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A Region-Centric Analysis of the Internet Peering Ecosystem

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***Abstract*—The Internet is transitioning from a hierarchical structure to a flat structure where more and more networks participate in public peering at IXPs and private peering at interconnection facilities to increase performance and reduce transit costs. PeeringDB is a public online database containing information about IXPs, facilities, and networks participating at IXPs and facilities. In this paper, we perform an in-depth analysis of the PeeringDB data to gain an understanding of the public and private peering ecosystems in the five regions of the world (i.e., North America, Europe, Asia Pacific, Latin America, and Africa). We study how IXPs, facilities, and peering networks are distributed across the five regions. We also investigate how distribution of network business type, peering policy, and traffic level varies across the five regions. Our analysis provides a snapshot of the current state of the peering ecosystems in the five regions of the world and reveals the similarities and differences between these peering ecosystems.**

I. Introduction

The Internet connects tens of thousands of autonomous systems (ASes). The ASes engage in two types of business relationships to exchange traffic: transit relationship and peering relationship. In a transit relationship, one AS (the customer) pays the other AS (the provider) for transiting traffic to the rest of the Internet. In a peering relationship, two ASes exchange traffic between themselves and their customers for free. Peering enables networks to exchange traffic directly rather than through their transit providers, leading to better performance and reduced cost. There are two types of peering: private peering and public peering. Private peering occurs at interconnection facilities where direct interconnections are set up between pairs of networks. Most of the traffic exchange between the largest networks occurs via private peering. Public peering occurs at the Internet Exchange Points (IXPs). An IXP deploys its switches at one or more interconnection facilities so that participants at the facilities can peer with each other through the IXP's switching fabric. Public peering is more cost-effective than private peering as ASes interconnect via shared switches instead of dedicated cross-connects. The number and size of IXPs have increased rapidly in recent years. As a result, the Internet is rapidly evolving from a hierarchical structure consisting of mostly transit links to a flat structure with mostly peering links [10], [9], [15], [12], [5], [4].

IXPs and the Internet peering ecosystem have received increasing attention from the research community in recent years [7], [8], [4], [16], [13], [11], [14], [6]. There are three main data sources providing information about IXPs, private peering facilities, and peering networks: PeeringDB [3], PCH [2], and Euro-IX [1]. Klöti et al. [14] provided a comparison of the three data sources and combined them to provide a complete set of publicly available IXP data. Lodhi et al. [16] studied PeeringDB data and assessed its representativeness and usability to Internet research. The authors also explored PeeringDB data from the network perspective and discovered correlations among three network properties: geographic expense, peering policy, and advertised prefixes. Both [14] and [16] focus on the public peering ecosystem by exploring data about IXPs and networks participating at IXPs.

In this paper we present the first region-centric analysis of the Internet peering ecosystem using PeeringDB data. Our goal is to understand the present status of both public peering ecosystem and private peering ecosystem in each of the five regions of the world. We use PeeringDB data because it provides detailed information about private peering facilities and a wide range of attributes about peering networks that are not available in PCH and Euro-IX datasets. First, we study how IXPs and facilities are distributed across the five regions. Second, we study how public peering networks and private peering networks are distributed across different regions. Third, we investigate how distribution of network business type, peering policy, and traffic level varies across the five regions. Our study reveals the similarities and differences between the peering ecosystems in different regions as well as the similarities and differences between public peering ecosystem and private peering ecosystem in the same region.

The rest of this paper is structured as follows. Section II describes our data source. Section III discusses the distribution of IXPs and facilities across five regions. Section IV studies the distribution of peering networks across five regions and analyzes those networks that participate in more than one region. In Section V we study the network business type distribution in each region. In Section VI and Section VII we discuss region-wise distribution of network traffic level and network peering policy, respectively. We conclude our work and discuss future directions in Section VIII.

II. Data Source

PeeringDB is a publicly available online database containing information about IXPs, facilities, and networks participating

at IXPs and facilities. Networks registered in PeeringDB self-report a wide range of attributes such as business type, traffic level, and set of IXPs and facilities where they are present. We download the MySQL dump of PeeringDB on 12/3/2015 and analyze this dataset to study the peering ecosystem in the five regions of the world. We focus on three attributes of peering networks: peering policy, business type, and traffic level.

Peering policy. There are three types of peering policies: open, selective, and restrictive. Networks with open peering policy generally are willing to peer with anyone in any location with no prerequisites. Networks with selective peering policy will generally peer but they maintain a set of criteria (e.g. minimum traffic volume, traffic ratio, meeting in multiple interconnect regions) that potential peers must meet. Networks with restrictive peering policy are generally not open to new peering.

Business type. There are six network business types: Network Service Provider (NSP), Cable/DSL/ISP, Content, Education/Research, Enterprise, and Non-Profit.

Traffic level. There are 14 traffic levels, ranging from 0-20Mbps to 1Tbps+.

III. IXPs and Facilities

There are 617 IXPs and 1863 facilities in our dataset. We group the IXPs and facilities into five regions of the world, namely Europe (RIPE), North America (ARIN), Asia Pacific (APNIC), Latin America (LACNIC), and Africa (AFRI-NIC). Figure 1 shows the number of IXPs and facilities in each region. The ranking of regions from the largest IXP/facility count to the smallest IXP/facility count is RIPE, ARIN, APNIC, LACNIC, and AFRINIC. As expected, more affluent regions offer more peering opportunities. RIPE has an extremely vibrant interconnection marketplace with significantly more IXPs and facilities than the other regions. At the other extreme, AFRINIC's interconnection marketplace is still in early stage of development with only 36 IXPs and 33 facilities. We observe that ARIN and APNIC have almost equal IXP count but facility count in ARIN is more than twice the facility count in APNIC. This indicates that while there are similar public peering opportunities in North America and Asia Pacific, North America offers twice as many private peering locations as Asia Pacific.

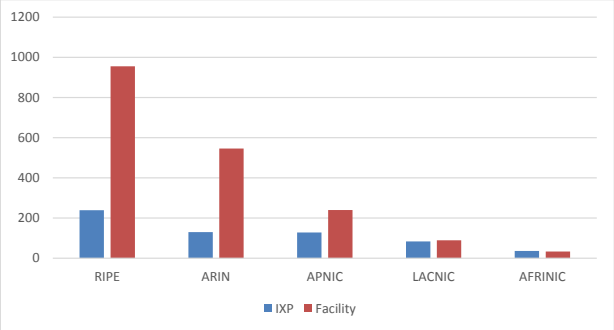

Fig. 1. Distribution of IXPs and facilities across five regions

A. Top IXPs and Facilities

Networks registered in PeeringDB self-report their presences at IXPs and facilities. Based on this data we compute the size of each IXP and facility in terms of number of participants. We obtain the top 5 IXPs and top 5 facilities in each region and find that generally the top IXPs/facilities in RIPE are the largest, followed by ARIN, APNIC, and LACNIC. Top IXPs/facilities in AFRINIC are the smallest in size. We note that the top IXPs/facilities in AFRINIC are all in South Africa and all but one top IXPs/facilities in LACNIC are in Brazil. Thus, most of the peering in AFRINIC and LACNIC occur in South Africa and Brazil, respectively. Other counties in the two regions offer very few peering opportunities.

Tables I and II list the top 10 IXPs and top 10 facilities in the world, respectively. The top three IXPs in the world are all in RIPE. This is different from the facility case, where one of the top three is in RIPE and the other two are in ARIN. Among the top 10 IXPs in the world, 7 are in RIPE, 2 are in ARIN, and 1 is in LACNIC. Among the top 10 facilities in the world, 5 are in RIPE, 4 are in ARIN, and 1 is in APNIC. As expected, AFRINIC does not have an entry in either table. RIPE has the most vibrant public peering scene while RIPE and ARIN have equally vibrant private peering scene. Outside of RIPE and ARIN, Brazil has a very vibrant public peering marketplace with the 4th largest IXP in the world and Singapore has a very vibrant private peering marketplace with the 7th largest facility in the world.

TABLE I
Top 10 IXPs in the World

IXP Name	Size	Region
AMS-IX, Amsterdam	693	RIPE
DE-CIX, Frankfurt	591	RIPE
LINX Juniper LAN, London	583	RIPE
PTT Sao Paulo, Brazil	482	LACNIC
LINX Extreme LAN, London	265	RIPE
France-IX, Paris	253	RIPE
NL-IX, Amsterdam	247	RIPE
Equinix Ashburn	246	ARIN
Seattle Internet Exchange	230	ARIN
Equinix Paris	226	RIPE

TABLE II
Top 10 Facilities in the World

Facility Name	Size	Region
Telehouse London (Docklands North)	319	RIPE
Equinix Ashburn (DC1-DC11)	236	ARIN
CoreSite Los Angeles	227	ARIN
Telehouse Paris 2	194	RIPE
Telehouse London (Docklands East)	187	RIPE
TelecityGroup Amsterdam 2	181	RIPE
Equinix Singapore	160	APNIC
Equinix San Jose	156	ARIN
NIKHEF Amsterdam	138	RIPE
Verizon Miami	136	ARIN

IV. Peering Networks

A network participates in public (private) peering in region X if the network participates at an IXP (facility) in region X.

A network could peer in more than one region because it can participate at multiple IXPs/facilities in different regions. Our dataset contains 5528 networks, 415 (422) of which participate in public (private) peering in more than one region. In this section we study network participation of peering in different regions.

A. Network Distribution across Regions

Figure 2 shows the number of public and private peering participants in each region. The ranking of regions from the largest number of peering participants to the smallest number of peering participants is RIPE, ARIN, APNIC, LACNIC, and AFRINIC. As expected, more affluent regions have more networks participating in peering. We observe that each region has more public peering participants than private peering participants. This is because public peering is more cost-effective than private peering. We also observe that LACNIC has significantly more public peering participants than private peering participants. This is consistent with the fact that LACNIC has the world's 4th largest IXP with 482 participants while its largest private peering facility hosts only 111 participants.

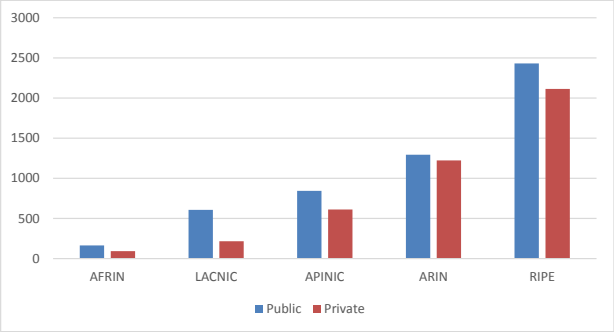

Fig. 2. Number of public and private peering participants in five regions

B. Networks Participating in Two to Four Regions

Figure 3 shows the number of networks participating in public peering and private peering in two regions. The 2-region combinations with zero or few peering networks are not shown in the figure. We see that the combination of ARIN and RIPE has the largest number of peering networks. This is expected because ARIN and RIPE are the most affluent regions. Interestingly, networks peering in APNIC is more likely to also peer in ARIN than RIPE, and networks peering in RIPE is equally likely to also peer in AFRINIC and APNIC. The ARIN and LACNIC combination has a decent share of networks due to geographical proximity of the two regions. For the same reason, RIPE and AFRINIC combination also has a decent share of networks.

Table III shows the number of networks peering in three regions. Only two 3-region combinations are shown because the other combinations have zero or few networks. As expected, the combination RIPE, ARIN, and APNIC has the largest number of peering networks–around 100 networks in both public peering and private peering cases. There is also a small number of networks participating in RIPE, ARIN, and LACNIC.

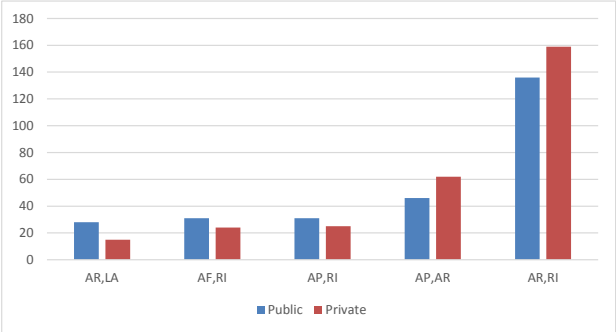

Fig. 3. Number of networks participating in public peering and private peering in two regions

TABLE III
COUNT OF NETWORKS PARTICIPATING IN PUBLIC PEERING AND PRIVATE PEERING IN THREE REGIONS

Region Combination	Public	Private
PIRE, ARIN, APNIC	102	99
RIPE, ARIN, LACNIC	7	9

There are 15 (17) networks participating in public (private) peering in the 4-region combination of RIPE, ARIN, APNIC, and LACNIC. Other 4-region combinations have zero or few peering networks.

C. Networks Participating in Five Regions

There are 9 networks participating in public peering in all 5 regions, as listed in Table IV. Two of these networks, namely Google and Microsoft, also participate in private peering in all 5 regions. The first 3 entries are Education/Research networks operated by Packet Clearing House (PCH) and Route Views. With AS3856 PCH collects and archives BGP routes from IXPs around the world. With AS42 PCH does anycast hosting for DNS root servers and about 250 top-level domains (TLDs). Route Views deploys servers at many locations around the world (typically at large IXPs) to collect and archive BGP data. Both PCH and Route Views offer valuable data sources for the Internet research community. Netnod is a non-profit Internet infrastructure organization offering DNS anycast and unicast slave services to TLDs worldwide. It is also the operator of the DNS root server I. The other five entries in the table are large content providers and large network service providers with network infrastructures spanning all 5 regions.

D. IXP-Only and Facility-Only Networks

In our dataset there are 1621 networks that participate only at IXPs and 550 networks that participate only at facilities. The IXP-only networks and facility-only networks engage only in public peering and private peering, respectively. We find that business type Cable has the largest share among IXP-only networks and business type Content has the largest share among facility-only networks. In terms of peering policy, open

TABLE IV
NETWORKS PARTICIPATING IN ALL FIVE REGIONS

ASN	Name	Business Type
42	Packet Clearing House	Education/Research
3856	Packet Clearing House	Education/Research
6447	Route Views	Education/Research
8674	Netnod	Non-Profit
36408	CDNetworks Inc.	Content
20940	Akamai	Content
15169	Google	Content
7342	Verisign	NSP
8075	Microsoft	NSP

is the dominant peering policy among both IXP-only and facility-only networks. However, facility-only networks have 33% share of nonopen (i.e., selective and restrictive) peering policy, whereas IXP-only networks have only 22% share of nonopen peering policy.

An IXP-only network may be present at multiple IXPs (possibly in different regions) and thus have multiple IXP presences. Similarly, a facility-only network may have multiple facility presences. There are 1725 IXP presences made by IXP-only networks and 592 facility presences made by facility-only networks. Figure 4 shows the distribution of IXP presences and facility presences made by IXP-only and facility-only networks across the five regions. RIPE has the largest share of facility-only network presences followed by ARIN. These two regions have 82% of the facility-only network presences. In terms of IXP-only network presences, RIPE has the largest share, AFRINIC has the smallest share, and the other three regions have similar shares.

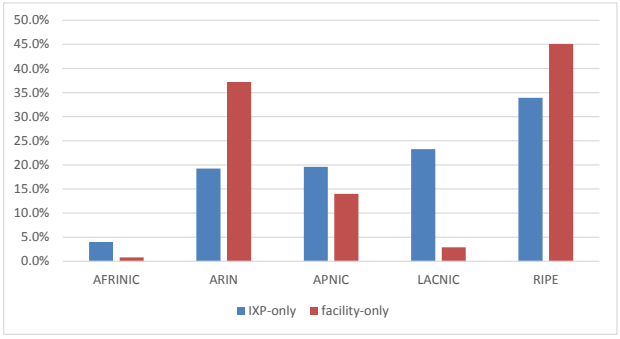

Fig. 4. Distribution of IXP-only network presences and facility-only network presences across five regions

V. NETWORK BUSINESS TYPE

Networks in PeeringDB are of six business types: Network Service Provider (NSP), Content, Cable/DSL/ISP, Education/Research, Enterprise, and Non-Profit. Figure 5 shows the distribution of the six business types in our dataset. The top three business types in terms of network share are Cable/DSL/ISP, NSP, and Content. These three types account for 89% of the peering networks.

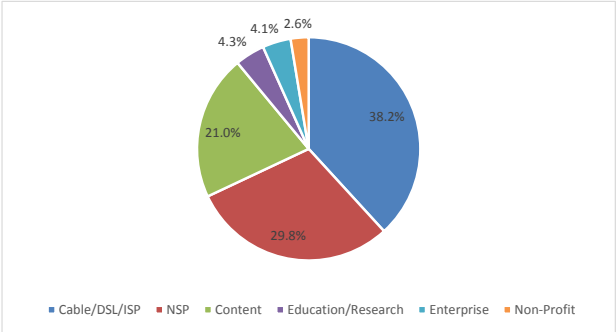

Fig. 5. Distribution of network business type

A. Distribution of Network Business Type by Region

Figure 6 shows the business type distribution of public peering networks in each region. Here we only show the distribution of Content, NSP, and Cable/DSL/ISP as these are the dominating business types. We observe that RIPE, ARIN, and APNIC (group 1) have similar distributions while LACNIC and AFRINIC (group 2) have similar distributions. There are two notable differences between the two groups. First, in group 1 Cable and NSP have similar shares of networks while in group 2 Cable dominates the other two types. Second, Content has much larger share in group 1 than group 2.

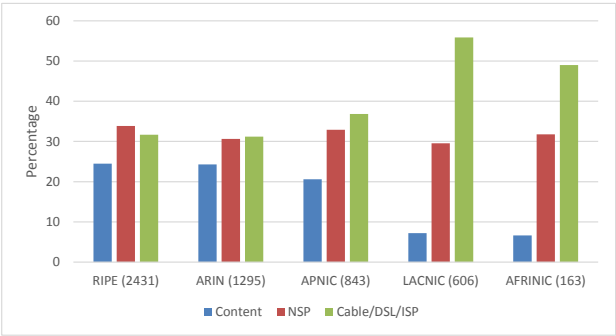

Fig. 6. Network business type distribution by region for public peering networks. Total number of public peering networks in each region is given in parentheses.

Figure 7 shows network business type distribution by region for networks that participant in private peering. Compared to Figure 6, we observe that NSP's share increases in all five regions and Cable's share decreases in all five regions. As a result, in all regions except RIPE there is notable difference between the distributions of network business type for public peering networks and private peering networks. Specifically, in ARIN and APNIC Cable has the largest share among public peering networks while NSP has the largest share among private peering networks. In LACNIC and AFRINIC, Cable has the largest share among both public peering networks and private peering networks. However, the gap between Cable's share and NSP's share is much smaller in the private peering case.

Both Figure 6 and Figure 7 indicate that content providers are less interested in peering in LACNIC and AFRINIC. As a result, latency to content is expected to be higher in these two regions compared to RIPE, ARIN, and APNIC.

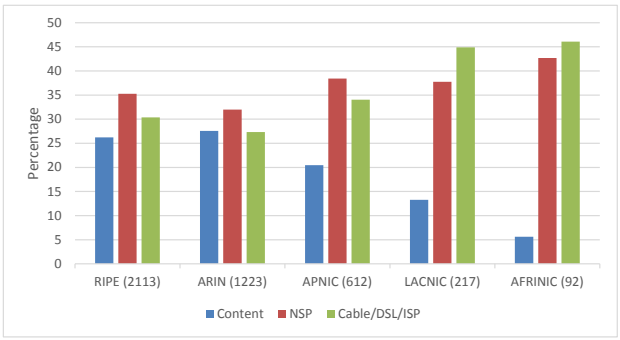

Fig. 7. Network business type distribution by region (private peering). Total number of private peering networks in each region is given in parentheses.

B. Networks Participating in One to Four Regions

Figure 8 shows the distribution of network business type for public peering networks participating in one to four regions. The distribution for private peering networks is shown in Figure 9. In both figures Cable has the largest share among networks participating in 1 region, NSP has the largest share among networks participating in 2 to 3 regions, and Content has the largest share among networks participating in 4 regions. As the number of regions increases from 1 to 4, Cable's share decreases and Content's share increases. Content providers are more likely to peer in all five regions than the other business types because they are interested in providing fast content access to users all over the world.

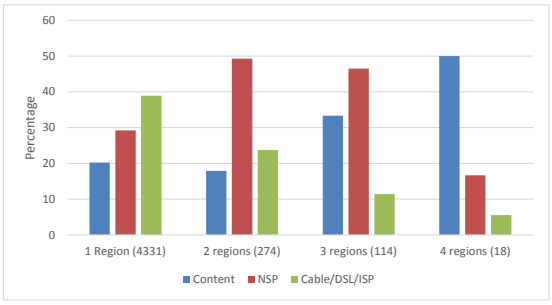

Fig. 8. Distribution of network business type for public peering networks participating in one to four regions. Total number of networks in each category is given in parentheses.

VI. Network Traffic Level

In this section we study the traffic level distribution of the networks in our dataset. PeeringDB defines 14 different traffic levels, ranging from 0-20Mbps to 1Tbps+. Figure 10 shows the number of networks for each traffic level. We see that traffic level 100-1000Mbps has the largest network count followed by traffic level 1-5Gbps. There are over 100 high traffic volume networks: 53 networks with 500-1000Gbps traffic level and

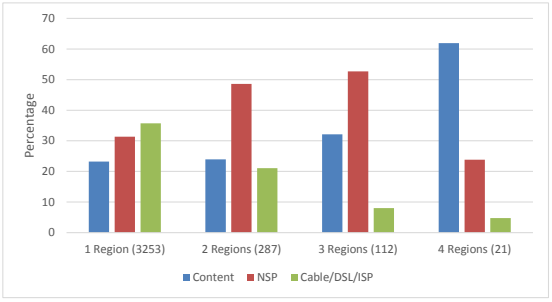

Fig. 9. Distribution of network business type for private peering networks participating in one to four regions. Total number of networks in each category is given in parentheses.

64 networks with 1Tbps+ traffic level. At the other extreme, there are 125 networks with 0-20Mbps traffic level.

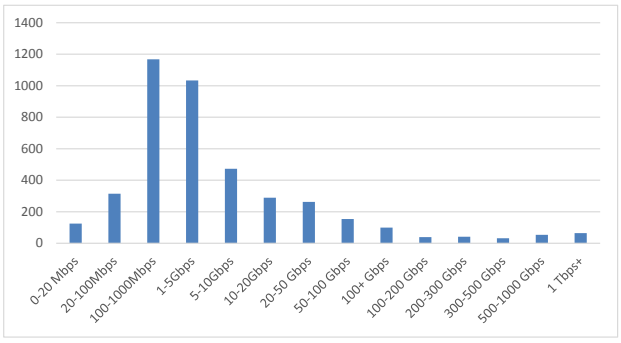

Fig. 10. Network count for different traffic levels

A. Distribution of Traffic Level by Region

Figure 11 shows traffic level distribution by region for networks participating in public peering. Here we group the 14 fine traffic levels in PeeringDB into 3 coarse traffic levels: 0-1Gbps (low traffic), 1-100Gbps (medium traffic), and 100Gbps+ (high traffic). We observe that low traffic networks dominate in AFRINIC, medium traffic networks dominate in RIPE, ARIN, and APNIC, and low traffic networks and medium traffic networks have similar shares in LACNIC. APNIC and ARIN have similar traffic level distribution. Their shares of medium traffic networks and high traffic networks are the largest among the five regions.

Figure 12 shows traffic level distribution by region for networks participating in private peering. The observations made for the public peering case also hold here except that LACNIC has the largest share of medium traffic networks among the five regions and this share is significantly higher than the share of low traffic networks. When comparing Figure 11 and Figure 12, we see that a region's share of high traffic networks is generally higher among private peering networks than public peering networks. This indicates that high traffic networks are more interested in private peering.

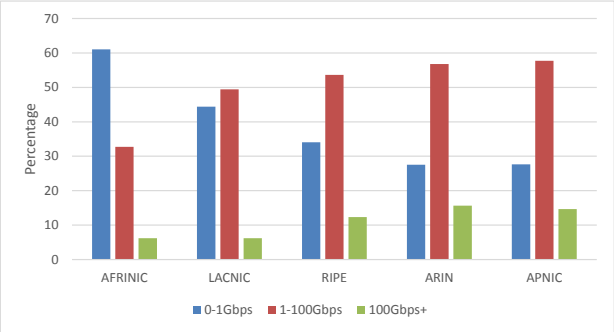

Fig. 11. Distribution of network traffic level by region: public peering

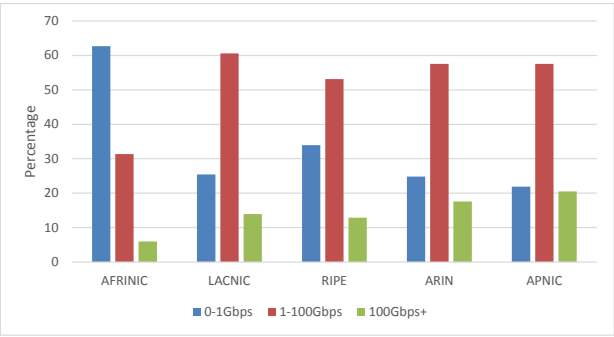

Fig. 12. Distribution of network traffic level by region: private peering

VII. Network Peering Policy

The peering policy of a network indicates the inclination of the network to peer with others. As described in Section II, there are three types of peering policies: open, selective, and restrictive. Out of the 5528 networks in our dataset, 75.1% has open peering policy, 21.6% has selective peering policy, and 3.3% has restrictive peering policy. This shows that most networks opt for the open peering policy in order to attract more peers and maximize benefit.

Figure 13 shows the distribution of peering policy by region for networks participating in public peering and private peering. We make the following observations for both public peering networks and private peering networks as the distribution is similar for the two cases. First, open is the dominant peering policy in every region. Second, LACNIC has the highest open policy percentage followed by AFRINIC. On the other hand, APNIC has the highest nonopen policy (i.e., selective and restrictive) percentage followed by ARIN. As presented in Section VI-A, APNIC and ARIN have large share of medium and high traffic networks. Since such networks are more likely to adopt nonopen peering policy, APNIC and ARIN have higher nonopen policy percentage than the other regions. Finally, we note that private peering networks generally have lower open policy percentage and higher restrictive policy percentage than public peering networks in each region.

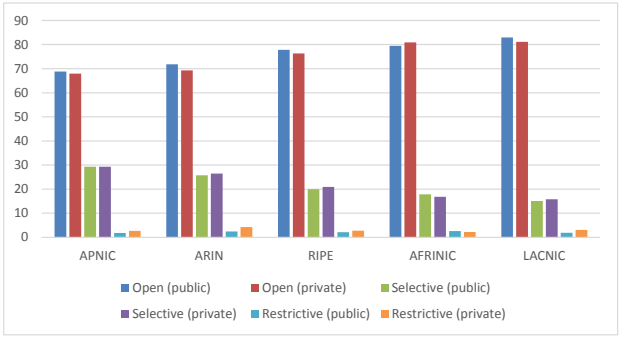

Fig. 13. Distribution of peering policy by region

VIII. Conclusion and Future Work

In this paper we analyze PeeringDB data to understand the present status of the public and private peering ecosystems in different regions of the world. We study how IXPs, facilities, and public/private peering networks are distributed across Europe, Asia Pacific, North America, Latin America, and Africa. We also study the distribution of network business type, traffic level, and peering policy in these regions. We find that Europe has the most vibrant peering marketplace with the largest number of IXPs, facilities, and peering networks. North America also has a very vibrant peering scene. Out of the top 10 IXPs and top 10 facilities in the world, 18 are located in Europe and North America. Africa's peering marketplace is still in early stage of development with the smallest number of IXPs, facilities, and peering networks among the five regions. In terms of network business type distribution, we find that content providers have much smaller share in Latin America and Africa compared to the other three regions, indicating that users in Latin America and Africa have slower access to content. In terms of traffic level distribution, we find that low traffic networks dominate in Africa while medium traffic networks dominate in the other four regions. North America and Asia Pacific have the largest shares of high traffic networks. In terms of peering policy distribution, we find that open is the dominant peering policy in all five regions. However, in North America and Asia Pacific higher portions of networks adopt nonopen (i.e., selective and restrictive) peering policy due to their larger share of high traffic networks.

The Internet peering ecosystem is constantly evolving. Thus it is useful to keep track of the evolution of the Internet peering ecosystem by performing our region-centric analysis periodically (e.g., once every quarter). In our future work we plan to automate our data access and analysis process to capture the status of the Internet peering ecosystem on a regular basis. We will publish our data online for public access and use. Our data will enable researchers to carry out longitudinal studies to observe how the Internet peering ecosystem changes over time and identify important trends. Our data can also help policy makers and network operators to make informed decisions to shape the future development of the Internet peering ecosystem.

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