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Internet Topology:Forces Behind A Shift From Hierarchical To Flattened Peering

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Abstract: *Internet is a network of networks which share information to each other through Internet Protocol. Internet taxonomy was designed to not depend on a single point of access to propagate information from host source to host destination, this had led to dependability among Autonomous Systems for reachability and connectivity information. Internet, a highly engineered, large scale complex system, viewed as a hierarchy of connected tiers of Autonomous Systems from which lower tier depend on higher tier for routing mostly transit traffic; this paper discusses the current hierarchical topology of Internet and analyses the forces behind the trending flat peering of Autonomous Systems which raise concerns of a shift of Internet structure from hierarchical to flattened topology.*

Keywords – Internet, Peering, Autonomous System

1. INTRODUCTION

Every node connected to the Internet is part of a network, and Internet to be precise. Accessing Internet; every network acquires access from Internet Service Access Provider (ISP) which at last become part of it, the agglomeration of Autonomous Systems (AS) internetworking is practically the Internet; a network of networks with majority of data retrieval, service access, and host-to-host applications such as telnet and file transfer protocols example ftp, http, etc. [3]. AS in this literature defined as set of routers under a single technical administration, common information propagation metrics and use single interior gateway protocol for routing within the AS [19].

I studied about flat inter-domain connection; peering that allow carriers to exchange traffic bound for one another's customers, also structure of Internet, its interconnection infrastructures, its hierarchical mode of traffic flow between Internet-based service Providers and finally theme of the paper which was flat peering of Autonomous Systems. \

1.1 Peering

Provider's peering forms backbone of unlimited Internet traffic routing; and infrastructure peering is exhausted at the interconnection facilities mainly the Internet Exchange Point (IXP), Colocation facility and

Internet Data Centre (IDC). Peering can be via *circuits* or *exchange-based* (private or public peering respectively). Providers usually exchange traffics to reach far end points; increased data transfer, reduced latency, fault tolerance, routing efficiency and getting closer to customers [16]. It is understood as a voluntary interconnection of administratively separate Internet networks. Interconnection of administratively separate networks (ASes) can take the layout of hierarchy or flat as expressed here below in Sub Sections I.II and I.III.

1.2 Internet Hierarchical Topology

Edge networks are access network which attaches hosts and servers to the Internet. A prototypical example is a switched layer-2 network such Ethernet Local Area Network [5], they correspond to networks at the edge of the Internet which have a single Internet access Provider, these enjoys Internet service by accessing Tier-3 ISPs which are small in scale described to cover regions and requires Provider with higher connectivity backbones and bandwidth to relay its traffics to greater distances. Tier-3 ISP connects to Tier-2 ISP to increase its routes of traffic propagation; classification continues to Tier-1 networks which are intercontinental ISPs and peer with each other at the Internet 'core'; Tier-1 networks forms the bedrock of Internet due to their large geographical coverage, higher traffic volume, number of customers so to list. This is traditional structure of Internet routing system [9].

1.3 Flattened Internet Topology

Flat topology takes the course from peering where bilateral business and technical arrangement among Providers normally are of the same size agree to accept traffic from one another, unlike hierarchy in which Transit Provider agrees to carry traffic to third parties on behalf of another Provider or an end user [15]. Autonomous Systems shifts to flat peering and speedy migrate from depending on Transit Providers for interconnection to respond to transit costs, uniform performance, improved redundancy, latency and maintaining local traffic. See figure 1 and 2 below.

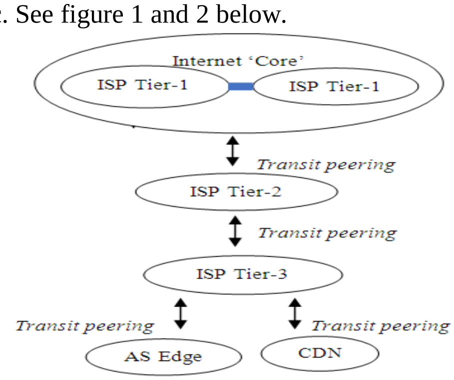

Figure1. above shows traditional structure i.e. hierarchical topology of Internet in which lower level Providers pays Transit Providers to route traffic.

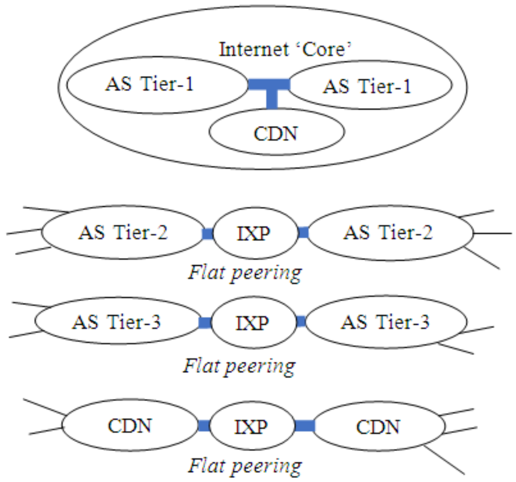

Figure. 2 above shows flattening peering of Internet.

Double arrow as used in figure 1 represents hierarchical transfer provided by IP Transit Providers to denote traditional taxonomy of Internet, Blue bold line as used in figure 2 denotes flat peering by Autonomous Systems without passing via Transit Providers and 'CDN' in this paper is a short form for large Content Distribution Networks which happened not to rely on Transit providers and connect directly to the 'core'.

2. BACKGROUND AND RELATED SUBJECTS

Article *"HAIR: Hierarchical Architecture for Internet Routing"* [5], suggests that Internet consists of a stable "core", formed by large Transit Providers, and a more dynamic "edge", consisting of small access network Providers.

In *"On the importance of Internet eXchange Points for today's Internet ecosystem"* [22], paper authored on business models and services provided at the Exchange Points, went further to acknowledge that largest IXPs handles huge traffic volumes comparable to those carried by the largest Tier-1 ISPs.

As per the paper titled "*Complexity of Internet Interconnections: Technology, Incentives and Implications for Policy*" [2], in the beginning, the pattern of ASes interconnection somewhat resembled a simple hierarchy, with campuses and other geographically local networks connecting to regional networks; and the regional network connecting to a single government backbone. In particular, two sorts of arrangements: *transit* i.e. vertical relationship where small networks pay larger network for access to the rest of the Internet and *peering* i.e.horizontal relationship where similar sized networks engage in settlement free interconnection.

[24], classified Internet Operators into several varieties, depending upon their position in the Internet hierarchy. At the top level there are the *Tier-1 Transit Providers* and *Internet Backbones;* they constitute upstream routing, providing universal connectivity to the downstream tiers, downstream tiers are Operators of smaller dimensions i.e. ISPs. At a further lower level in the Internet hierarchy there are the so-called Internet Access Providers, which usually obtain connectivity through a single connection to an ISP.

3. METHODOLOGY

The methodology adopted by this study was literature reading. The study visited various sources on the Internet to establish facts about the presented issues. Necessary websites of resource were visited, website of some journals which only put materials in html format rather than pdf or documents. The listed articles are mostly available on the Internet and where possible in some areas frameworks were translated to facilitate the discussion. So generally secondary sources were used in large part to come up to conclusion.

4. DISCUSSION

Providers out of geographical constraints, and the economics of IP transit; establishes interconnection agreements of two kinds; transit peering agreement where one sells global Internet connectivity to the other and flat peering where two Autonomous Systems bilaterally agree to exchange their routes for free. Transit and flat peering differ in terms of traffic that originates from source Providers.

A. Forces behind shifting to flat peering by ases

Flat Peering is recently dominating major Transit Providers interconnection worldwide, these are the ones who defined hierarchical topology of traffic taxonomy of other networks i.e. Contents Distribution Networks, Edge Networks, local IXP Providers, etc. since they have had absolute advantage in infrastructure capabilities; but it is changing; flat peering is currently the value-creation engine of the Internet as discussed hereforth:

(a) Reduced Interconnection Cost

In the report '*2016 Survey of Internet Carrier Interconnection Agreements'* [8], Packet Clearing House (PCH) analyzed 1,935,822 million agreements and specifically on mode of association, it found 1,935,111 million agreements (99.98%) had symmetric terms, in which each party gave and received the same conditions as the other i.e flat peering, rest 403 agreements (0.02%) had asymmetric terms i.e. paid peering in which the parties gave and received conditions with specifically defined differences, and these exceptions were down from 0.27% in 2011. Other analyses published [14] over reduced cost to Operators when join peers, acknowledges comfort financially since expenses spent on Transit Providers are saved and in turn improves performance by cutting off transit connections that might add round trip time delay (RTT).

(b) Conducive Peering Models

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Autonomous Systems are enjoying reciprocal flat benefits including global traffic reachability; on-time augmenting of circuits for uncongested interconnection paths, prompt resolving of security, stability, resilience, proper Border Gateway Protocol route advertisement and increasing local content [6].

In [23], analyzed optimal flat peering for asymmetric ISPs and concluded that from a network of relations perspective, ISPs' asymmetry in bilateral flat peering agreements need not be a problem, since when form a closed network, asymmetries are pooled and information transmission on best effort quality is faster. Peers can implement high quality connections for lower discount factors with multilateral strategies, which use targeted, time-limited, harsh punishment of cheaters, than with transit strategies, which punish cheating by de-peering. This shows how flat peering provides technical and economic viable solution in data exchange among Providers.

(c) Increasing Flat Interconnection Bandwidth

Flat bandwidth rose up as a result of solved complexity brought with transit peering, reduced cyber security risk by bypassing transit networks and activating local security perimeters; flat peering supports proximity of Providers in reducing latency especially taking international transfer in reaching destination host, and most important accelerating resilience and business interactions with their customers [2].

As per "*Global Interconnection Index 2017, Volume 1"* by Equinix, report looked at how flat interconnection bandwidth is shaping and scaling global digital economy. Statistics and Projections in Table 1 [9]. CAGR in the table means cumulative average growth.

Table: 1 Interconnection Installed Bandwidth Capacity at Terabytes per second (Tb/s).

Symmetrical Service Provider Interconnection	Year					CAGR
	2016	2017	2018	2019	2020	
Interconnecting to Network Provider	537	703	913	1,167	1,459	28%
Interconnecting to Cloud and IT Providers	30	50	85	145	248	70%
Interconnecting to Contents Providers	35	52	79	117	170	49%
Interconnecting to Financial Service Providers	46	61	81	109	148	34%
Interconnecting to Supply Chain Partners	13	26	45	46	40	33%
Total Service Provider Use Case	660	893	1,203	1,584	2,065	33%

(d) Growth of Providers own Networks

Contents Providers build their own global backbones. Over time and with growth of Transport Networks technologies, industry has seen large scale Internet traffic carriers migrate to horizontal traffic flowing, Content Networks are evident and as identified in [18], [20] that content distribution is the primary use of Internet today.

As of latest report by Packet Clearing House (PCH) [7], the current total number of Exchange Points globally amount to 850 with some countries having multiple Points; these Exchange Points are the major sources of traffic and drive to peering links thus to say interconnection infrastructures have increased rapidly in number, making it easy and cheap for Autonomous System to establish peering links with other co-located at the same exchange point.
The shift to own backbones by Providers by far is brought about by immense application of CDN products likes of e-commerce, live streaming, replacement of peer-to-peer file sharing with direct download services, etc.

(e) Increasing Flat Peering Traffic

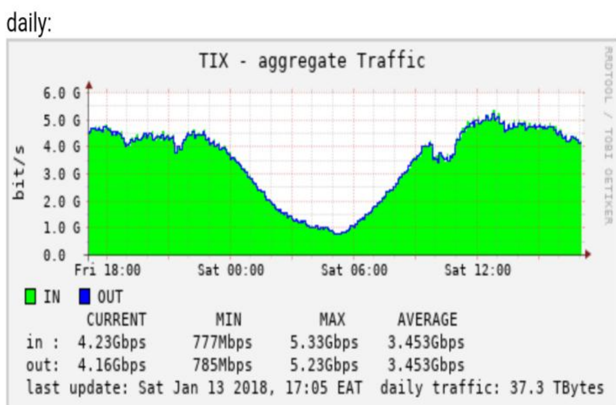
Leading Internet traffic carriers move huge amount of data from services; Providers likes of Google, Facebook, Microsoft and the rest have invested in long distance networks and abstained vertical peering to counter out of many is jitter from search engines, email accounts, google docs, google maps, office365, Azure cloud services, facebook, messenger, Whatsapp, Instagram and many others.

In common Facebook, Telxius and Microsoft in year 2017 had completed 'MAREA' highest capacity submarine cable from United States to Spain shuttling traffic across 4,000 mile-long of Atlantic Ocean providing up to 160 Tb/s with the capability to stream 71 million High Definition videos simultaneously [12]. Google and a Consortium of Asian Telecommunication Companies dubbed 'FASTER'; a 60 Tb/s bandwidth subsea fibre optic cable from United States to Japan 5,600 miles across Trans-Pacific Ocean [13].
Flat traffic also rises in Internet Exchange Points, AMS-IX, DE-CIX, LINX, and EQUINIX few to mention. Recently,

majority of inter-domain traffic by volume flows directly between giant Datacentres, Contents Distribution Networks, Exchange Points and edge networks.

(f) Increased Local Traffic Exchanges

Local traffic has reduced load in IP transit broadband backbones. This happened in developed countries and now being observed in Latin America and Africa as whole with unleashing of more building of peering infrastructures, example Tanzania launched its national data centres [31], in year 2015, fibre optic networks replacing copper networks, mobile payments penetration like M-Pesa, tigopesa, Airtel-Money, registered '.tz' domain increases i.e. 14,598 domains as of year 2018 [32], 40 peers at Tanzania Internet eXchange - TIX by year 2017 [33], etc. See TIX daily traffic in Table 2 below [34].



Local traffic has improved economies of scale and local contents to host nations. Now largest Providers who used to depend on Transit Providers for long distance routing are building cross country fibre optic cables linking their remote sites globally bypassing transit peering [12]**.** Certainly, Internet is dominated by interconnection facilities and Contents Distribution Networks while room for Transit Providers diminishes [17]; it is no longer about getting users to digital contents as was the case but contents to users [10]

B. Traffic quality diferences at interconnections

Both transit peering and flat peering does not guarantee quality traffic by only interconnecting networks. Traffic quality is influenced by several aspects including resilience, peers topology, and service level agreement [25], [26], [29]. Regardless of its merits, flat peering poses economic challenges *"backbone free riding"* and *"increased market competition"* for asymmetry networks while hierarchical offers multiple routing advantage *"hot potato routing"* take into consideration Transit Providers connects to several facilities to assure propagation.

[27] points out that variation in traffic quality between transit and flat peering respectively is not well known and understood since both are affected by distinct factors; while flat benefits data transfer, reduced latency, fault tolerance, routing efficiency and getting closer to customers; transit peerings are crowded with growing congestion forcing Provider's diversion to using circuits commonly referred to as private peering.

Poorly engineered links causes loss, jitter and delay. The quality of traffic is as good as the quality offered by the link along its path. Not the common case for Tier-1 ASes since load balancing and peering links seem to work fine as they have timely maintainability muscles compared to when Tier-3 ASes are involved. Poor intra-domain traffic engineering, BGP, and usage of AS-path lengths as the routing metric also influence traffic quality**. U**nderstanding link level degradations will help characterize the extent to which various factors in the Internet affect perpetual traffic quality [28], [30].

5. CONCLUSION

This article covered long time hierarchical nature of Internet taxonomy and flat peering which observed to bypass transit networks and as discussed; several conclusions were drawn in this survey paper as follows.

Out of huge and rising traffic requirements of large scale traffic producers, flat peering gives freedom to upgrade infrastructures when needed to ensure uniform performance of services.

Global transit traffic is declining while flat rises.
Investment in Transport Networks by IP transit Providers has changed mode into flat and there is continuing peering of IP transit Providers by themselves globally which ultimately sees new structure. Despite its prospect dominance, flat peering still required to be in research field.

6. FUTURE WORK

Need to strengthen route servers to cement its capability to handle stress traffic and alternative routing as for is used in multi-homing peers at the Exchange Points.

Security in Border Gateway Protocol is of paramount, BGP speaking routers need to upgrade control metrics since peering is all about connecting networks.

In conclusion, I believe that my findings will spur further studies into this important domain.

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