The Evolution of the U.S. Internet Peering Ecosystem

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Abstract

A new Internet Peering Ecosystem is rising from the Ashes of the 1999/2000 U.S. Telecommunications Sector crash. Global Internet Transit Providers have gone bust and a critical broadband infrastructure provider has failed, leaving in their wake a large set of Internet players to fend for themselves to provide their customers with Internet services. A broad set of Service Providers that were once focused only on growing their market share (at any cost) now are bending down to shave pennies off of their cost structure. Those who can not prove the viability of their business model while satisfying their customer demands are out of business.

In this paper we share research carried out over the last four years with hundreds of Peering Coordinators to document the recent chaotic evolution of the Peering Ecosystem. We do this by first defining the notion of an Internet Peering Ecosystem as a set of autonomous Internet Regions, each with three distinct categories set of participants. Each of these groups of participants has their own sets of characteristics, motivations and corresponding behaviors and interconnection dynamics. We describe four classes of Peering Inclinations as articulated in Peering Policies.

*The bulk of the paper however focuses on the **Evolution of the U.S. Peering Ecosystem.** Several key players, some abandoned by their service providers, have entered into the Peering Ecosystem and caused a significant disruption to the Ecosystem. Peer-to-Peer application traffic has grown to represent a significant portion of their expense. We describe five major events and three emerging evolutions in the Peering Ecosystem that have had and continue to have a significant disintermediation effect on the Tier 1 ISPs.*

In the appendix we share a simple mathematical Internet Peering Model that can be used to demonstrate this Peering Ecosystem evolution. While not complete or by any means precise, it does allow us to demonstrate the affect of these disruptions in the Peering Ecosystem.

The Global Internet Peering Ecosystem

The description of the evolution of the U.S. Internet Peering Ecosystem requires a set of terms and definitions. With this lexicon we can more precisely describe the evolution that has been occurring over the last few years.

The Internet[1] consists of millions of network devices (routers, servers, workstations, etc.) operated by a wide variety of network operators, content providers, and end users. We will call these operators of network devices “Internet players”. These “players” are independent (but interconnected) members of a system we will call an “Ecosystem”; each player has a definable role, an associated set of motivations and corresponding behaviors. We will focus in this paper only on the core of the Internet Ecosystem : the network operators that make up the Internet *Peering* Ecosystem.

Definition: The “Internet Peering Ecosystem” consists of a community of loosely affiliated network operators that interact and interconnect their networks in various business relationships.

There are many Internet Peering Ecosystems around the world, each with their own set of network operators collectively providing Internet access to the Internet Region.

There are vast differences between each region of the Internet Peering Ecosystem[2], so we model the Global Internet Peering Ecosystem as a loosely coupled set of “Internet Regions” each with its own Peering Ecosystem.

Internet Regions

In order for an ISP to provide access to the global Internet, it must get attached to the Global Internet. It does so with either Transit[3] or Peering[4] relationships, or a combination of both within an Internet Region.

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[1] By convention, when we refer to the big ‘I’ Internet we mean the global Internet.

[2] As a second follow-on paper, we document some of the International Peering Dynamics, detailing some general characteristics and some unique characteristics of the Japan, Australia, Hong Kong and Singapore Peering Ecosystems. It also touches on several dynamics unique to the International Internet Peering environment.

[3] **Definition: Transit** is a business relationship whereby one ISP provides (usually sells) access to the Global Internet.

[4] **Definition: Peering** is a business relationship whereby two ISPs provide reciprocal access to each others’ customers. This is typically a free exchange of traffic.

Definition: An **Internet Region** is a portion of the Internet, usually defined by geographical boundaries (country or continent borders), in which an Internet Peering hierarchy is contained as shown below.

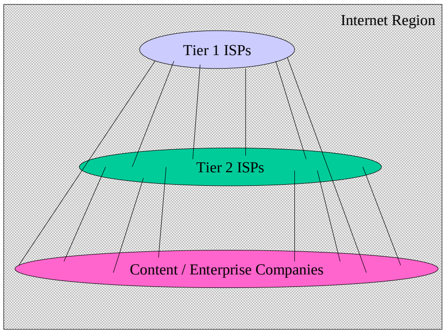

Figure 1 – Internet Players within an "Internet Region"

Each Peering Ecosystem is generally composed of three general classes of Internet players: Tier 1 ISPs, Tier 2 ISPs, and Content Providers / Enterprise Companies. Each Player within these classes hold similar power positions within the Peering Ecosystem and therefore tend to have similar motivations and exhibit similar behaviors within the Peering Ecosystem. We will describe each of these players next.

Ecosystem Player: The Regional Tier 1 ISP

The phrase "Tier 1 ISP" has been an overloaded and misused term in the industry, but for this discussion we will use the following working definition:

Definition: A <u>Regional Tier 1 ISP</u> is an ISP that has access to the entire Regional Internet routing table solely through Peering relationships.

Regional Tier 1 ISPs are at the top of the hierarchy and don't have to pay transit fees (since by definition they have access to the entire Internet Region solely through peering relationships with the other Tier 1 ISPs). All other ISPs operating in the region are required to purchase transit from one or more of the Regional Tier 1 ISPs (or indirectly from their downstream ISPs) in order to reach all destinations in the Internet Region.

This Regional Tier 1 definition is important for this discussion as it allows us to explain some of the Peering motivations.

Regional Tier 1 ISP Model. The figure below is the graphical representation of the Tier 1 ISP Peering Presence, a set of routers. There are three essential elements of the Tier 1 ISP Peering presence: Downstream Transit Link(s) to Transit Customers, Peering Interconnections[5], and Backbone Backhaul links to the ISP's other core routers. We will discuss each of these interconnections in turn.

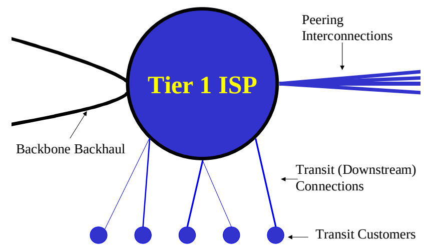

Figure 2 – The Tier 1 ISP Model

Regional Tier 1 ISP Transit Links to Transit Customers. Shown attached lines underneath the ISP core routers, transit customers connect either directly to the core routers, or more commonly, to tributary routers that feed up into the core router. In either case, these Transit Attachments are often referred to as "Downstream Customers."

Regional Tier 1 ISP Backbone Backhaul. On one side of the core router are backbone interconnections (called "backhaul connections") linking a Tier 1 ISP's core routers together. These core routers and core links together represent the core of a Tier 1 ISP transit network, and must be sufficiently large to carry the aggregate[6] traffic back to the core and on to the end-customers.

Regional Tier 1 ISP Regional Peering Interconnections. The interconnections between the Tier 1 ISPs tends to be **full-mesh** across each Interconnect Regions[7]. Each interconnect link needs to have enough capacity to handle the aggregate traffic to and from the other Tier 1 ISPs. The generalized Interconnection Region is shown

[5] Definition: An **Interconnection** is a general term that refers to a connection between two ISPs. An Interconnection can refer to a Peering or Transit relationship.

[6] Peering and customer Transit traffic.

[7] This statement is roughly true; there may be delays before all Tier 1 ISPs migrate into each Interconnect Region.

graphically below.

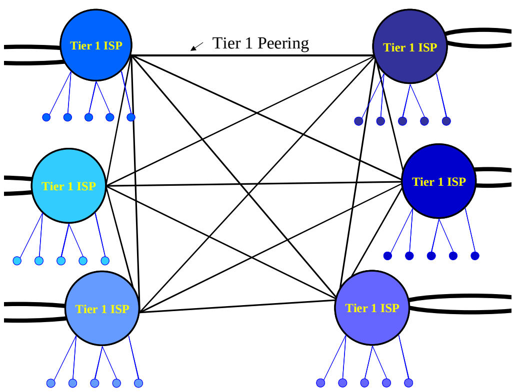

Figure 3 - Generalized Tier 1 Interconnection Model

Regional Tier 1 ISP Peering Motivation. By definition, Tier 1 ISPs don't pay transit fees, so they are only motivated to peer with each other as a way to provide connectivity for their customers.

Regional Tier 1 ISP Relationship with non-Tier 1 ISPs. Since non-Tier 1 ISPs represent current or prospective customers, or customers of other Tier 1 ISPs, there is little incentive to peer with them. Peering policies tend to reflect this inclination – we will discuss this more in the section on Peering Policies.

We can group the Tier 1 ISPs into a cluster as shown below showing this group collectively provides access to the entire Internet region.

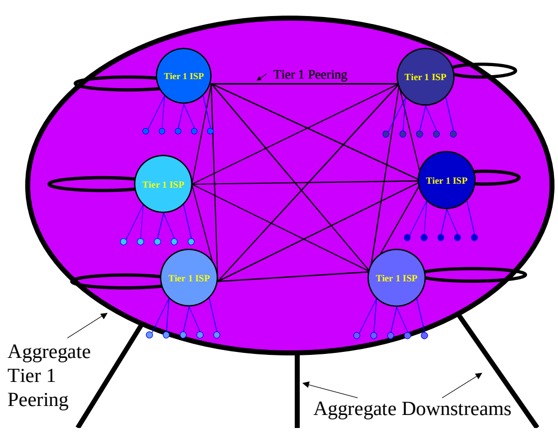

Figure 4 - The Grouping of Tier 1 ISPs in the Peering Ecosystem.

<u>Interconnect</u> Regions. Some Internet Regions are large enough to require multiple "Interconnect Regions" to distribute the load of peering across multiple points.

<u>**Regional** Tier 1 ISPs in the United States</u>

To make this model more concrete, the figures below shows *some* of the United States Tier 1 ISPs and their Interconnection Region Peering.

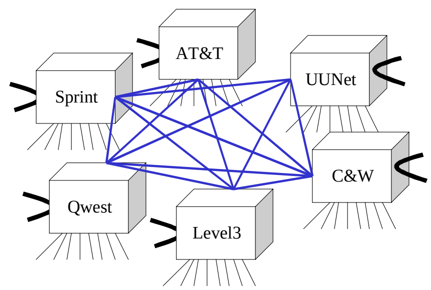

Figure 5 – The U.S. Tier 1 Interconnect Region

These U.S. Tier 1 ISPs generally peer with each other in eight Interconnection Regions across the United States Internet Region, using private peering circuits or cross connect meshes[8] as shown below[9].

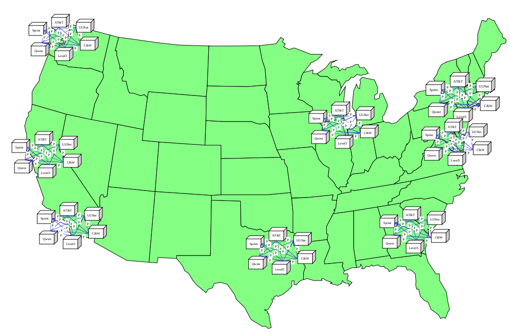

Figure 6 - Tier 1 Interconnection Regions in the U.S.

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[8] A Cross connect is a dedicated fiber run directly between pieces of networking equipment for the purposes of private peering (or for transit/transport purchases).

[9] New York City Area, Washington DC Area, Atlanta, Chicago, Dallas, Seattle, Bay Area, Los Angeles. Source: Cable & Wireless Peering Policy http://www.cw.com/template_05.jsp?ID=us_10_02

Ecosystem Player: The Tier 2 ISP

Roughly speaking, all other (non-Tier 1) ISPs can be broadly categorized as Tier 2 ISPs in the Peering Ecosystem.

Definition: A **Tier 2 ISP** is an Internet Service Provider that purchases (and therefore resells) transit within an Internet Region.

Tier 2 ISP Model. The Tier 2 ISP model is similar to the Tier 1 model but includes one (or more) "Upstream" transit connections as shown graphically below.

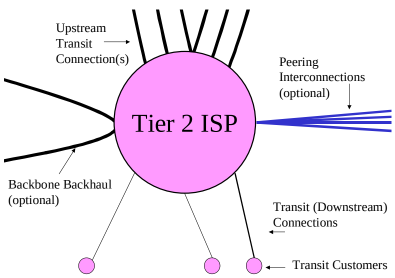

Figure 7 – The Tier 2 ISP model

Tier 2 ISP Transit Links and Customers. Just as with the Tier 1 ISPs, Tier 2 ISPs sell transit to their customer base, using a variety of techniques to target market and differentiate themselves from the Tier 1 ISPs. These market focus techniques include serving underserved or rural areas, focusing on niche markets or serving specific industry sectors.

Tier 2 ISP Backbone Backhaul. A subset of Tier 2 ISPs that operate in multiple markets have backbone links constituting their core backbone network. Other Tier 2 ISPs operate in a single market and do not require any backbone backhaul. As with the Tier 1 ISPs, these links are drawn on the side of the graphic.

Tier 2 ISP Peering Motivations. Tier 2 ISPs have several motivations for Peering:

1. **Reduce Transit Costs**. By directly peering with willing players, traffic is exchanged directly with the peer, and typically is done so settlement-free. This peering traffic therefore reduces the load on and therefore the cost of transit. For non-Tier 1 ISPs, Peering is one easy way to reduce transit fees.
2. **Improved Performance.** Traffic that flows directly between players has lower latency than traffic that first traverses a transit providers network before being handed off to the peer.
3. **Greater Control over Routing**. Some ISPs prefer to have tight control over the path and performance of the traffic[10]. If a poor performing path is preferred by the routing protocols[11], an alternative path can be configured.
4. **Regulatory Reasons.** In the U.S. for example, the consent decree prevents RBOCs from interconnecting their backbone nodes across LATA boundaries. This restriction makes it impossible for the RBOCs to meet the geographic peering requirements of many of the Tier1 ISPs. Therefore, one way for the RBOCs to reduce the traffic exchange costs is to peer openly regionally at least until regulatory relief is granted[12].

Tier 2 ISP Regional Peering Interconnections.

The Tier 2 ISPs generally interconnect with each other across shared Peering fabrics[13] located in an Interconnection Region. These interconnections have historically required smaller capacity interconnects than the Tier 1 ISP Peering interconnects. As a result, public peering (using a shared peering fabric like Ethernet) has been a cost effective method to interconnect with a lot of players and aggregate traffic over a single router port.

Tier 2 ISPs tend to peer only in Interconnect Regions in which they sell services. This creates a diverse population of peering Tier 2 ISPs in each Interconnection Region. There is a set of larger Tier 2 ISPs that peer at many exchange points in many

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10 Some Peers have to carefully control Peering Traffic Exchange Ratios in order to maintain peering relationships.

11 BGP as it is deployed today uses a set of criteria for path selection that doesn't automatically take into account the cost of traffic going along a particular path, nor the performance of the path.

12 Ren Nowlin – SBC, paraphrased.

13 See the "Interconnection Strategies for ISPs" for a comparison of these two interconnection techniques. Available from the author: wbn@equinix.com and on the Equinix web site: http://www.equinix.com..

Interconnect Regions.

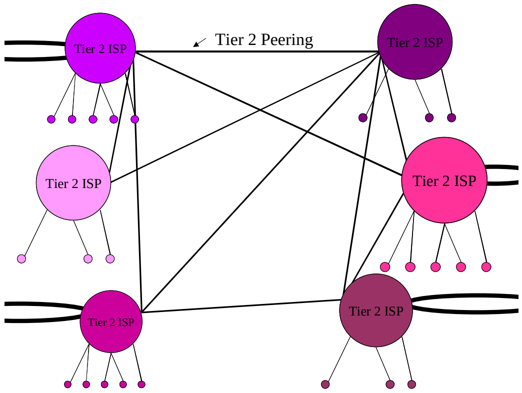


Figure 8 – Generalized Tier 2 Interconnection Model

As a result, **t**he category of Tier 2 ISPs is much broader and more diverse category than that of the Tier 1 ISPs. There is a wider range of peering policies, and the Tier 2 interconnect mesh tends to be more sparse than that of the Tier 1 ISPs. The Tier 2 ISPs after all have an alternative to peering (transit!) For Tier 2 ISPs, Peering is a local routing optimization.

Tier 2 ISPs Relationship with each other. At the same time there is great heterogeneity of this Tier 2 ISP group, there is also great cooperation, driven by aligned interests. Tier 2 ISPs by definition all purchase transit and therefore generally are interested in peering with each other.

Tier 2 ISPs Relationship with Tier 1 ISPs. Tier 1 ISPs are transit providers, as well as competitors for the really big customers. Since the Tier 2 ISPs know that they will be referred to as the "middle man" in competitive situations with the Tier 1 ISPs, they tend not to mention that they purchase transit at all. Hence Sean Donelan's comment that "Everyone is a Tier 1 ISP[14]."

If we model the Tier 2 ISPs as a group, we see an aggregate set of traffic that is exchanged within the group, a set that gets exchanged up through the transit provider(s), and a set of customers being provided with transit services as shown below.

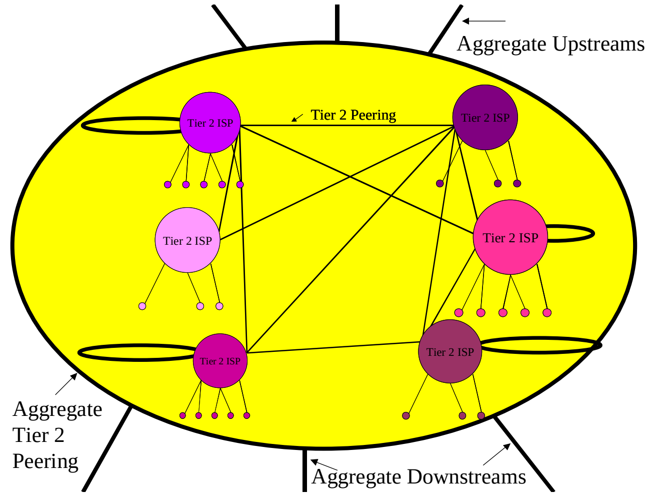


Figure 9 - The Grouping of Tier 2 ISPs in the Peering Ecosystem.

Ecosystem Player: The Content Provider

Definition: **Content Providers** are all companies that operate an Internet Service but do not sell transit within the Peering Ecosystem.

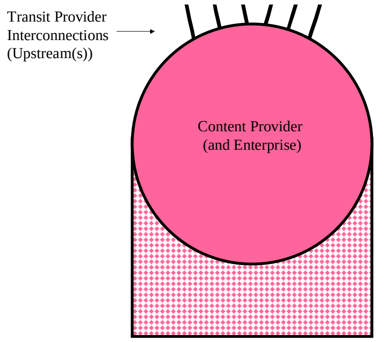
Large-scale content players have always purchased transit to deliver their content to the end-users on the Internet. Therefore, their role and behavior in the Peering Ecosystem is similar to the Tier 2 ISPs with the exceptions that most Content Players:

- do not sell transit[15]
- focus on content creation and do not generally want to operate a network.
- do not have the staff or expertise to even examine the peering option, much less configure routers, or build and manage peering relationships.

Content Provider Model. The Content Provider model is a simple model. On the bottom of the model is content connected to the Internet via one or more transit (upstream) connections.

[14] The "Tier 1" label has varied in meaning from "A Top Shelf ISP", to a "Global Player", to a "large national player" to "whatever we decide Tier 1 means!" Since definitions shape thought and meaningful consistent dialogue, it is a necessary prerequisite to consistently use terms and definitions. This in part has led to some confusion over the Peering Ecosystem players.

[15] This is significant because ISPs often will not peer with an entity they consider a potential transit customer. By not being in the transit sales business, there is no such disincentive to peer.



Content Players include companies like Amazon.com, eBay, and Staples.com. Enterprises include Avon.com, Hertz, Agilent, and General Electric.

Content Providers Relationship with Each Other. Generally speaking, there is no relationship between the content providers. They either compete with each other (so don't communicate) or they have no interest in each other (so don't communicate). There are two exceptions: some e-mail providers exchange e-mail freely and directly, and some content providers interact using extranets in supply chain integration forms. None of these however has been directly seen to influence the peering ecosystem.

Content Providers Relationship with the other Players. The Content Providers generally see the ISPs as vendors, and select vendors along widely varying parameters, increasingly looking at the ISPs peering infrastructure[16].

The Peering Ecosystem

Pulling these individual player models together into a Regional Peering Ecosystem leads to a generalized picture below.

[16] Ren Nowlin (SBC) described the conflicts a Peering Coordinator faces. On one hand, there are some peering relationships that can not be divulged due to non-disclosure agreements. One the other hand, the prospective customers genuinely care about the degree of interconnection and therefore connectedness of the ISP.

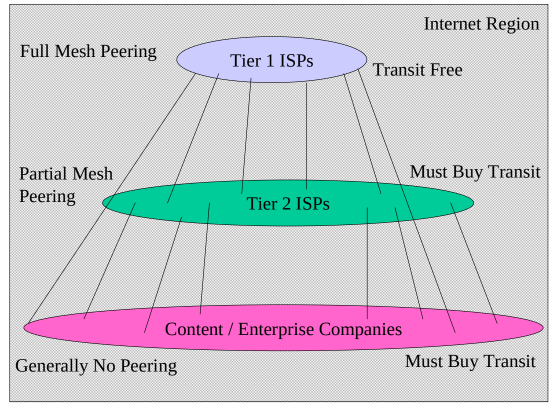


Figure 10 - Generalized Peering Ecosystem, consisting of Tier 1 ISPs, Tier 2 ISPs, and Content/Enterprise Players.

Grouping these three models of Ecosystem participants (Tier 1 ISPs, Tier2 ISPs, Content Providers) we see the relative roles in the hierarchy of traffic exchange as shown below.

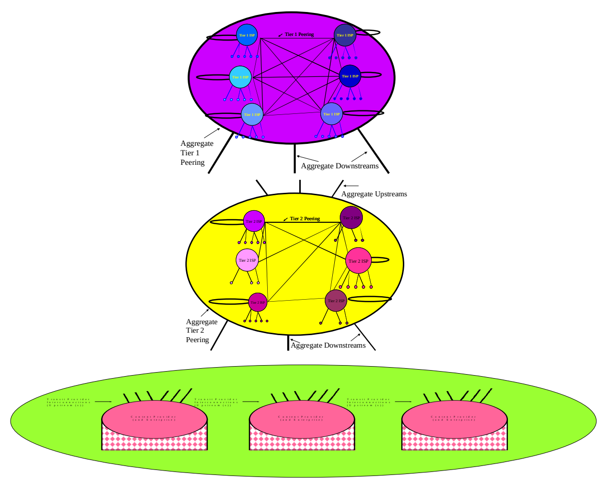


Figure 11 - Tier 1 ISPs, Tier 2 ISPs, and Content Providers in the Peering Ecosystem

Key aspects of the International Peering Ecosystem. One key characteristic of an Internet Region is the degree to which traffic stays within an Internet Region and the degree to which traffic is destined to / originating from other Internet Regions. Another key dynamic is that an ISP that establishes a presence in another Peering Ecosystem, regardless of their position in the origin Peering Ecosystem, tends to be relegated to the Tier 2 ISP position within the foreign Ecosystem. These topics are explored more in the companion white paper "The International Asia

Pacific Peering Ecosystem." For the purposes of this paper, assume that foreign ISPs are in same category as the Tier 2 ISPs.

Peering Inclinations and Peering Policies

We will now generalize the Peering Behavior in the Peering Ecosystem using the terms Peering Inclination and Peering Policy[17].

Definition: A **Peering Inclination** is a predisposition towards or against peering as demonstrated by Peering behavior in a Peering Ecosystem.

Definition: A **Peering Policy** is an articulation of the Peering Inclination; it documents and defines the prerequisites to peering.

There are three general classes of Peering Inclinations seen in the Peering Ecosystem:

1. **Open** means that the entity will generally agree to peer with anyone in any single location with no prerequisites.
2. **Selective** means that the entity will generally peer but there are some prerequisites (such as meeting in multiple Interconnect Regions, with a minimum traffic volume, not to exceed a certain In/Out traffic ratio[18], etc). The Peering Policy documents these prerequisites, which, once met, generally lead to peering.
3. **Restrictive** means that the entity is generally not open to new peering. The Peering Policy documents extremely difficult to meet peering prerequisites, with the unstated purpose of denying peering[19].
4. **No Peering** means that there is no intention for the entity to ever peer. Content Providers who prefer Internet Service solely through transit agreements are the largest set of players within this category.

Examples of Peering Inclinations and Peering Policies. To apply these definitions to the Internet Peering Ecosystem, we see in the field that most Tier2 ISPs and peering Content Providers have an Open Peering Inclination, and may or may not even have an articulated Peering Policy. Yahoo! for example has a one word Peering Policy: "Yes![20]"

Some Tier 2 ISPs, particularly those deployed across many markets and Interconnection Regions, have a Selective Peering Inclination intended to manage traffic effectively and perhaps to ensure that they are getting equal value from a peering relationship. They may design a peering policy to make sure that the peer adheres to engineering criteria (adequate backbone scale, multiple interconnection regions, etc.) or operations criteria (a 24/7 NOC and updated contact and pager information, etc.). There are a wide range of Selective Peering Policies[21] reflecting a Selective Peering Inclination.

Tier 1 ISPs generally have a Restrictive Peering Inclination articulated in their Restrictive Peering Policies. Since they are only required to peer to ensure connectivity for their customers, and they forego revenue by peering[22], there is not much incentive to accept additional peers[23]. The Sprint

[17] Generalized from the authors four years of research with the Peering Coordinator Community.

[18] Eyeball networks don't want to carry traffic across the world for free… See both sides of this argument at: http://www.cctec.com/maillists/nanog/historical/9808/msg00138.html

[19] This is difficult to prove but it is nonetheless a view widely held in the Peering Coordinator community. Note that there are business-rational motivations for this stance. The "Art of Peering" (freely available from the author) white paper documents some tactics and business arrangements that have led to peering with Tier 1 ISPs. Some Tier 1 ISP Peering coordinators made the case that "What is out of reach for some is reasonable and reachable for another." This is a valid criticism of this categorization, but there are many stories from the field supporting this categorization.

[20] Many conversations with Brokaw Price (Yahoo! Peering Coordinator).

[21] See the SBC Peering Policy at http://www.sbcbackbone.net/peering and AOL's Selective Peering Policy at http://www.atdn.net/settlement_free_int.shtml for good examples of well articulated Selective Peering Policies. Other Peering Policies can be viewed at http://vision.opentransit.net/docs/peering_policy/peering_policy.html , http://global.mci.com/uunet/peering/

[22] A denied peer may become a direct or indirect customer.

[23] However, recently, there has been greater government scrutiny over Tier 1 Peering Policies. The threat of government regulation is resulting in the Tier 1 ISPs applying their Peering Policies with consistency.

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Peering Policy is not available on the web but was cited to include an OC-48 capacity to Europe and an OC-12 to Asia[24].

Now that we have generalized the Peering Ecosystem today, and touched on some of the Peering Behaviors of the players, we will move on to some recent significant changes in the U.S. Peering Ecosystem.

In order to show the evolution of the Peering Ecosystem, we will use the generalized representation below to show the peering within these groups and transit between these groups of players.

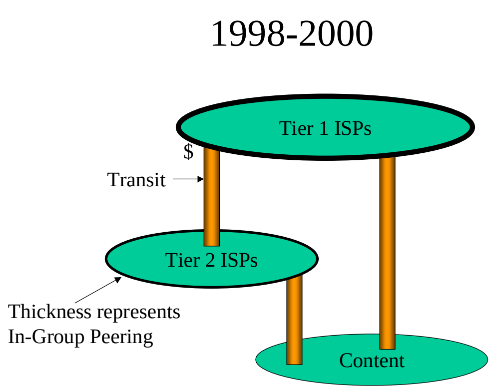


Figure 12 - Generalized Representation of the Regional Peering Ecosystem

Evolution of the U.S. Peering Ecosystem

During the last few years, five significant events contributed to a dramatic change on the U.S. Peering Ecosystem. In particular:

1. **The 1999/2000 Economic Collapse of the Telecom Sector** has led to the bankruptcy of several major Tier 1 ISPs[25], many Tier 2 ISPs[26], as well as a long list of content companies. This has generally caused Internet players to ensure that their business model and practices are financially sound. (The author notes that this has led to an increased interest in the Economics of Peering White Papers[27].)
2. **The Growth of the Used Networking Equipment Market** (selling equipment reaped from the bankrupt companies) allows ISPs to reduce the capital cost of Peering lowering the breakeven point for peering[28]. Michel Py points to a used Cisco 12000 series router loaded available on eBay for $25,000 as an example.
3. **The Upstream Provider for the Cable Companies (@Home) Went Bankrupt.**. This forced each North American cable company to negotiate emergency multi-Gigabit per second transit connections with several of the Tier 1 ISPs.
4. **Peer-to-Peer File Sharing Networks grow exponentially in popularity and Traffic between Access Network Providers.** Napster (and later) Kazaa, Morpheus, etc. Peer-2-Peer file sharing users around the world have shifted from sharing 4MB[29] music files to sharing 700MB movies on the Internet. These applications relentlessly consume all of the end user's available Internet bandwidth attempting to download chunks of the files from any sources on-line at the time. It may take weeks, but eventually, the music files or video files are downloaded. Since many Kazaa users leave their PCs on 24/7, the access networks are filling up 24/7, resulting in significant costs to the access-heavy ISPs (Cable Companies and DSL Providers in particular).

24 Source: Several NANOG conversations. It is interesting that requirements for U.S. peering include a global footprint. Others have commented that what is restrictive to one ISP, is reachable to another ISP.

25 WorldCom, Genuity, Global Crossing are among a few of the Tier 1 ISPs that have gone bankrupt.

26 Covad, Broadwing, Williams, etc.

27 Also see Bill Woodcock's papers on Peering at http://www.pch.net/resources/papers/

28 See "Do ATM-based Internet Exchanges Make Sense Anymore" to see how the used equipment market affects the Peering Breakeven Analysis. Capital expense is a major concern for many Peers: "Nobody buys new anymore!".

29 Source: Michel Py.

5. **Transit Rates Drop and Transport Rates Drop.** At the same time that transit prices plummeted, the transport prices into exchange points dropped. The revenue the ISPs can expect to extract from their deployed equipment has diminished. The cost for customers to get transport into an exchange point for peering has dropped dramatically. This further motivates companies to peer with each other.

   This has led some to peer as a risk mitigation strategy; peer to mitigate the risk of transit prices rising, buy transit to mitigate rise transport and peering costs[30].

As a result of these forces we are seeing three major shifts of the Peering Ecosystem.

Evolution #1: The Cable Companies are Peering

Most Cable Companies were forced to replace the Internet Service that @Home once provided. They had 30 days to establish multi-gigabit-per-second transit relationships with Tier 1 ISPs! After some initial analysis, they found that about 40% of this Cable Company traffic is Peer2Peer traffic[31], and ultimately destined for other cable companies[32].

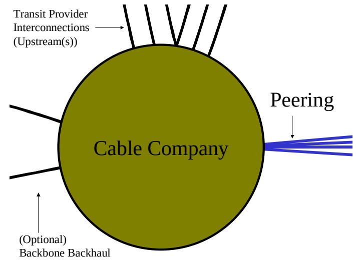


Figure 13 - Cable Company Model

As a result of this analysis and as a routing optimization, the cable companies migrated into exchange points to peer with each other as shown graphically below.

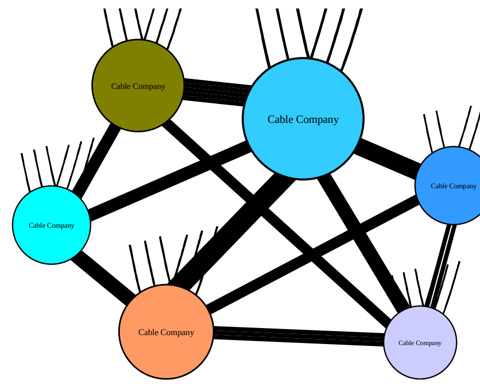


Figure 14 - Cable companies Peer with each other with huge traffic volumes

The Peering Cable Companies and their Peer2Peer traffic represent a significant change in the Peering Ecosystem because:

The volume of traffic being directly exchanged in peering relationship is in the Gigabits per second[33], second only to the Tier 1 ISPs traffic exchange volume estimates[34]. The aggregate number of North American Internet Cable Subscribers is about 12 Million as shown in the

30 Eric Bell – Time Warner Telecom white paper walk through July 2003.

31 Joe Klein (Adelphia) demonstrated this at the Chicago Gigabit Peering Forum in 2002 in his talk "Peer-to-Peer Traffic Growth and its Impact on Peering". This statistics was validated (roughly) with the other cable companies, and has been seen as high as 75% by a large scale overseas ISP.

32 Note that this traffic is ultimately destined to any Access Heavy ISP with end users running Peer2Peer Applications.

33 At the time Adelphia estimated 4 gigabit per second of traffic went to their upstream ISPs. If 40% of that is peering traffic to the other Cable Companies, we have 1.6Gbps of peering traffic! Source: Conversations with Joe Klein, North American Cable Company Peering Conference Call 4/16/2002.

34 Tier 1 ISPs are peering with each other in each Interconnect Region using multiple OC-12s (n*622Mbps) and OC-48s (2.5Gbps). Source: Anonymous Tier 1 Operator, June 1, 2003.

table below[35], each potentially with multiple PCs.

Cable Modem Subscribers

MSO	Country	YE02	Change in 02
Comcast	USA	3,620,300	1,199,100
Time Warner	USA	2,613,000	1,027,000
Cox	USA	1,407,900	524,400
Charter	USA	1,180,000	572,300
CableVision	USA	770,100	263,500
Shaw (Big Pipe)	Canada	750,000 ?	
Rogers	Canada	650,000 ?	
Adelphia	USA	610,000	305,900
Bright House	USA	490,000	159,000
Mediacom	USA	191,000	76,000
RCN	USA	160,400	49,800
Insight	USA	144,800	56,700
Cable One	USA	78,100	45,200
Total		12,665,600	4,278,900

Cable companies generally[36] have an Open Peering Policy. The cable companies are not generally interested in selling transit to ISPs or Content Providers, and they generally work in non-overlapping regions so they don't compete against each other. As a result, there is no economic disincentive for the cable companies to peer with each other, the Tier 2 ISPs, or the Content Providers.

AOL, the 800 Pound Gorilla. Worth noting is that by far the largest traffic exchanger among the cable companies is AOL. In each Interconnection Region where AOL peers, the other cable companies tend to establish a peering presence[37]. This gravitational pull of the cable companies further accelerates the number of peers pulling into exchange points which accelerates the volume of traffic migrating from transit relationships to peering relationships in the Ecosystem.

The Kazaa Effect. The typical ISP sinusoidal demand curve is replaced with a flatter demand curve with Peer-2-Peer file sharing software on the Cable company networks. Peering with each other allows the cable companies to offload this traffic from their transit connections (which they pay for) onto free peering interconnections.

Another interesting effect, originally noted by Eric Troyer (CableVision)[38] shows that empirically Peer-2-Peer traffic volume grows when the cable companies peer with each other. Peering causes Kazaa to prefer to fetch files across the recently peered network path. The Kazaa selection protocol uses latency to determine which Kazaa file sharer is "more local", and automatically selects that file sharer. The result is that when Cable Companies (or any access heavy companies for that matter) peer with each other, they can expect an immediate 20% growth in Kazaa-based peering traffic volume.

Sidebar: A related Kazaa story[39] involves a grandmother in Australia that had her grandkids over during the holidays. In Australia, end users are charged for Internet access on a per-Megabytes-downloaded basis. When the grandkids wanted to hear the latest Britney Spears song on grandma's computer, they installed Kazaa and downloaded the song. By default Kazaa shares all files it downloads, and soon grandma's computer became the preferred source for the Britney Spears songs! Grandma's bill from Telstra was several hundred dollars as opposed to the usual $25 she pays per month! In the U.S. where broadband is typically a flat fee there is no such disincentive to use all the bandwidth available.

Other Broadband Players. One question that often comes up when describing the Peering Ecosystem is: Why do you pick out the Cable Companies and not the RBOCs and other DSL providers? The RBOCs and many of the DSL Providers sell transit to other companies in the Peering Ecosystem, and therefore may have a disincentive to peer with them. Aside from providing large amount of access bandwidth, they generally have a Selective Peering Inclination, and are not changing the Peering Ecosystem as dramatically as the Open Peering Cable Companies.

35 Source: I$P HO$TING ReportMay 2003, Volume VII, Number 5, Page 8, Article "Dialup Bakeoff - Is it really so bad at EarthLink? Or so good at United?" citing The Bridge & Leichtman Research. Shaw and Rogers estimates are from the author conversations with these companies.

36 A few of the Cable Companies are refining their peering policies. Cox for example has articulated a rather Selective Peering Policy: http://www.cox.com/INETPeering/ and AOL/Roadrunner has documented a selective peering policy at http://www.atdn.net/ .

37 This is proving to be an example of a strong Peering gravitational pull. See http://www.atdn.net for Peering Policies and Interconnection Regions for the AOL Transit Data Network.

38 Shared with the audience at the Los Angeles Gigabit Peering Forum, Feb 13, 2003.

39 Read about this story on the web at: http://www.smh.com.au/articles/2003/06/16/1055615717838.html

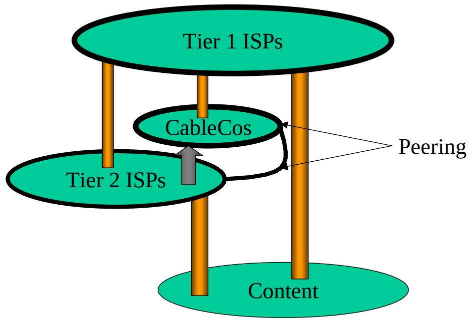


Figure 15 - Evolution #1 - Cable Company Peering.

Evolution #2: Network Savvy Large Scale Content Companies are Peering

A select group of network savvy Content Providers are emerging as large volume peers. Most of them peer bi-coastally, some peer more broadly across the country. The dominant motivations to peer are similar to the Tier 2 ISP motivations to Peer:

1. **To Reduce Transit Costs**. Any traffic that can be sent directly to the Access-Heavy (also called Eyeball) Networks is traffic that doesn't have to go over the metered transit connection. Likewise, E-Mail Service Providers such as MSN HotMail and Yahoo! can exchange E-Mail without incurring any transit charges[40].
2. **To Improve the end-user experience**. Yahoo! for example applies considerable resources monitoring (in real-time!) the application performance along the various Internet paths to identify congestion points and to alter the network path to improve the end-user experience.
3. **They need a move to a new collocation area anyway**. Many collocation and datacenters have gone out of business. Given the choice, some content players prefer a location where they can peer as well as buy transit[41].

The model for the Network Savvy Large Scale Content Provider is shown in the figure below.

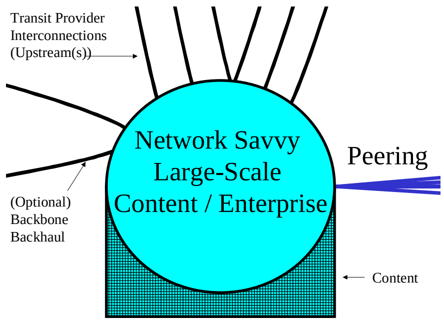


Figure 16 - Network Savvy Large-Scale Content player Model

These players still purchase transit (generally from the Tier1 ISPs), but supplement this by peering openly with anyone and everyone. Examples of these Large Scale Content Players are Yahoo!, Google, Microsoft, Amazon, Walmart.com, Apple, Electronic Arts, and Sony Online.

This represents a significant change to the Peering Ecosystem because:

- **The volume of traffic** now being peered is huge (10's of Gigabits per second), and represents traffic that previously was sent through and only available from the Tier 1 ISPs
- **The Content Providers have Open Peering Policies**, and even actively promote peering with them[42].
- **These leading players are paving the way** for other Large Scale Content Companies and Enterprise companies to examine Peering as a cost reducing /

40 Note that there are costs associated with peering here including transport fees, colo fees, port fees, etc.

41 Cook Report: Nov/Dec 2002 Issue. Several people reached the same conclusion in this peering study.

42 Brokaw Price (Yahoo!) actively participates in NANOG Peering BOFs and industry Peering Forums such as the Gigabit Peering Forums.

performance improving strategy.

We can see an example of this effect in the graphic below.

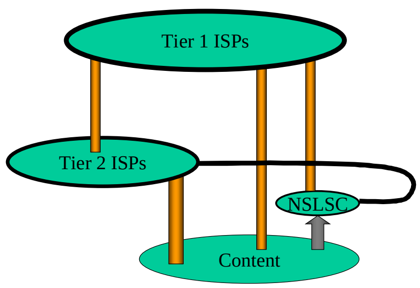


Figure 17 – Content Company Peering Effect

Evolution #3: Cable Companies Peer Directly with Content Companies

The peering of the Network Savvy Large Scale Content Companies with the Cable Companies puts the most popular content on the Internet on the same network as the largest set of subscribed broadband eyeballs. The end result is a major disruption in the Internet Ecosystem, motivated by network performance between the customers of both and significant cost savings from peering!

The Network Savvy Large Scale Content Companies and the Cable Companies can be shown as a substrate above the other Content Companies, demonstrating different behavior (peering, operating networks, detailed network flow analysis, etc.). The degree to which traffic is exchanged ***below*** the Tier 1 clouds, is the degree to which the traffic and revenue is being pulled away from the Tier 1 players as shown in the graphic below.

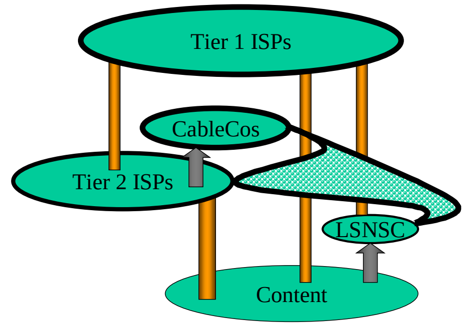


Figure 18 – Evolution #3 : Cable Companies peer with Large Scale Network Savvy Content Providers

This represents a significant dynamic shift in the Peering Ecosystem since the Tier 1 ISPs are being cut out of a high volume traffic exchange loop. The Tier 1 ISP significance has decreased as can be measured in the growth of the Tier 1 ISP traffic. A hierarchy has evolved to a mesh with the Tier 1 transit providers required only for the route of last resort. Traffic destined to locations too far away or too expensive to reach will ultimately need the services of an international transit provider. Other than that the Tier 1 transit providers have lost their grip on the U.S. Internet Peering Ecosystem.

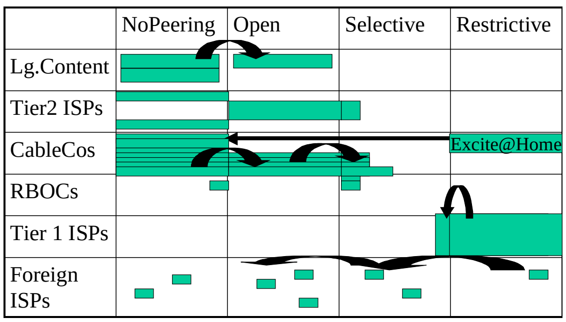
Summary

This paper introduced some terms including the *Internet Region* and *Interconnect Region* as an environment in which the Internet Peering Ecosystem exists. Tier 1 ISPs are at the top of the Peering Ecosystem providing transit services to the rest of the Internet Region. Tier 2 ISPs are distinct from the Tier 1 ISPs in that they must purchase transit from one or more ISPs to reach the Regional Internet. The Content Providers have traditionally purchased transit.

We are seeing some interesting and dramatic changes in the Peering Ecosystem as the Network Savvy Large-Scale Content Companies and the Cable Companies are getting into Peering with large volume peering sessions.

We introduced four categories of Peering Policies that reflect Peering Inclinations. Open Peers will peer with anyone anywhere. Selective Peers will peer with some prerequisites, detailed in a Peering Policy. Restrictive Peers generally do not peer. Content Providers may have a No Peering inclination, preferring solely to buy transit. Recent shifts in the Peering Inclinations can be summarized in the graph below:

2003 Peering Ecosystem Evolving



Here we see some of the Network Savvy Large Scale Content Providers shifting from a NoPeering Peering Inclination to an Open Peering Inclination in order to reduce Transit Fees and better control traffic and the end user experience. Tier 2 ISPs for the most part remain Open Peers or NoPeering. Some Tier 2 ISPs, particularly those that expand beyond a few Interconnect Regions have a more Selective Peering Policy. The RBOCs remain split into two categories: Selective Peers and those who choose NoPeering because they prefer to only buy transit. The Tier 1 ISPs are highly Selective or Restrictive in their Peering Inclination. The Foreign ISPs follow a pattern: first applying their perceived market strength in the country, and then realizing that they don't have market power, are reduced to peering Openly with the Tier 2 ISPs.

Follow On Research Topics

We have laid out the Ecosystem and the players, their behavior and motivations in a way that leads nicely into a Simulation or Modeling system. Can we further refine the models to identify prospective peering candidates and why they should want to peer with each other? Can we pull in data (such as the Internet Exchange Point participant's lists[43]) to populate an Ecosystem model with currently peering Tier 2 ISPs? Comparing the network topology maps for these ISPs, can we infer their role in the Peering Ecosystem?

It would be interesting to map out the Cable Company territories across the Interconnect Regions and see if they are peering in the local Exchange Point. Do they have Peering Policies on their web sites, and are they indeed evolving from Open to Selective? Will AOL, the largest of the Cable Companies, become a Tier 1 ISP, and will their Peering Policy change when that happens[44]? Is AOL incented then to de-peer its Cable Company peers?

Can we quantify the effect of the Cable Companies peering with the Content companies? Is there evidence of the reduction of load on the Tier 1 ISP networks, or at least a slowing of growth as the traffic prefers the more direct path? Can we more precisely define and quantify the notion of *value* to the Peering Ecosystem? Is the model of eyeball networks peering scalable or will a hierarchy develop?

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The following people have greatly contributed to and influenced the development of this white paper by providing insight, advice, and/or allowing me to walk them through the early, very rough, drafts of this document, providing critical feedback and suggestions: Ren Nowlin (SBC), Christina Chu (NTT/Verio), Joe Zhu (China Telecom USA), Joe Provo (RCN), Terry Manderson (APNIC–formerly from Optus), Dave McGaugh (PCCW/BTN), Philip Smith (Cisco), Keith Mitchell (ExchangePoint), Fumio Terashima (Japan Telecom America), Geoff Huston (Telstra), Patrick Gilmore (Akamai), Jonathan Chou (Equinix), Phil Grasso (NTT), James Spenceley (Comindico), Chris Chaudry (Comindico), Gavin Tweedie (WAIX), Lloyd Taylor (Keynote Systems), Tatsuo Sato (KDDI America), Sam Habash (SuperNews), Joe McGuckin (Via.Net), Mike Leber (Hurricane Electric), Morgan Snyder (Equinix), Eric Bell (Time Warner Telecom), Peter Cohen (Telia), Dan Golding (AOL), Alexander Tudor and Lance Tatman (Agilent Labs), Eric Aupperle (President Emeritus, Merit Network), Dave Meyer (Sprint, Cisco), Michel Py, Keith Young, Nenad Trifunovic

43 See http://www.ep.net for a list of Regional Interconnect Points (Exchange Points) which typically have their customers listed.

44 See the presentation from the GPF VII in Ashburn, VA: "The Road to Tier 1 Nirvana", Vikas Mehta, AOL. https://ecc.equinix.com/peering/agendas.htm

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About the Author

Mr. Norton's title is Co-Founder and Chief Technical Liaison for Equinix. In his current role, Mr. Norton focuses on research on large-scale interconnection and peering research, and in particular scaling Internet operations using optical networking. He has published and presented his research white papers ("Interconnections Strategies for ISPs", "Internet Service Providers and Peering", "A Business Case for Peering", "The Art of Peering: The Peering Playbook", "The Peering Simulation Game", "Do ATM-based Internet Exchange Points Make Sense Anymore?") in a variety of international operations and research forums.

From October 1987 to September 1998, Mr. Norton served in a variety of staff and managerial roles at Merit Network, Inc., including directing national and international network research and operations activities, and chairing the North American Network Operators Group (NANOG) Internet industry forum. Mr. Norton received a B.A. in computer Science and an M.B.A. from the Michigan Business School, and has been an active member of the Internet Engineering Task Force for the past 15 years.

About the White Paper Series - Network Operations Documents (NODs)

The Network Operations Documents (NODs) identify a critical but undocumented area of Internet Operations. We research that area with the Operations Community to document the area definitions, motivations, strategies, etc. The initial drafts are reviewed in "walk throughs", where Internet Operators provide their views, their data points, their criticisms, and their experience. These are credited in the Acknowledgements section and footnoted where appropriate for the next walk throughs. After enough walk throughs, the responses tend to migrate from constructive feedback to nods of acceptance, at which time a draft to is made available to the broader Internet Operations community. The papers are never "done" but rather are considered living documents, evolving with input from the community, hopefully reflecting the current practices in the previously undocumented area. Here are the NODs available from the author:

1. **Interconnection Strategies for ISPs** documents two dominant methods ISPs use to interconnect their networks. Over 200 ISPs helped create this white paper to identify when Internet Exchange Points make sense and the Direct Circuit interconnect method makes sense. Financial Models included in the paper quantify the tradeoffs between these two methods. All relevant data points are footnoted as to source.
2. **Internet Service Providers and Peering** answers the questions: "What is Peering and Transit? What are the motivations for Peering? What is the ISP Peering Coordinators Process for obtaining peering? What are criteria for IX selection?"
3. **A Business Case for Peering** builds upon the previous white papers but focuses on the questions important to the Chief Financial Officer: "When does Peering make sense from a financial standpoint? When do all the costs of Peering get completely offset by the cost savings?"
4. **The Art of Peering: The Peering Playbook** builds on the previous white papers by asking the Peering Coordinators to share the "Tricks of the Trade", methods of getting peering where otherwise they might not be able to get peering. These 20 tactics range from the straight forward to the obscure, from the clever to the borderline unethical. Nonetheless, Peering Coordinators might be interested in field-proven effective ways of obtaining peering in this highly controversial white paper.
5. **The Peering Simulation Game** finishes up my half day Peering Tutorial by engaging the audience in the role of the Peering Coordinator. Each ISP in turn rolls the dice, expands their network, collects revenue for each square of customer traffic, and pays transit fees to their upstream ISP. They quickly learn that if they peer with each other, the costs of traffic exchange

are much less, but they need to negotiate how to cover the costs of the interconnect. ISP Peering coordinators have commented on how close the peering simulation game is to reality in terms of the dialog that takes place.

6. **Do ATM-based Internet Exchange Points Make Sense Anymore?** Applies the "Business Case for Peering" financial models to ATM and Ethernet-based IXes using current market prices for transit, transport, and IX Peering Costs.

7. **The Evolution of the U.S. Peering Ecosystem**, introduces and focuses on several fundamental changes in the Peering Ecosystem spurred by several events following the telecom collapse of 1999/2000.

8. **The Art of Peering: The IX Playbook** follows the same tact as The Peering Playbook; we first introduce the framework theory of how and why IXes are valuable from an economic perspective. We then enumerate about a dozen tactics IXes use to get over the "Start Up Hump", to build a strong critical mass of participants, and finally, defense tactics to maintain that population. (To be released at a future date.)

9. **The Asia Pacific Peering Ecosystem** follows the "Evolution of the U.S. Peering Ecosystem" by exploring the Asia Internet environment from a peering perspective. What did Peering Coordinators find as counter-intuitive? What are the challenges peering in Tokyo, Hong Kong, Sydney and Singapore? This paper provides insights into these and related questions. (To be released at a future date.)

Appendix A – A Simply Modeled Peering Ecosystem

In this section we detail a minimalist peering simulations model, using only the needed characteristics necessary to demonstrate the findings in this paper. Where greater complexity exists, we will footnote it and move on.

To do: We need consistent and reasonable labels and subscripts. Put into spreadsheet model and play with it.

Start with the Eyeballs. All **ISPs** are assumed to have customers with a sinusoidal traffic pattern **s.** Customer traffic is assumed to be uniformly distributed across each ISPs downstream connections with an identifiable **P** Mbps of peak traffic volume from direct attached customers[45] that is exchanged in transit relationships *evenly* across **U** upstream ISPs

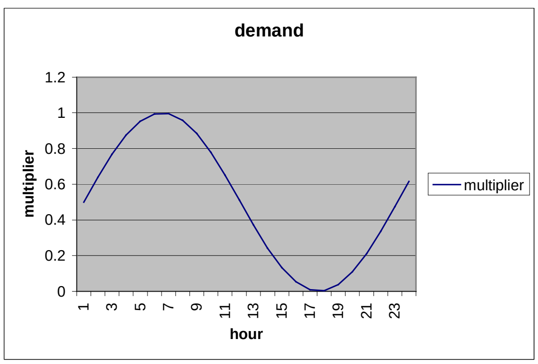
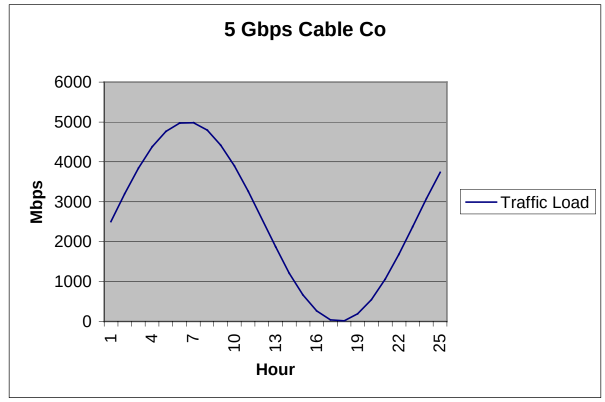
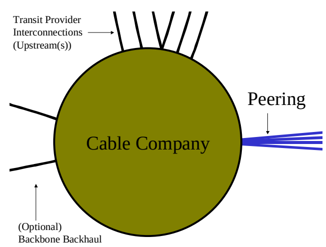


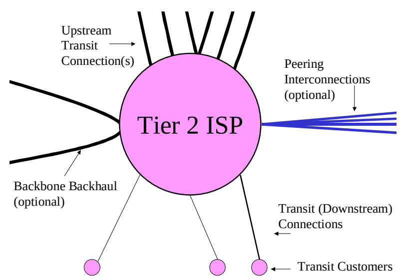
Figure 19 – End-User Traffic Demand Curve=(SIN((A2/10)*(68/24))+1)/2

From the model so far we can see a cable company with 5Gbps peak traffic has a pattern roughly like the graph below:



A percentage of this traffic **X%** is siphoned off through peering relationships. Later we can allocate these percentages differently across the other players. There are no Peering Costs[46]. We ignore the backhaul component of the model[47].





Tier 1 ISPs have no upstream ISPs so 100%[48] of its traffic goes to peering connections.

[45] Simplifying assumption that we assume a homogeneous set of customers and players within a class.

[46] Simplifying assumption.

[47] Simplifying assumption that all traffic is handled in one interconnect region with one router.

[48] Ignoring international (inter-Ecosystem Traffic) to make math easier.

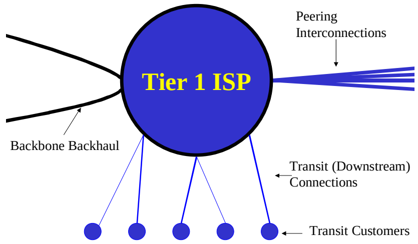
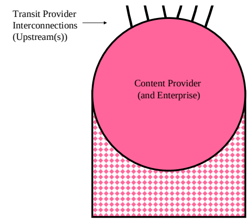


Figure 20 - Tier 1 ISPs have no upstreams to 100% goes to peering relationships

$$\mathrm{Revenue\$} = P * T_{DownStream}$$
$$PeeringMbps = P * X\%$$
$$TransitCost = (P * (1 - X\%)) * T_{Upstream}$$
$$\mathrm{Profit} = \mathrm{Revenue} - TransitCost$$

Each of ***C*** **Content Providers** each have ***U*** upstream connections to spread its **u** Mbps of aggregate traffic *evenly*[49] across using a roughly sinusoidal traffic patter ***s***[50]. Transit providers each charge ***T***[51] dollars per Mbps[52]. Each content provider makes money as a function **b** of its traffic volume[53]. All circuits for peering and transit are assumed to be already in place[54], of unlimited capacity[55] and free[56].



$$PerUpstreamCPTraffic = ((C * u) / U) * s$$
$$PerUpstream\mathrm{Revenue} = PerUpstreamCPTraffic * T$$
$$PerCPTransitCost = T * u$$
$$PerCP\mathrm{Revenue} = u * b$$

Network and Traffic: The notion of a Network, with its own source and destination profile is a logical expansion for this model, and probably necessary for modeling the Foreign competitor effects. Each Access player should have a set of maybe 10 <DestinationNetwork,Volume> tuples to drive traffic to its Upstream Object. This complicates the models since we would need to have routing table lookups to allocate traffic to a particular transit provider and peer. The other assumption would be to spread traffic evenly across peers as a % of transit traffic.

The End Goal of this section is to describe a simulation environment (maybe a Peering Simulation Game 2) that allows players to view the various effects described in the paper.

---

49 Simplifying assumption for first pass development of a peering model.

50 Internet traffic generally follows a sinusoidal pattern with peaks and valley based on the time zones of the end-users. We create a sin wave curve between .1 and .9 as a multiplier, then add some jitter with a randomizing function, and multiply that times the expected Peak BW.

51 Simplifying assumption that all transit providers charge the same transit fees.

52 Simplifying assumption that the average Mbps measure is used for metering, whereas in reality the 95th percentile is more often used.

53 Simplifynig assumption that the content player makes money as a simple multiplicative function of volume. We are trying to capture the click-through, subscription-based, etc. revenue models so we can capture the profit incentive for the content players, and the impact of peering on that profit function.

54 Simplifying assumption to ignore the cost, timing, and deployment complexities such as schedule slips, landlord delays, equipment delays or DOA failures, etc. of building out a network.

55 Ignoring the multilink load sharing and planning aspects.

56 Simplifying assumption that the cost of circuits is not an issue and not taken into account.

Appendix B – Peering Challenges for Foreign ISPs entering new Ecosystem

The following are challenges with Peering in general, but are made worse by having cultural and language oceans between the players:

1. Does the ISP know anyone in the target Internet Region?
2. Why go into the target Internet Region given the lack of knowledge and risks involved.
3. Face-to-Face meetings, the most effective peering contact method, is also now very expensive.
4. Language differences can make the interactions, particularly over voice and e-mail, very difficult.
5. Cultural differences including hidden assumptions make peering in a new environment fraught with unpredictability.
6. Time Zone differences make timing conference calls a bit more difficult, particularly across date lines, and across more than a few hours.
7. Hidden costs (local loop fees and adjustments) may not be avoidable.
8. Each Internet Region seems to have their own quirks, some with government intervention on peering issues (like Australia and Singapore), and others completely deregulated (like the U.S. and Japan).