impacted the interconnection models between the Internet Service Providers (ISPs) and the content providers (CPs). The balances between global and local content, and larger and smaller service providers brings a plethora of interconnection models within the same Internet market that depends on a set of strategies followed by competing Internet actors.

Global CPs, with presence in most worldwide Internet markets (like the *big five* Google, Facebook, Yahoo, Microsoft and Amazon), need to design and invest in interconnection models to reach end-users in a cost-efficient way. Those players, with strong market position, are able to make extensive use of costly direct (and peer) connections to deliver their services with higher quality and performance (peak and average rate, stable jitter and low delay). Local players, with less economic muscle need to use other interconnection strategies mostly based on shared connections (by using third-parties or Internet eXchange Points) to provide similar performance with much affordable investment. In this paper we analyze those strategies using recent measurements to figure out the Internet topology for each type of actor (content or service providers; with global or local presence).

The emergence of content delivery networks (CDNs) influences the evolution of the traditional interconnection models, by having specialized actors that concentrate the heaviest traffic, being able to deliver it globally and changing their business models [10]. This dynamic and continuously evolving market forces some actors to reinvent themselves and adapt to the fierce competition for traffic delivery. Tier-1s are a clear example of those dynamics, moving from mere traffic transit services to provide hosting and CDN interconnection services as a central value in their offers.

In this paper, we analyze the interconnection models followed by local and global providers by measuring the current Internet topology at the Autonomous System (AS) level. The analysis is done from both sides: how CPs are interconnected to ISPs to reach end-users; and how ISPs allow their customers to reach global and local contents. The research done combines partial and fragmented publicly available information with a deep knowledge of the Internet market and protocols to process the measurements. Although the results obtained are for the Spanish Internet market, where global (Telefonica, Vodafone, Orange) and local (Jazztel, ONO) actors coexist targeting global (Google, Facebook, Yahoo) and local (ElPais, UnidadEditorial, Softtonic) contents, it is reasonable to expect similar results for other European and U.S. Internet interconnection markets. The same analysis can be easily extended to other markets by using the same measurement tool[1] to collect exhaustive measurements in other areas.

The paper identifies different interconnection models depending on the provider's profile: while the *big five* content providers tend to be directly connected with most ISPs, content delivery actors and hosting providers have extensive presence to provide efficient alternatives to reach local and global content.

The paper is organized as follows: following the introduction, we present a literature review in interconnection models and measurements tools is provided. Section 3 presents the methodology used and the analysis of collected data to show the results in Section 4. Finally, Section 5 explains the conclusions of the analysis done.

2 Related Work

In the last years many authors have noticed substantial changes in the Internet interconnection models. Gill et al. [11] identify that large content providers began to deploy their own wide-area networks (WANs) allowing them to have end-users closer in detriment of the tier-1 ISPs usage. Faratin et al. [10] not only identified the emergence of the large content providers and CDNs but also observed an expansion of the access ISPs with a progressive upgraded of their

[1] BETA version of Mercury Platform available at `http://mercury.upf.edu/mercury`

international backbones. Labovitz et al. [14] confirmed the evolution of the Internet topology from hierarchical to a more flattened and meshed model where large content providers and CDNs tend to concentrate most of the Internet traffic. More recently, Shavitt and Weinsberg [21] have analyzed the interconnection trends during the 5 years for large CPs concluding that there is an exponential increase and diversification of interconnections among actors (using IXPs), confirming a loose of presence of tier-1 providers.

The previous literature used measurements processed at AS level targeting overall trends in interconnection models and techniques. Most of the related studies are based on performing extensive traceroute measurements combined with BGP data from public datasets like RouteViews [15]. For example, Shavitt et al. propose DIMES [20], a measurement infrastructure using a large number of software agents to obtain the Internet graph at the AS and IP levels. DIMES collects traceroute and ping traces from a set of specific agents and process the IP addresses assigned to AS numbers. In parallel, Dimitropoulos et al. [9] focused on modeling and generating synthetic but realistic AS topologies using BGP data from RouteViews. The need for more extensive measurements has been conducted by efforts like the ARK project [5] as a large-scale infrastructure that coordinates large-scale traceroute-based topology measurements including both IP and AS levels. Another example is RETRO, implemented by He et al. [12] that uses public traceroute servers to collect measurements from many diverse locations. One of the challenges in Internet measurements methodologies is to deal with partial information and possible missing peering links, most of them located at IXPs [12]. Chen et al. [8] used a plugin called ONO embedded in a BitTorrent client to perform random traceroute measurements from end-users. ONO is centered in the detection of hidden peering links combining data from public IXP and interconnection information from CAIDA datasets [6].

Other studies analyse the hosting infrastructures and facilities of content providers. Huang et al. [13] measured the number of servers used by the main CDN providers Akamai and Limelight. Adhikari et al. analyzed the infrastructures of the two major video content providers: Youtube and Netflix. This analysis, based on Planetlab servers [19], showed that YouTube [2] accumulates up to 80% of the analyzed IP addresses whereas the rest belong to other ISPs like Comcast or Bell Canada. In contrast, Netflix [1] bases its video delivery services combining three different CDNs. Calder et al. [7] looked at the Google infrastructure determining the geographic location of the cache servers based on an approach called client-centric geolocation that consists in geolocating front-end servers by the geographical mean of client locations combined with the use of the EDNS-client-subnet extension. Ager et al. [3] also used a new methodology based on BGP snapshots and DNS queries for detecting web content infrastructure, and realizing that few hosting infrastructures (e.g. Akamai and Google) are serving a large number of hostnames.

Although the research in interconnection models based on measurements is vast, there are no studies dealing with the strategies and models targeting the differences between global and regional (access and content) providers. Some articles aim to infer the AS interconnections while other studies are more case-centered addressing an specific provider (Google, YouTube, Akamai or Netflix). To address these shortcomings, in [16] we presented a starting point of this research: a new measurement platform called Mercury that combines elements from prior work and focuses on discovering interconnection from an end-to-end (access ISP to CP) point of view. In this paper, we use this measurement methodology to discover the CP interconnections based on a simple taxonomy and to characterize the different interconnection models of a large data set of CPs.

3 Methodology

The methodology used in this analysis is based on active traceroute measurements. The data collected allows to explore the existing interconnections among the Internet actors and snapshot the existing topology. The methodology used consist in analysing the measurements to get the Autonomous Systems (ASes) involved in each traceroute path to then discover the interconnection models of the affected players. The analysis allows the detection of direct connections between actors, the existence of CDN servers in between or the use of Internet eXchange Points (IXPs). The tool used also detects corrupted traceroute paths and the analysis is only base on successful routes. In this section (and in [16]) we provide more details regarding the measurement process and the data collected.

3.1 The measurement platform

Towards this end we use a measurement platform called Mercury that was introduced in [16]. Mercury is a multi-purpose platform consisting of a central server (MCS) and downloadable clients (MC) that perform AS-level traceroute measurements and upload them to the MCS (see Figure 1.a). Once the MCS has stored the processed measurements from the distributed MCs, it offers the possibility of inspecting the resulted data using a web interface or via its API.

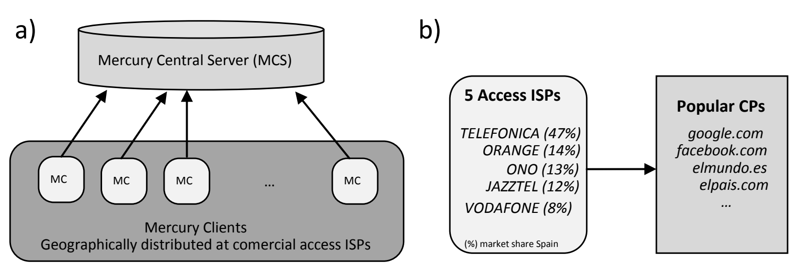

Fig. 1: Mercury platform: a)General view, b)MCs at Spanish Access ISPs targeting popular CPs

3.2 Data collection

Mercury Platform crosses information from existing databases to get the Internet paths between providers (see Fig. 2): CAIDA [6] to get neighbour relationships; PeeringDB [17] to detect interconnections at IXPs; and routing data from [18] to collect BGP information and translate IP addresses into ASes. More information about how Mercury deals with different anomalies (AS-loops or missing hops) along the internet path process can be found at [16].

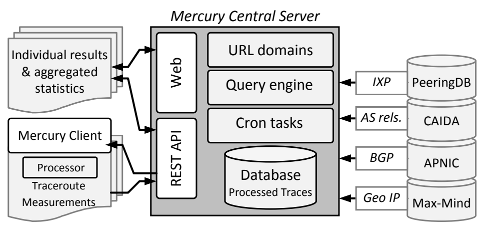

Fig. 2: Mercury architecture

The data to carry on the analysis has been collected from the Spanish Internet market. Spain shows a mature Internet market in terms of competition (number and size of ISPs), usage (most visited places and penetration) and networking infrastructures (tier-1s, IXPs and fiber-based access networks), comparable to other western countries. Therefore, the methodology can be extended to other countries and areas expecting quite similar results in terms of interconnection models.

The measurement is performed in different steps. First, we select a set of URLs from the *TOP100* most popular web sites of Alexa Top Sites [4]. This includes large CPs like Google, Microsoft, Facebook, Yahoo!, YouTube or Amazon and popular web sites from Spain, e.g., ElMundo, ElPais or Softonic. Second, we analyze each web site and we extract all the resource URLs (links, images, videos, gadgets, etc) from each popular web site (using web scraping of the HTML code, see more at [16]), resulting in between 700 and 800 URLs. Extracting URLs from embedded resource is important because they are likely to point to CDNs. Third, we run an MC from each of the major Spanish access ISPs (Telefonica, ONO, Orange, Jazztel and Vodafone) pointing to the previous set of discovered URLs (see Fig. 1.b). Running the MCs from commercial ISPs, rather than using platforms like PlanetLab [19] which nodes are mostly located within research networks, allows us to include the effect of existing a variety of access ISPs and how the content reach end-users. We only use one MC for each access ISP because our observations of routes taken by local traffic indicate that national ISPs rely on few interconnection points with CP or transit AS-es. This reinforces our methodology decision to rely on few vantage points, rather than more geographically distributed measurements. Fourth, MCs execute the multiple traceroute measurements, process the AS-paths using the internal algorithms and finally upload the data to the MCS. The MCs were executed in the area of Barcelona (Spain) and the measurements were done from each access ISP during the first week of September 2014.

3.3 Data analysis

Once all the traceroute measurements are stored in the MCS database, we use the MCS API to execute queries that provide us the required data. For each URL, we analyze the different ISPs along the AS-path and its interconnection relationships. Then, we compare different traces from different CPs to find interconnection similarities.

To facilitate the analysis of the different content delivery strategies, we define different metrics based on the valid traces. We locate where CPs have their hosting infrastructures: within the access ISPs, within a tier-1, within a commercial CDN or within their own network. Finally, we analyze whether CPs tend to interconnect at IXPs and whether CPs tend to direct-connect with access ISPs bypassing tier-1s when possible.

3.4 Definition of the interconnection models

Three main interconnection models have been defined to classify them: using an ISP as intermediary; using a direct connection; or by means of an IXP. Each model may include the use of a CDN provider to speed up some of the contents. Here we provide more details for each one of the models:

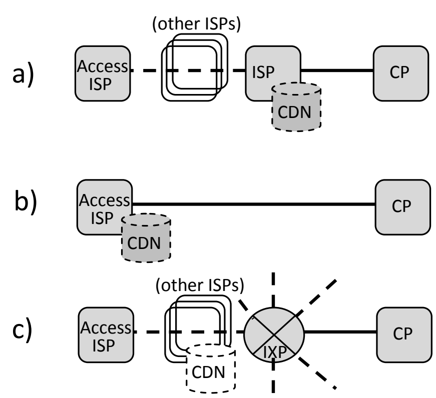

Fig. 3: Interconnection Models

A) Interconnection through an intermediary transit provider: In this model of interconnection (see Figure 3.a) the CP uses a transit provider as intermediary to carry its traffic. CPs usually use the same or a set of providers to reach end users for each particular access ISPs. This interconnection is commonly based on a transit agreement where the CP contracts from the transit ISP a transport service. There is also the option to use a CDN solution to deliver the traffic.

B) Direct interconnection: In this model of interconnection CP has a direct link to the access ISP (see Figure 3.b). The direct model, which avoids intermediaries ISPs in contrast to the previous one, tends to use (paid) peering agreements to improve the performance of the traffic delivery. As in model A, the access ISP can deploy its own CDN service or use a third party CDN, like Akamai[2], to speed up the traffic. This situation is extremely difficult to detect (require other techniques based on DNS resolutions to detect the originating CPs) because it does not affect the interconnections and the CDN service is deployed within the access ISP.

C) Interconnection through an IXP: In this model of interconnection (see Figure 3.c) the CP is directly connected to an Internet eXchange Point (IXP) where it has the possibility to interconnect with other actors (both transit or access ISPs) within the same location. At the IXPs, ISPs interconnect based on both transit and peering arrangements. Strictly speaking, we could consider the IXP interconnection model together with the previous two models. However, the broad flexibility that provides the use of an IXP in terms of number of interconnections incline us to treat it as a separate case.

4 Results

In this section we use the collected data to analyze the interconnection models between the Spanish ISPs and the top CPs. All the measurements are processed to group the traces belonging to the same organization by checking the Autonomous System Number. Following that grouping rule, traces from providers such as YouTube belong to Google ASN or MSN to Microsoft ASN, having all those measurements united in the same set.

4.1 Content delivery interconnection models

The measurements analyzed allow us to identify the interconnection models for each content provider according to the models defined in the previous section. A first observation of the collected data gives interesting insights that complement other databases such as CAIDA. An example is Google that appears directly connected to either the Spanish access ISPs or a tier-1 (Level3), while CAIDA only reports direct links to Cogent, Telia, NTT and Tinet. These results do

[2] We consider Akamai part of this model (B) only when it uses the IP-address space belonging to the access ISP

not affect the final conclusions based on interconnection models rather than in connections between particular peers.

The results are presented in three groups: i) CPs with their own networking infrastructure, ii) CPs using specialized CDNs, iii) CPs using CDN/hosting solutions of carrier ISPs and iv) CPs using hosting or cloud solutions. The motivation for each CP to use one model or other depends on different factors such as transit or hosting costs, the status of their current infrastructure or their needs to offer an enhanced QoS. The analysis is done for each CP type depending on the models previously defined in Section 3: A)interconnection through tier-1, B)direct interconnection between CP and access ISP and C)interconnection through an IXP.

Interconnection models of CPs with network infrastructure: Table 1 crosses the interconnection model used for each pair of (global or regional) CPs and access ISPs. The results show how the *big five* providers (Google, Facebook, Microsoft, Yahoo and Amazon) tend to use direct interconnections (B model) with the access ISPs, by-passing tier-1s (A model). These large global CPs have extensive networking infrastructures, that facilitate more efficient interconnections instead of relying only on tier-1 providers. In addition, the more strict low-latency requirements for most Internet services, makes more cost-effective peering interconnections with better performance than regular transit services. Leading Spanish local CPs, such as ElMundo or ElPais, use direct links (B model) with the two largest operators (Telefonica and Orange). The rest of the CPs tilt the balance towards transit services (A model) avoiding the costly direct connections.

ASN (name)	15169 (Google)	32934 (Facebook)	8075 (Microsoft)	10310 (Yahoo)	16509 (Amazon)	20049 (LinkedIn)	13414 (Twitter)	19679 (Dropbox)	43821 (Wikimedia)	33612 (Tumblr)	15224 (Adobe)	43996 (Booking)	11643 (Ebay)	12678 (Badoo)	47195 (Gameforge)	51773 (Softonic)	50974 (ElPais)	9052 (Unidad Ed.)
Telefonica	AB	AB	B	B	AB	A	A	A	A	A	A	A	A	B	A	A	B	B
Orange	B	AB	B	A	AB	A	A	A	A	A	A	A	A	A	A	A	B	B
Jazztel	B	B	C	BC	ABC	A	BC	A	AC	A	A	C	A	A	C	A	A	A
Vodafone	B	B	B	ABC	BC	A	BC	A	BC	A	A	A	A	A	A	A	C	A
Ono	B	A	A	A	B	A	A	A	A	A	A	A	A	A	A	A	A	A

Table 1: Interconnection models of CPs with network infrastructure

Interconnection models of CPs hosted in a specialized CDN: Table 2 presents the interconnection models for CPs using specialized CDNs to deliver their traffic. CDNs like Akamai, Edgecast, CDNetworks, Limelight or CloudFlare, combine multiple models prioritizing the use of direct interconnections (B model) to connect with the access ISPs. This model provides the best performance which is an interesting incentive to reduce interconnection costs. However, in some sporadic cases, these CDNs also use tier-1s (A model) or IXPs (C model) less frequently.

ASN (name)	20940 (Akamai)	15133 (Edgecast)	36408 (CDNetworks)	22822 (Limelight)	13335 (CloudFlare)
Telefonica	B	A	A	B	B
Orange	B	B	A	B	A
Jazztel	BC	B	AC	B	C
Vodafone	B	B	AC	C	C
Ono	A	BC	A	BC	A

Table 2: Interconnection models of CPs hosted in specialized CDN

Interconnection models of CPs hosted in hosting and cloud providers: Table 3 shows the interconnection models used for a list of CPs that use hosting and cloud providers to deliver their services. These CPs are mostly regional and local web sites without a strong networking infrastructure and require more affordable interconnection models. The analyzed hosting companies mostly use IXPs (C model) to deliver their services. This solution is mainly adopted by companies with presence in local markets and with the aim to optimize resources having most interconnections in a single point. The majority of the measured IXP interconnections use ESPANIX (located in Madrid, Spain) and LINX (London, UK) IXPs. It is noteworthy that, although measurements are done from Barcelona, there are few CPs using the CATNIX IXP located in the same city which it could be more efficient. However, these companies also combine this interconnection model with the use of tier-1s (A model) and rarely use direct interconnections (B model).

Adapt or perish - Interconnection models of CPs hosted in carriers: Table 4 shows the interconnection models of a list of CPs that use carrier ISPs to deliver their traffic. Tier-1 ISPs like Level3, Cogent, NTT or Interoute have detected that their transit services are losing share in front of the direct interconnections (peering) and the CDN solutions. As a response, these carrier ISPs have decided to take advantage of their large backbone networks to extend their services porfolio adding CDNs or hosting services to CPs. The motivation for CPs to host their contents using carriers is because these ISPs are in a good market position to build a new offer consisting of an affordable connectivity performance and highly cost-efficient to middle-size CPs. Typically, CPs hosted

ASN (name)	8220 (Colt)	3324 (Fujitsu)	36351 (SoftLayer)	13768 (Peer1)	16276 (OVH)	8560 (1and1)	16371 (Acens)	20718 (Arsys)	39020 (Comvive)	45037 (Hispaweb)	24592 (Nexica)	24931 (DediPower)	39743 (Voxility)
Telefonica	C	C	B	A	A	A	B	C	A	A	A	A	A
Orange	C	C	A	A	B	A	C	C	A	C	C	A	nd
Jazztel	C	C	C	BC	C	C	A	C	C	C	A	C	C
Vodafone	C	C	AC	A	BC	A	C	C	C	C	A	A	A
Ono	A	nd	A	AB	A	A	C	A	C	A	A	A	A

Table 3: Interconnection models of CPs hosted in hosting and cloud companies. (nd: not determined)

by these tier-1s have direct interconnections (B) with the access ISPs although some of them are transit agreements rather than (paid) peering. Access ISPs with sibling international networks (Telefonica, Orange and Vodafone) tend to have peering agreements while regional access ISPs (Jazztel and ONO) have transit agreements.

ASN (name)	3356 (Level3)	174 (Cogent)	2914 (NTT)	8928 (Interoute)
Telefonica	B	B	B	BC
Orange	B	B	B	BC
Jazztel	B	B	B	B
Vodafone	B	B	B	BC
Ono	B	B	B	A

Table 4: Interconnection models of CPs hosted in carriers

Placing servers inside access ISPs: Another interesting result from the measurements is to observe a new interconnection strategy where CPs decide to locate the servers within the access ISP network. Based on the *akamaized*[3] URLs of some traces, we detected that some of the CPs are using Akamai to deliver their static content. Akamai delivers this content using servers at their vantage points or using servers located within the access networks. Table 5 shows that a large number of CPs are using the Akamai servers located in Telefonica, Orange, Vodafone and Jazztel. The first three ISPs use the Akamai servers located in their sibling backbones (Telefonica Backbone, OpenTransit and CableWire-

[3] An Akamaized URL is an URL which contains lexical references to be part of the Akamai CDN, e.g. *s-static.ak.facebook.com*

less) while Jazztel use their local network. We have observed that global CPs like Microsoft, Facebook, Yahoo, Ebay or Apple and local media CPs like RTVE, Antena3, Telecinco, ElPais, ElPeriodico or LaVanguardia require enhanced content delivery solutions like Akamai to ensure the better quality of service.

	Akamai	Access ISP hosting/CDN
Telefonica	Apple, Facebook, eBay, Microsoft, LinkedIn,	ElCorteIngles, BancSabadell, Europapress, Fotocasa, Segundamano
Orange	Yahoo, ElPais, As, Badoo, LaVanguardia,	-
Jazztel	Mundodeportivo, RTVE, Abc, Antena3,	-
Vodafone	Telecinco, Mediaset, Sport, ElPeriodico	-
Ono	No detected Akamai servers within Ono	20minutos

Table 5: CPs using Akamai servers and hosting solutions within access ISPs

In addition, we have also observed that some measurements targeting Google never leave some access ISPs (e.g. Jazztel or the Spanish research network RedIRIS). We identify a similar behavior to the one used by Akamai, where Google places its content servers inside the access ISPs. These results are consistent with Calder et al. [7] who previously observed this new trend. It may seem reasonable to expect this interconnection model from Google to optimize its transit costs and improve the latency in some services like YouTube.

Multiple interconnection model: There is also a specific case in which a CP with its own AS requires one or multiple intermediary ISPs (tier-1s) to reach the access ISPs. The particularity of this case is that these CPs host their dynamic content at their own AS but they delegate its cached content to the CDN service of an intermediary ISP. This can be seen in Fig. 4, where one of the major Spanish press groups (ElMundo.es) maintain its own AS, but they contract a third party for delivering their multimedia content. The main motivation of this model is to reduce transit costs using cache servers for static content while boosting the user experience.

5 Conclusions

In this study, we have explored the Internet paths between the most popular CPs and the major access ISPs in Spain. The obtained results are consistent with the literature and confirm that large CPs tend to bypass tier-1 networks and prefer direct interconnections with access ISPs. This strategy was initially exploited by Google. However, the results obtained show that this model is also followed by other global CPs like Facebook, Microsoft, Yahoo or Amazon. This fact is threatening tier-1s and it must be seriously considered as large CPs are moving a significant fraction of the total Internet traffic/business. To face this, tier-1s like Level3, Cogent or NTT are taking advantage of their large networks to offer CDN/hosting services to those CPs without "highly-developed" networks. This confirms that tier-1s are evolving their business offering cost-effective services to

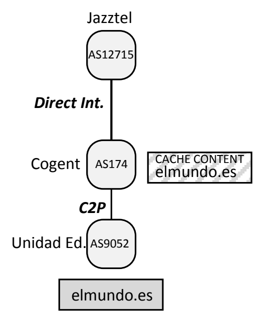

Fig. 4: Multiple content delivery strategies for web sites

smaller and local CPs. We also highlight the presence of Akamai servers within the networks of 4 of the 5 surveyed access ISPs. Finally, we have identified a large number of CPs that rely on CDN/hosting companies which mainly use their presence at IXPs to interconnect. This last model is a good choice for those companies that want to optimize resources and facilitate the interconnection with other networks. According to the obtained results, the Internet market is in continuous evolution and there are sufficient content delivery alternatives to cover the necessities of heterogenous CPs.

Acknowledgments: This work was partially supported by the Spanish government, through the project CISNETS (TEC2012-32354) and AGAUR (SGR2014-1173).

References

1. V. Adhikari, Y. Guo, F. Hao, M. Varvello, V. Hilt, M. Steiner, and Z.-L. Zhang. Unreeling netflix: Understanding and improving multi-CDN movie delivery. In *INFOCOM, 2012 Proceedings IEEE*, pages 1620–1628, March 2012.
2. V. Adhikari, S. Jain, Y. Chen, and Z.-L. Zhang. Vivisecting YouTube: An active measurement study. In *INFOCOM, 2012 Proceedings IEEE*, pages 2521–2525, March 2012.
3. B. Ager, W. Mühlbauer, G. Smaragdakis, and S. Uhlig. Web Content Cartography. In *Proceedings of the 2011 ACM SIGCOMM Conference on Internet Measurement Conference*, IMC '11, pages 585–600, New York, NY, USA, 2011. ACM.
4. Alexa. Alexa Top Sites. `http://www.alexa.com/topsites`.
5. CAIDA. Archipelago Measurement Infrastructure. `http://www.caida.org/projects/ark/`.
6. CAIDA. The CAIDA AS Relationships Dataset. `http://www.caida.org/data/active/as-relationships/`, July 2012.
7. M. Calder, X. Fan, Z. Hu, E. Katz-Bassett, J. Heidemann, and R. Govindan. Mapping the Expansion of Google's Serving Infrastructure. In *Proceedings of the 2013 Conference on Internet Measurement Conference*, IMC '13, pages 313–326, New York, NY, USA, 2013. ACM.

8. K. Chen, D. R. Choffnes, R. Potharaju, Y. Chen, F. E. Bustamante, D. Pei, and Y. Zhao. Where the Sidewalk Ends: Extending the Internet AS Graph Using Traceroutes From P2P Users. In *Proceedings of the 5th International Conference on Emerging Networking Experiments and Technologies (CoNEXT)*, pages 217–228. ACM, 2009.
9. X. Dimitropoulos and G. Riley. Modeling Autonomous-System Relationships. In *Proceedings of the 20th Workshop on Principles of Advanced and Distributed Simulation (PADS)*, pages 143–149. IEEE Computer Society, 2006.
10. P. Faratin, D. Clark, P. Gilmore, S. Bauer, A. Berger, and W. Lehr. Complexity of Internet interconnections: Technology, incentives and implications for policy. In *in Proc. 35th Res. Conf. Commun., Inf. Internet Policy (TPRC*, 2007.
11. P. Gill, M. Arlitt, Z. Li, and A. Mahanti. The Flattening Internet Topology: Natural Evolution, Unsightly Barnacles or Contrived Collapse? In *Proceedings of the 9th International Conference on Passive and Active Network Measurement*, PAM'08, pages 1–10, Berlin, Heidelberg, 2008. Springer-Verlag.
12. Y. He, G. Siganos, M. Faloutsos, and S. Krishnamurthy. A systematic framework for unearthing the missing links: Measurements and impact. In *Proceedings of 4th USENIX Symposium on Networked Systems Design and Implementation (NSDI)*, pages 187–200. USENIX, 2007.
13. C. Huang, A. Wang, J. Li, and K. W. Ross. Understanding Hybrid CDN-P2P: Why Limelight Needs Its Own Red Swoosh. In *Proceedings of the 18th International Workshop on Network and Operating Systems Support for Digital Audio and Video*, NOSSDAV '08, pages 75–80, New York, NY, USA, 2008. ACM.
14. C. Labovitz, S. Iekel-Johnson, D. McPherson, J. Oberheide, and F. Jahanian. Internet inter-domain traffic. *SIGCOMM Comput. Commun. Rev.*, 41(4):–, Aug. 2010.
15. D. Meyer. University of Oregon Route Views Project. `http://www.routeviews.org/`.
16. M. Palacin, A. Bikfalvi, and M. Oliver. Mercury: Revealing Hidden Interconnections Between Access ISPs and Content Providers. In *Proceedings of the 20th EUNICE Conference*. Springer's Lecture Notes in Computer Science, 2014.
17. PeeringDB. PeeringDB. `https://www.peeringdb.com/`.
18. Philip Smith, Cisco Systems. BGP Routing Table Analysis. `http://thyme.apnic.net/`.
19. Planet Lab. Planet Lab. `http://www.planet-lab.org/`.
20. Y. Shavitt and E. Shir. DIMES: Let the Internet Measure Itself. *ACM SIGCOMM Computer Communication Review*, 35(5):71–74, 2005.
21. Y. Shavitt and U. Weinsberg. Topological Trends of Internet Content Providers. In *Proceedings of the Fourth Annual Workshop on Simplifying Complex Networks for Practitioners*, SIMPLEX '12, pages 13–18, New York, NY, USA, 2012. ACM.