A Business Case for Peering in 2004

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Abstract

Transit prices have fallen dramatically since 2001 when the first Business Case for Peering white paper was written. Does Peering still financially make sense, given that the alternative to peering is to buy increasingly inexpensive transit from an Internet Service Provider? How does one financially optimize a blend of peering and transit in 2004? What are the optimal combinations of transit commits and peering build outs when the primary goal is to minimize the costs of exchanging traffic?

This paper seeks to answer these questions, using current (2004) market prices for transit, transport, IX fees, and peering equipment costs. We present cost models for peering at 100 Megabit-per-second, 1000 Megabit-per-second and 10 Gigabit-per second levels to identify where peering is less expensive than simply purchasing transit.

In this update, we also introduce the notion of "Optimal Transit". Optimal Transit optimizes the transit cost model by committing early to a higher level of transit in order to reduce the effective unit cost of transit. Further, we take into account that ISPs can generally only peer a percentage of their traffic. Therefore, the transit commit volume is often much higher than the peering traffic volume, and the corresponding transit prices are accordingly lower.

We take all of these factors into account in comparing Peering against Transit in 2004.

Introduction

The Internet is a decentralized network of networks. An Internet Service Provider (ISP), as a seller of access to the Internet, must itself get connected to the Internet. Content Providers too, in order to distribute its content across the Internet, must find a way to connect to the Internet. There are two methods of connecting to this network of networks: Transit and Peering.

The Transit Model

Definition: ***Transit*** *is a business relationship in which an ISP sells access to the global Internet.*

Transit is Simple. The transit service is simple. An "Upstream Transit Provider" accepts and attempts to deliver all data packets between the customer and the Internet. Transit is analogous to a port on the wall that says "Internet – this way"; the upstream provider takes care of the rest.

Transit is a Metered Service with a monthly bill. Every five minutes, the customer's interface card is sampled. At the end of the month, the number of bytes per five minute sample are converted into Megabits-per-second (Mbps), and sorted, lowest to highest. The 95th percentile measurement is typically used to determine transit volume for the month, which is multiplied by the negotiated transit rate to determine the monthly transit bill.

Transit Commits and Discounts. Upstream ISPs provide volume discounts based on negotiated commit levels. Thus, if you commit to 1000Mbps of transit per month, you will likely get a better rate than if you commit to only 10Mbps of transit per month. The cost of transit is shown mathematically below:

$$MeteredTransit = T_C * T_V$$
$$T_C = Transit\_Price\_Per\_Mbps$$
$$T_V = Transit\_Volume(95thPercentile)$$
$$C = CommitLevelinMbps$$

This "Transit Commit" model provides a tiered pricing structure for transit as shown graphically below.

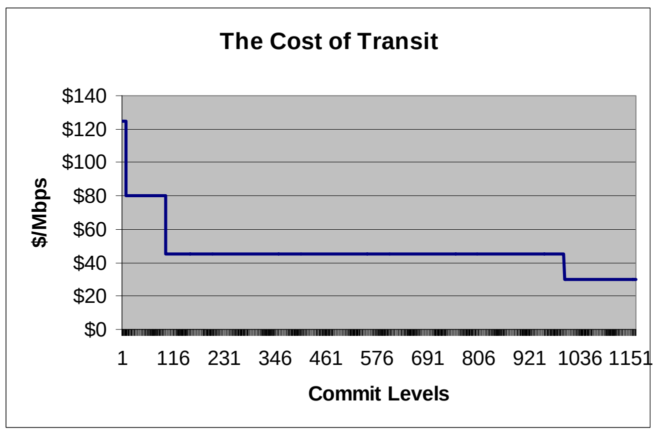

Figure 1 – Step Graph of Transit Prices in 2004

To obtain the 2004 market prices for transit we asked several people in the Peering Coordinator Community for the current market price of transit, and shared their rough estimates (shown below) with the North American Network Operators Group (NANOG) mailing list. We asked the list for validation of the price points and received about thirty responses, most saying that the prices were about right. A few people said the prices were too low; one reported that they were paying roughly double these prices. A similar number said that they were paying less than these prices. For modeling purposes, we believe these prices (T_C) based on these commit levels (C) aren't too far off[1].

Transit Prices (August 2004) (T_C)		
1 Mbps Commit	$125	per Mbps
10 Mbps Commit	$80	per Mbps
100 Mbps Commit	$45	per Mbps
1000 Mbps Commit	$30	per Mbps

Figure 2 - Transit Prices in 2004

Definition: Transit Commit Risk is the risk of paying more on a unit cost basis than the next best alternative. In other words, the financial risk of committing to more traffic than one can source. At its maximum, Transit Commit Risk is the full cost of the commitment when no traffic is actually sent: $T_{Risk\,C} = C * T_C$

If for some reason a company commits to a gigabit-per-second of transit and sends 0 Mbps, the result is a Transit Commit Risk of $30,000 per month!

Commit to (c)	At Risk Volume		max Commit Risk	
1 Mbps	0-1	Mbps	$125	per month
10 Mbps	0-10	Mbps	$800	per month
100 Mbps	0-100	Mbps	$4,500	per month
1000 Mbps	0-1000	Mbps	$30,000	per month

Figure 3 - Transit Risk

Taking the Transit Commit Risk into account, the monthly transit bill can be modeled as:

$$MonthlyTransitBill = \max(T_{Risk_C}, T_V * T_C)$$

Transit prices have dropped significantly over the years. Below is a graph showing the approximate market prices for purchasing and committing to a 1Mbps transit service[2]. Although purchasing a 1Mbps service in the U.S. is rare these days, that transit prices have been dropping as a trend is undeniable.

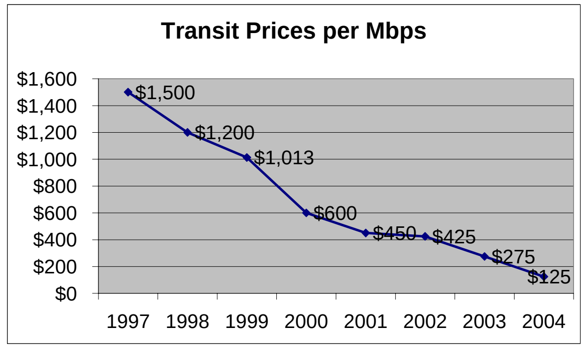

Figure 4 - Plummeting Transit Prices

Now that we have the market prices for transit in 2004, let's consider an optimization based on selecting the *best* commit levels.

The Optimal Transit Model

In the transit market place there are a variety of contract term lengths, and certainly more gradations than 1Mbps, 10Mbps, 100Mbps, and 1000Mbps. However, for the sake of simplicity, in this paper we will assume that all transit commitments are for one year and that these are the only four gradations of transit service available. We will further assume that the transit agreements specify that the burst rate (the rate for the volume of traffic over the commit level) is the same as the commit price for transit.

What is the *optimal* commit level given an expected transit volume?

The **100% Heuristic** suggests that one should commit only to the level of traffic that they know they will need for the next commit term. So, a 100M commit contract would be negotiated only when there was a reasonable expectation that traffic levels will be about 100Mbps.

Another approach is the **Leo[3] Transit Commit Heuristic**: commit to 70% of your current transit load in order to make sure you are not paying for transit that you are not using. So if you expect to have 143 Mbps of transit traffic, you would commit to your upstream at the 100Mbps level. This seems intuitive,

[1] At NANOG32 Dan Golding (Burton Group) suggested an explanation for the variability; that there is a retail market for transit (for enterprises) and a wholesale market for transit (primarily for ISPs and network savvy Content Players). Several others point out that these prices are probably about right if not a little high - most peering candidates are savvy enough to purchase transit in the wholesale market.

[2] Data collected from the field, based on previous white papers where transit prices were quoted, and recollections from a handful of Peering Coordinators.

[3] Suggested by a Peering Coordinator for AboveNet, Leo Bicknell.

but is this financially optimal?

To compare these approaches, consider the unit cost for transit at the 1 and 10 Mbps commit levels side by side:

Mbps	$/Mbps at 1M Commit	$/Mbps at 10M Commit
1	$125	$800
2	$125	$400
3	$125	$267
4	$125	$200
5	$125	$160
6	$125	$133
7	$125	$114
8	$125	$100
9	$125	$89
10	$125	$80
11	$125	$80
12	$125	$80
13	$125	$80
14	$125	$80
15	$125	$80

Figure 5 - When to commit to next higher level of transit? Transit at 1 M vs. Transit at 10M

We first note that it is actually less expensive to commit to 10Mbps even if you expect to send only 7 Mbps to the upstream. Even though we aren't using the remainder of the 10Mbps commit at this point, the unit cost is less than the 1Mbps commit price!

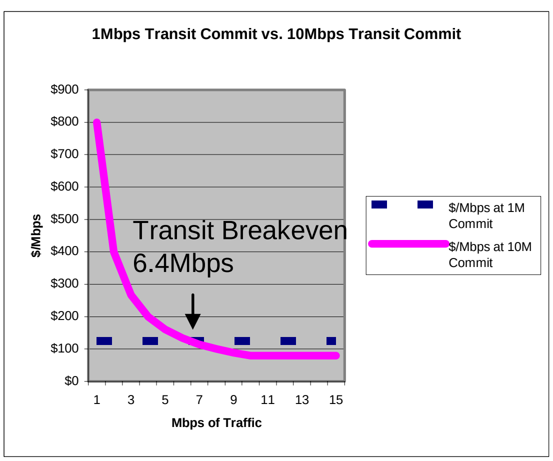

Figure 6 - 1M Transit vs. 10M Transit

If we renegotiate this transit contract to the next higher level of commitment (10Mbps) when we reach 7Mbps of traffic, we see modest improvements over the 100% Heuristic, and greater improvements over the Leo Heuristic.

We compare these heuristics side by side in the chart and graph below:

Mbps	$/Mbps at 1M Commit	$/Mbps at 10M Commit	100% Heuristic	Leo Heuristic	Norton Transit Heuristic
1	$125	$800	$125	$125	$125
2	$125	$400	$125	$125	$125
3	$125	$267	$125	$125	$125
4	$125	$200	$125	$125	$125
5	$125	$160	$125	$125	$125
6	$125	$133	$125	$125	$125
7	$125	$114	$125	$125	$114
8	$125	$100	$125	$125	$100
9	$125	$89	$125	$125	$89
10	$125	$80	$80	$125	$80
11	$125	$80	$80	$125	$80
12	$125	$80	$80	$125	$80
13	$125	$80	$80	$125	$80
14	$125	$80	$80	$125	$80
15	$125	$80	$80	$80	$80

Figure 7 – Transit Commit Heuristics Comparison

The area between the Optimal Transit (Norton Heuristic) and the other Heuristics is the cost savings.

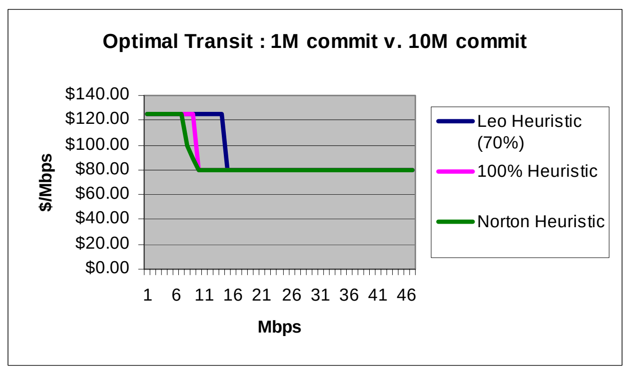

Figure 8 - Graph showing Cost Savings of Transit Commit Heuristics

As we scale between the 10Mbps to the 100M commit, we see this optimization is much greater than the first optimization; at 56.25 Mbps, we start saving money with the higher level 100Mbps commit as shown below (Figure 9 below).

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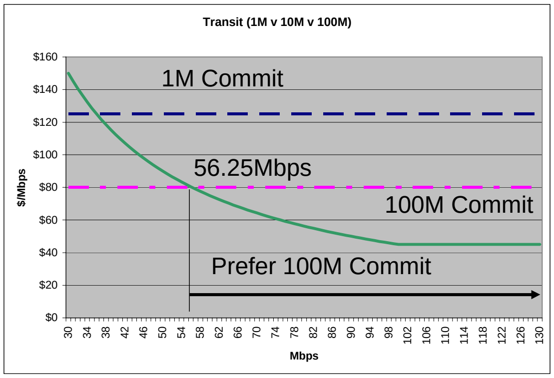

Selecting the appropriate commit levels for optimal transit can be accomplished with a simple heuristic[4].

Norton Heuristic

We introduce the Norton Heuristic as mechanism to automate this optimization; it uses a formula to minimize the unit cost per Mbps based on the commit pricing structure. The customer renegotiates to a higher level commit[5] when they exceed the traffic volume that results in a lower unit cost at the next higher commit level.

Mathematically speaking, this heuristic says that we migrate to the next higher level of transit commit at the Transit Breakeven Point, the point where the total cost of transit at the lower level equals the total cost of transit at the higher commit level. We identify this point by setting the two transit equations equal as shown below. Once a company can be sure they will need $V_{(c)}$ worth of transit for the contract term, it makes sense to commit to the next higher level. From this point forward, an increasing traffic volume results in a lower price per Megabit-per-second.

$$CurrentTransitCost = NextTransitCost$$

$$T_{(c)} * V_{(c)} = T_{(c+1)} * V_{(c+1)}$$

$$V_{(c)} = \frac{T_{(c+1)} * V_{(c+1)}}{T_{(c)}} = T_{BE}$$

$$T_{(c)} = CurrentTransit\,\mathrm{Pr}\,ice$$

$$V_{(c)} = CurrentTransitVolume$$

$$T_{(c+1)} = NextCommitTransit\,\mathrm{Pr}\,ice$$

$$V_{(c+1)} = NextCommitTransitVolMin$$

$$CommitLevel = (C+1) iff V_c > \left(\frac{T_{(c+1)} * V_{(c+1)}}{T_{(c)}} \right)$$

Figure 9 - The Norton Heuristic

$$Transit\,\mathrm{Pr}\,ice_{Commit}$$

$$T_{1Mbps} = \$125 / Mbps$$

$$T_{10Mbps} = \$80 / Mbps$$

$$T_{100Mbps} = \$45 / Mbps$$

$$T_{1000Mbps} = \$30 / Mbps$$

Using today's prices, we see several Transit Breakeven Points, well below the commit level.

Norton Heuristic for Optimal Transit	
Commit to (C):	when traffic exceeds (T_{BE})
10 Mbps	6.40 Mbps
100 Mbps	56.25 Mbps
1000 Mbps	666.67 Mbps

Figure 10 - Transit Breakeven Points

To close out this section, the summary Optimal Transit Curve with the Transit Breakeven Points are highlighted in the graph below.

[4] Dan Golding (Burton Group) points out that we are assuming traffic growth, and in particular, non-seasonal traffic loads in these assumptions. Walmart.com for example has huge peaks between Thanksgiving and Christmas, followed by relative lull in traffic.

[5] Renegotiating a contract mid-term to the next higher level of commitment is rarely turned down by the upstream transit provider.

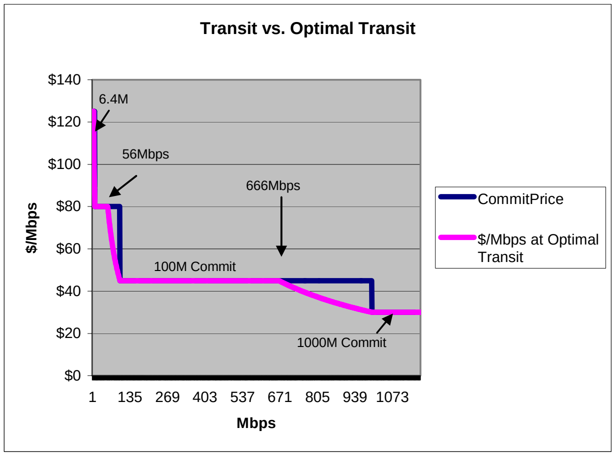

Figure 11 - Cost Savings from Optimal Transit

Note that each commit level has an associated transit commit risk, that could be drawn as a dotted line on the optimal transit graph. Since traffic volume is bursty and somewhat difficult to predict exactly, this refined graph, while crowded, would help decision makers understand the risks and rewards associated with any of these transit commit heuristics.

The Peering Model

Definition: ***Peering*** *is a business relationship whereby two companies reciprocally exchange access to each others customers.*

Note that Peering does not provide access to all destinations in the Internet; that would be a Transit relationship. Peering is a local optimization in which companies exchange routes to each others customers so that neither pay an upstream provider for that traffic. There is a cost for peering however.

The Cost of Peering. For the purposes of this paper we will assume that peering is accomplished at an Internet Exchange (IX)[6]. The IX cost model for peering involves three monthly recurring costs:

1. Local Loop fees (the cost to get into the IX),
2. IX collocation fees, and
3. IX peering port fees.

We will also consider the capital cost of equipment for peering.

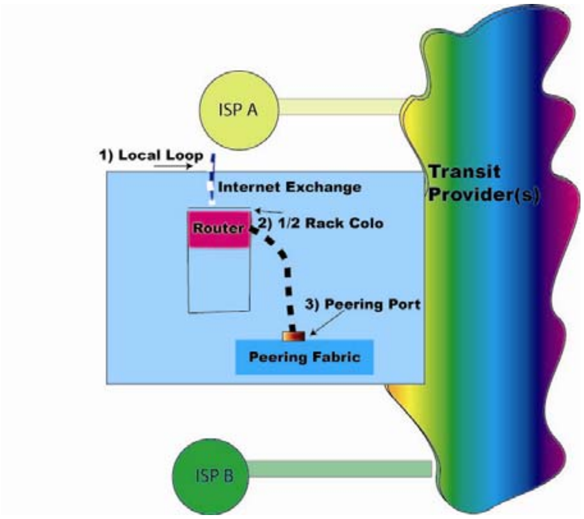

Figure 12 - Peering Costs

Note that these transport costs are only necessary if the company is not already in the IX. For this reason we will analyze two models:

First, with Model I the company has to purchase peering equipment, transport into the IX, IX rack space and an IX peering port.

With Model II we assume the company happens to already be collocated in the IX, perhaps for selling transit, or as a metropolitan Point-of-Presence (POP), or perhaps to participate in an application layer financial exchange. In Model II we will only consider only the incremental cost of peering – the 100M or 1000M interface card and the peering port(s) at the IX.

Peering versus Optimal Transit

To compare Peering against the next best alternative (Optimal Transit), we need to do two things.

[6] The alternative is peering using point-to-point circuits. A comparison of peering using point to point circuits and peering using the IX model are shown in the (now dated) white paper "Interconnection Strategies for ISPs."

1) Normalize the Peering and Transit units. To compare Peering and Transit we need to normalize both to common units. Since peering and amortized equipment costs are on a $-per-month basis, and transit is charged on a $-per-Mbps-per-month basis, we will plot them both on a $/Mbps/month vs. Mbps exchanged. The graph below shows peering and transit, and highlights a couple of key points.

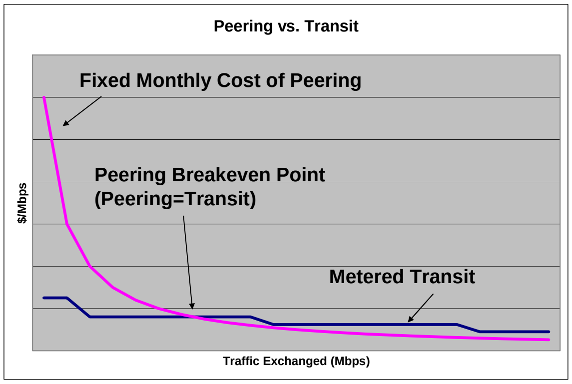

Figure 13 - Peering Breakeven Graph

First, as we discussed before, transit costs are tiered, providing a step function based on commit levels. Peering costs on the other hand, are fixed on a monthly basis, and allocated across the number of Mbps of traffic exchanged with peers.

For example, if an ISP only exchanges 1 Mbps with the peering population at an IX, and it costs $9,000 per month to do so, the unit cost for peering is $9,000 per Mbps. Not a bargain when that traffic can be exchanged via a transit provider for $125 per Mbps or less. But if the ISP can peer 300 Mbps with the peering population and it costs $9,000 per month to do so, the unit cost is $30 per Mbps to exchange that traffic. Now peering is financially more attractive. The point where peering exactly equals the cost of transit is called the **Peering Breakeven Point (P_{BE}).**

2) Compare Peering at P_V and Transit at T_V. The more traffic one can peer beyond the Peering Breakeven Point, the more financially attractive peering becomes. However, there is a wrinkle in our analysis. Many companies can only peer a portion of their traffic; empirically the author has found that Peering Coordinators can peer away 20% of their transit traffic in a single peering point. The non-peered traffic goes to the upstream transit provider. Since the transit price is determined by the transit commit, which is determined by the transit volume, transit volume is usually much larger than peering volume. It is not fair then to compare the cost of peering against the cost of transit at the *peering* volume point - one needs to compare the price of peering against transit at the likely *transit* volume point. One might find that if 100% of the traffic was sent to the upstream transit provider, one would meet the Transit Breakeven Point, and the lower price at the next higher level of commit is financially attractive! Let's consider an example.

We will assume for this paper that the company can peer away 20% of their transit traffic[7]. This suggests that a blended peering and transit solution (80% Transit and 20% Peering) should be compared against the next best alternative, a 100% Transit solution. This will allow the decision maker to compare Peering (blended with Transit) against the next best (100% Optimal transit) solution. Using this analysis method, let us consider an example where Peering has a monthly cost of $9000.

We see below that the Peering Breakeven Point appears to be around 350Mbps, where a company is financially indifferent between the Peering blend and simply send all the traffic through optimal transit.

Sample Blended Peering w/Optimal Transit vs. Optimal Transit
(Assume 20% peering in Blend)

Peering (20%) Mbps	Peering at PV	Transit (80%) Mbps	Transit at TV	Peering and Transit Blend	Transit Only Mbps	Optimal Transit (100%)	Monthly Cost Savings
25	$360.00	100	$60.00	$ 120.00	125	$ 45.00	-$9,375
50	$180.00	200	$45.00	$ 72.00	250	$ 45.00	-$6,750
75	$120.00	300	$45.00	$ 60.00	375	$ 45.00	-$5,625
100	$90.00	400	$45.00	$ 54.00	500	$ 45.00	-$4,500
125	$72.00	500	$45.00	$ 50.40	625	$ 45.00	-$3,375
150	$60.00	600	$45.00	$ 48.00	750	$ 40.00	-$6,000
175	$51.43	700	$45.00	$ 46.29	875	$ 34.29	-$10,500
200	$45.00	800	$45.00	$ 45.00	1000	$ 30.00	-$15,000
225	$40.00	900	$44.44	$ 43.56	1125	$ 30.00	-$15,250
250	$36.00	1000	$40.00	$ 39.20	1250	$ 30.00	-$11,500
275	$32.73	1100	$36.36	$ 35.64	1375	$ 30.00	-$7,750
300	$30.00	1200	$33.33	$ 32.67	1500	$ 30.00	-$4,000
325	$27.69	1300	$30.77	$ 30.15	1625	$ 30.00	-$250
350	$25.71	1400	$30.00	$ 29.14	1750	$ 30.00	$1,500
375	$24.00	1500	$30.00	$ 28.80	1875	$ 30.00	$2,250
400	$22.50	1600	$30.00	$ 28.50	2000	$ 30.00	$3,000
425	$21.18	1700	$30.00	$ 28.24	2125	$ 30.00	$3,750
450	$20.00	1800	$30.00	$ 28.00	2250	$ 30.00	$4,500
475	$18.95	1900	$30.00	$ 27.79	2375	$ 30.00	$5,250
500	$18.00	2000	$30.00	$ 27.60	2500	$ 30.00	$6,000
525	$17.14	2100	$30.00	$ 27.43	2625	$ 30.00	$6,750
550	$16.36	2200	$30.00	$ 27.27	2750	$ 30.00	$7,50
575	$15.65	2300	$30.00	$ 27.13	2875	$ 30.00	$8,25

Figure 14 - Comparison of Peering and Optimal Transit

[7] The author has found that many companies can peer 20-40% of their traffic at a single well populated IX, and that the peering beyond 40%-50% gets exponentially more difficult to obtain.

In this example, if a company purchases transit at 1750 Mbps, we assume that they can peer at least 350 Mbps (20%) at an Internet Exchange. In this case the cost of peering ($9000 per month in this example) is completely covered by the monthly cost savings of Peering shown graphically below.

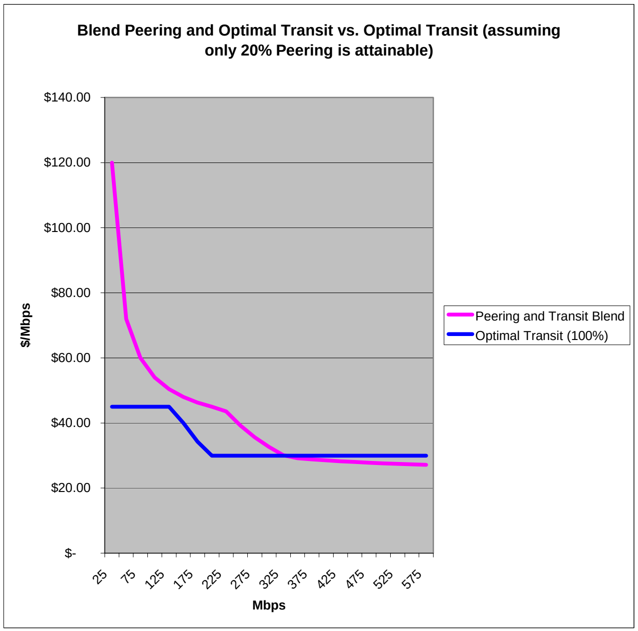

Figure 15 - Sample Peering vs. Optimal Transit Breakeven Analysis

While these lines may appear close together on a unit basis, note that the monthly savings by blending peering in the last column above and shown as monthly savings graphically below where peering monthly savings approach $10,000 per month.

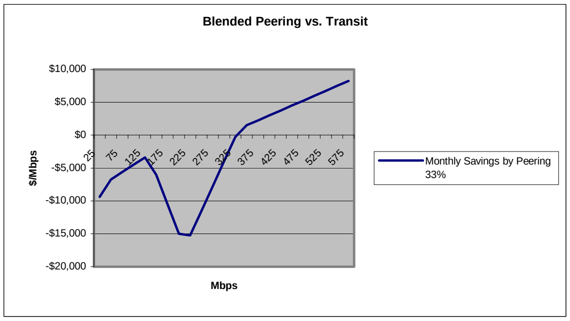

Figure 16 - Monthly Cost Savings from Peering

With this slightly more complex Peering Blend vs. Optimal Transit model, we can clearly determine when peering becomes an attractive alternative to simply purchasing transit.

Note that we can only grow the peering traffic to the size of our peering infrastructure. In the case of Ethernet, about 6% of the bandwidth is taken up with layer two framing, leaving a maximum of 94% of the capacity available for traffic exchange, which leads to our next definition.

Def: The **Effective Peering Bandwidth (EPB)** is the maximum bandwidth available for peering**.** Peering Coordinators generally try and minimize the amount of traffic lost on their peering links, and expect that when the peering approaches about 75% of the capacity of the peering link[8], that traffic will generally peak towards the capacity of the link. Thus the Peering Coordinator will generally upgrade the peering infrastructure at or before 75% of the peering capacity is in use. To model this behavior, we will assume that the peering infrastructure, when constrained by the 100M Ethernet media, will reach its **Effective Peering Bandwidth** at 75% * 94Mbps = 70.5Mbps. We will similarly assume that a Peering Coordinator will upgrade the capacity of the gigabit Ethernet peering when it reaches 75% * 940Mbps=705Mbps.

$$EPB_{100M} = 70.5Mbps$$
$$EPB_{1000M} = 705Mbps$$
$$EPB_{10000M} = 7050Mbps$$

Definition: The **Effective Peering Range (EPR)** is the range between the Peering Breakeven Point and the Effective Peering Bandwidth. This is the range where peering makes sense financially.

Note that the Effective Peering Range is capped by the Effective Peering Bandwidth, a physical limitation, while the Peering Breakeven Point is a function or the market price for transit, the point where the market price for transit exactly equals the unit cost of peering. Since the upper bound cannot be adjusted, as transit prices drop, the Effective Peering Range shrinks accordingly. The more narrow the Effective Peering Range, the less financially attractive peering becomes.

Definition: The **Minimum Cost of Traffic Exchange** is the unit cost at the Effective Peering Bandwidth. This is the lowest unit cost the peering company can hope to achieve with their peering infrastructure.

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8 Measured at 95th percentile – Scott Bradner (Harvard).

$$MinimumCostOfTrafficExchange = \frac{CostofPeering}{EffectivePeeringBandwidth}$$

Definition: The **Peering Risk** is the range where the unit cost of peering is more expensive than the alternative unit cost for transit. The alternative unit cost of transit of course depends of on the transit commits.

All of these are detailed in the generalized peering graph below.

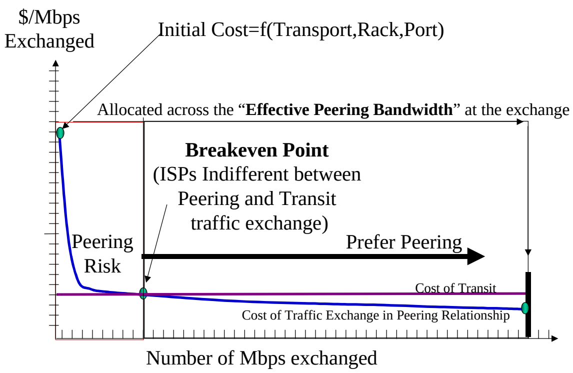


Figure 17 - Generalize Peering Breakeven Graph

2004 Peering vs. Transit Analysis

We will now apply the market prices for peering and transit and see if peering makes sense in 2004.

Peering Model I – Not Collocated at IX Already

We will consider two cases here: 100M Peering and 1000M Peering.

Peering Equipment. There is great variability across peering equipment, but for this analysis we have priced and factored in a few basic router configurations that could be used to implement peering.

The used equipment market remains very strong in 2004. A used Foundry 4000 Big Iron with a 24-port FastE (100M) card with a management card suitable for FastE peering can be purchased on the used equipment market for about $2400[9].

For a gigabit peering solution, a new Cisco 7301 is estimated to cost about $13,000[10]. Some Peering coordinators prefer the widely available used Cisco 12008 costing about $7500 on the used market[11]. Interestingly, according to Richard Steenbergen, the used Juniper market has recently dried up. "The Juniper market is no longer attractive for used equipment. The GSR (Cisco 12000 Series) market on the other hand is booming. Used 12008, 12012, 12016, 3xGE line cards are all dirt cheap."

On the really low end, Todd Underwood suggested that one could purchase a PC-based gigabit peering router[12] for less than $2000. On the high end, a new Juniper 7i router with two gigE cards for peering is estimated to cost $28,925.

For this discussion, we will consider the used Foundry BigIron 4000 for peering at 100M, and both used and new Cisco and Juniper equipment for analyzing 1000M peering. We will further assume, in order to allocate the capital equipment costs to the monthly recurring costs of peering, a 3-yr straight line amortization for all equipment discussed.

Used Peering Equipment		
100M Peering Equipment		
Foundry Big Iron 4000 w/24 FEs	$2,400	
3yr Straight Line Depreciation	$66.67	per month
1000M Peering Equipment		
Cisco 12008, loaded, with 2*GE	$7,000	
3yr Straight Line Depreciation	$194.44	per month
New peering Equipment		
1000M Peering Equipment		
Cisco 7301	$13,000	
3yr Straight Line Depreciation	$361.11	per month
High End 1000M Peering Equipment		
Juniper M7i, loaded, dual gigEs	$28,925	
3yr Straight Line Depreciation	$803.47	per month

Figure 18 - Peering Equipment Cost Models

When we explore expanding a peering presence, trunking multiple peering ports together or expanding to 10gigE peering, we will use the following expected

[9] Richard Steenbergen shared a sample configuration on eBay.

[10] Source: Patrick Gilmore, new negotiated price for two gigE peering 7301router.

[11] Source: Richard Steenbergen.

[12] 1RU supermicro box with 2*250G SATA drives, 2G of ram and 3*Gig-E running FreeBSD or Linux for $1800 or so new.

equipment costs[13]:

10GE Peering Equipment		
Cisco 6509 w/4*10GE Ports, 4*XE	$55,000	
3yr Straight Line Depreciation	$1,527.78	per month
Router Interface Cards		
Fast E Interface Card	$100	
Amortized over 3 yrs	$2.78	per month

Figure 19 - Peering Interface Card Cost models

We will use these amortized monthly equipment costs to the cost of peering for a rough idea of how much peering costs as compared with buying optimal transit.

Model I – Build into IX for 100M Peering

We surveyed the Peering Coordinator Community for price points in 2004 for 100M transport, 100M IX peering port and IX collocation fees. The results are shown below along with equipment costs as described earlier.

Model I : Monthly 100M Peering Costs		
Transport	100 Mbps	$ 1,000.00
IX Fees (Port + 1/2 rack)	100 Mbps	$ 2,500.00
Base IX Participation Peering Costs		$ 3,500.00
Amortized used Foundry Equipment Cost		$ 66.67
Total Monthly Cost of 100M Peering		$ 3,566.67

Figure 20 - Model I: The Cost of Peering at 100M

A company considering building into an IX for peering (and using the used Foundry Big Iron 4000) will have peering expenses of $3,566.67 per month, allowing them to peer up to EPB=70.5 Mbps. If this full Effective Peering Bandwidth is used for peering, the Minimum Cost of Peering (the best the company could hope for with this FastE peering infrastructure described so far) is **$50.59 per Mbps**. It is difficult to evaluate the Peering vs. Transit graph since the lines are so close together, so we will zoom in on the EPB section of the graph.

The company that is expecting to peer at this level (EPB=70.5Mbps) is probably purchasing transit from an upstream ISP at the 100M commit level; remember we are assuming the company can peer 20% of their traffic, so the transit traffic volume is estimated to 4*70.5=282 Mbps, and therefore currently able to buy transit at **$45 per Mbps**!

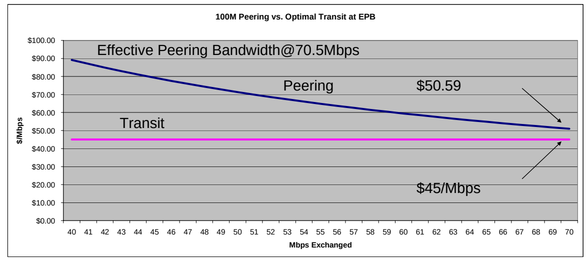


Figure 21 - Peering vs. Optimal Transit at the Effective Peering Bandwidth point

Since the transit price point is less than the Minimum Cost of Peering (the best a Peering Coordinator can hope for), why do companies continue to build in and purchase 100M peering ports in the US?

Why Peer when $P_{100}>T_{100}$?

Many companies see peering as strategic, or as part of an longer term growth plan. We asked some of these companies why companies they were adopting peering at 100M levels as a strategy even when the economics make peering look more expensive than transit at 100M and 1000M commit levels. Below are the most common answers they gave:

1) **Performance** - lower latency and pkt loss. Some companies focus on the end-user experience more than the economics of peering.

2) **Greater control over routing**. The flexibility of being able to adjust traffic to deal with special events, to deal with growth spikes and network congestion issues is more important than the cost issues.i

3) **Meeting Peering Prerequisites.** For these companies there may only be a small about of traffic to exchange at this IX, but they must meet a key peering partner at multiple IXes in order to meet their geographic peering prerequisites. A peering presence here, while by itself uneconomical, as part of a broader peering picture may make good economic sense.

4) **Already at the IX.** Many companies are already at the IX for other reasons as discussed earlier. For these folks, Model II, discussed later in this paper applies.

[13] See the Apendix for complete specifications on several 10G router configurations from about $23K for used to $250K for a carrier-grade new 10G router configuration. We chose the middle of the line new Cisco for 10G router modeling purposes.

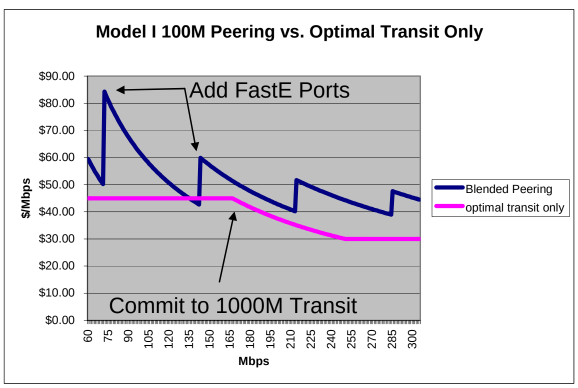
5) **Marketing value**. These companies see value in being at all the major IXes. Customers often ask for detailed network and peering maps when selecting between ISPs. More peering implies better performance and more network expertise among other things.

6) **100M Peering is a stepping stone** to more economical gigE peering.

7) **Currently paying high transit fees.** Some content companies for example reported paying transit fees as much as twice what we saw in our survey. For these companies, peering makes sense at much lower levels of traffic exchange.

8) **Peering Costs are immaterial.** For these companies, peering represents a relatively insignificant part of their networking budget..

Don't dismiss FastE Peering just yet. Before we dismiss peering 100M completely, consider the cost of expanding the peering beyond a single FastE. Let's assume each incremental IX peering port will cost $1,500 per month plus the cost of an additional FastE Local Loop at $1,000 per month. If we continue to add FastE ports for peering when we reach multiples of 70.5 Mbps, we the saw the toothed graph below.



We see in this graph that FastE peering approaches and flirts above and below the Optimal transit at $45/Mbps, the commit point where the company would be if he is peering 20% and sending 80% to transit providers. Since the Foundry configuration we selected includes a 24-port FastE blade, we have $0 incremental equipment costs for adding up to 12 FastE ingress circuits into the IX and 12 trunked FastE to peer on the Peering fabric. It is worth noting that once we get to four fastE ports of peering, we could, for the same price, get a gigE loop in and a gigE port on the switch. This thought provides a nice segue to the next sub-model : 1000M (gigE) peering.

100M Peering Summary: Peering at 100M is a tough sell under the assumptions in this model. In particular, current transit prices, peering percentage (20%), peering port fees, equipment fees, current transit prices, etc. make peering at this level not financially reasonable. There are many folks who peer a this level however, for the reasons listed above.

Model I – Build into IX for <u>1000M</u> Peering

In this analysis, we focus on a company that purchases a router, builds into an IX for peering using a gigabit Ethernet local loop, and connects their router to a gigabit Ethernet peering port on a switch. For this first scenario, let's purchase a used Cisco 12008, provided before at $7,000 amortized to $194.44 per month.

Model I : Monthly 1000M Peering Costs		
Transport	1000 Mbps	$ 4,000.00
IX Fees (Port + 1/2 rack)	1000 Mbps	$ 5,000.00
Base IX Participation Peering Costs		$ 9,000.00
Amortized used Cisco 12008 Equipment Cost		$ 194.44
Total Monthly Cost of 1000M Peering w/used Cisco12008		$ 9,194.44

Figure 22 - Model I : Peering vs. Optimal Transit at the 1000 Mbps level

Adding the equipment costs to the cost of the local loop, IX rack and port fees, and we see the monthly recurring cost is $9,194 per month.

If we divide this monthly recurring fee by the 705 Mbps (the Effective Peering Bandwidth of the gigE peering infrastructure) we see the Minimum Cost of Peering is $13.04 per Mbps, significantly below the transit price of $30 per Mbps the company would have achieved with a 1000M commit! The Peering Breakeven Point is $9,194 per month divided by $30 per Mbps=306.5 Mbps.

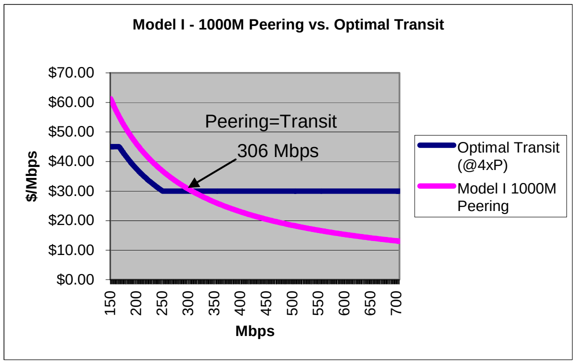


Figure 23 - A correct analysis of Peering vs. Transit at 1000M levels

If a company can peer 306.5 Mbps, the total cost of building in, buying equipment for peering, and connecting the peering fabric is completely covered by the cost savings of peering.

From 306.5 Mbps to 705 Mbps (the **Effective Peering Range)**, the cost of peering decreases from $45 per Mbps down to $13.04 per Mbps, the **Minimum Cost of Traffic Exchange**. At the **Effective Peering Bandwidth** point (705 Mbps), the company could save $11,956 per month by building in and peering that traffic away instead of sending it to the transit provider!

We can summarize the peering metrics in the table below.

Summary Stats for Model I Peering 1000M w/used 12008

Effective Peering Bandwidth			705.0 Mbps
Minimum Cost of Peering (at 705Mbps)		$	13.04 per Mbps
Peering Breakeven Point (w/$30/Mbps transit)			306.48 Mbps
Effective Peering Range	306.5 until		705.00 Mbps

Figure 24 - Summary Stats for Peering at the 1000M level with used Cisco 12008

If we use new equipment, it is interesting to see that the monthly cost, the corresponding Minimum Cost of Peering, and the Peering breakeven Point do not change significantly:

Model I : Monthly 1000M Peering Costs		
Transport	1000 Mbps	$ 4,000.00
IX Fees (Port + 1/2 rack)	1000 Mbps	$ 5,000.00
IX Participation Peering Costs		$ 9,000.00
Amortized new Cisco 7301 Equipment Cost		$361.11
Total Monthly Cost of 1000M Peering with new Cisco 730		$ 9,361.11

Figure 25 - Peering at the 1000M level with new Cisco 7301

Summary Stats for Model I Peering 1000M w/new 7301

Effective Peering Bandwidth			705.0 Mbps
Minimum Cost of Peering (at 705Mbps)		$	13.28 per Mbps
Peering Breakeven Point (w/ $45/Mbps transit)			312.04 Mbps
Effective Peering Range	312.0 until		705.00 Mbps

Figure 26 - Stats for Peering at the 1000M level using a new Cisco 7301

Even using the Juniper 7i costing $28,925 doesn't have a dramatic effect after amortizing the cost over 36 months:

Model I : Monthly 1000M Peering Costs		
Transport	1000 Mbps	$ 4,000.00
IX Fees (Port + 1/2 rack)	1000 Mbps	$ 5,000.00
IX Participation Peering Costs		$ 9,000.00
Amortized Juniper 7i Equipment Cost		$803.47
Total Monthly Cost of 1000M Peering w/new Juniper 7i		$ 9,803.47

Figure 27 - Peering at the 1000M level with new Juniper 7i

Summary Stats for Model I Peering 1000M w/used 12008

Effective Peering Bandwidth			705.0 Mbps
Minimum Cost of Peering (at 705Mbps)		$	13.91 per Mbps
Peering Breakeven Point (w/ $45/Mbps transit)			326.78 Mbps
Effective Peering Range	326.8 until		705.00 Mbps

Figure 28 - Stats for Peering at the 1000M level using a new Juniper 7i

We can see the cost functions for alternative equipment configurations do not making a material difference in the peering economics.

Peering 1000M: Comparison Between Used and New Equipment		
Total Monthly Cost of 1000M Peering w/used Cisco12008	$ 9,194.44	per Month
Minimum Cost of Peering (at 705Mbps)	$ 13.04	per Mbps
Peering Breakeven Point (w/$30/Mbps transit)	306.5	Mbps
Total Monthly Cost of 1000M Peering with new Cisco 7301	$ 9,361.11	per Month
Minimum Cost of Peering (at 705Mbps)	$ 13.28	per Mbps
Peering Breakeven Point (w/$30/Mbps transit)	312.0	Mbps
Total Monthly Cost of 1000M Peering w/new Juniper 7i	$ 9,803.47	per Month
Minimum Cost of Peering (at 705Mbps)	$ 13.91	per Mbps
Peering Breakeven Point (w/$30/Mbps transit)	326.8	Mbps

Add a second peering gigE. At 705 Mbps, let's assume that the peering company will add:

- another gigE local loop (assume the same price as before, $4,000 per month),
- a second gigE peering port at the same $4,000 per month as before, and
- two additional gigE card to the router (costing about $1,527.78 each, or per month),

If we assume the same ½ rack is sufficient for the peering infrastructure we see a monthly cost of $17,277.78 per month. At this point, we are still sending 705 Mbps to the peering point, not utilizing the second gigE yet, yielding a unit cost of $24.51 per Mbps, still less than the current assumption for the cost of transit ($30/Mbps at a 1G Commit)!

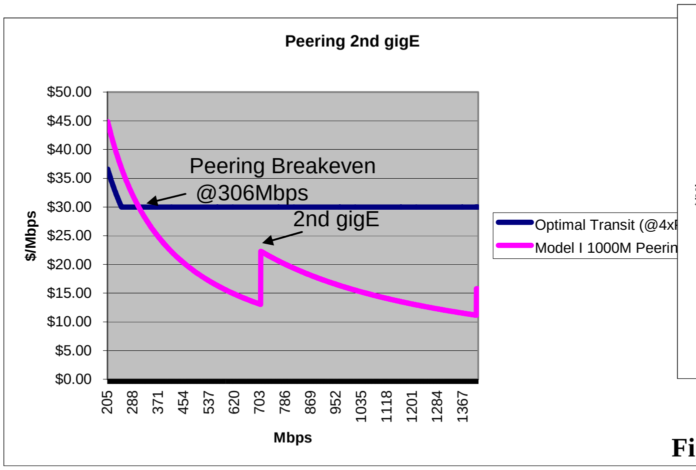


Figure 29 - Peering at the 1000M Level adding a second gigE

Scaling from 705 Mbps, we can grow up to the effective peering bandwidth of the peering infrastructure (1410 Mbps), at which point the cost for peering is $12.25 per Mbps. This is significantly less than the metered transit alternative.

Beyond 1410 Mbps we would probably consider scaling the peering infrastructure to 10 Gigabit Ethernet. Here we will make some major assumptions. First, assume that the IX fees for the 10GE port is 3 times the full cost of the gigabit Ethernet port, or per month[14]. We will assume that this port price will include the cost of a ½ rack for the equipment. If we further assume that the 10G Local Loop is 4 times the cost of the gigE Local Loop, we get a price of $16,000.00 per month[15]. Finally, let's assume that we replace the peering infrastructure with a new enterprise-class 10G router (a Cisco 6509 w/SUP720, 4-port 10GE, 4xXENPAK) costing $55,000, amortized over 36 months to $1527 per month[16]. The total cost of 10 gigE peering is therefore $29,527.78 per month.

At 1410 Mbps, when we decommission the gigE local loops, line cards and peering ports, and install the 10gigE local loop, interface card and peering port at the IX, but before we use any more than the 1410 Mbps, the unit price is $20.94 per Mbps, still less than the cost of transit. As we scale up to 7050 Mbps, we see a **Minimum Cost of Peering** at $4.19 per Mbps! This certainly beats the $30 per Mbps.

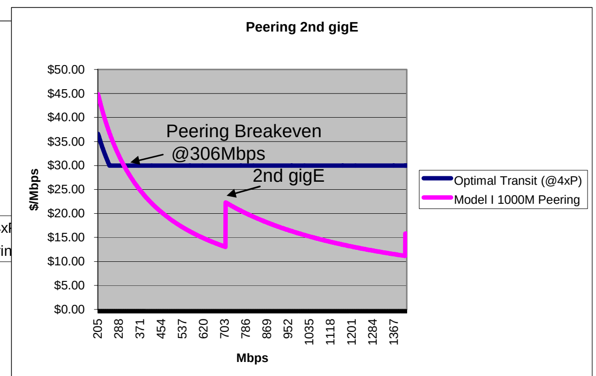


Figure 30 – Adding a 2nd gigE card and port for peering

The graph below shows the terminating values comparing a 10GigE peering connection full using its 7050Mbps of Effective Peering Bandwidth compared to the assumed price of transit. While it is true that multi-gig commits will yield lower prices than the $30 we show here, it is unlikely that multi-gig commits will approach the Minimum Cost of Peering in 2004.

---

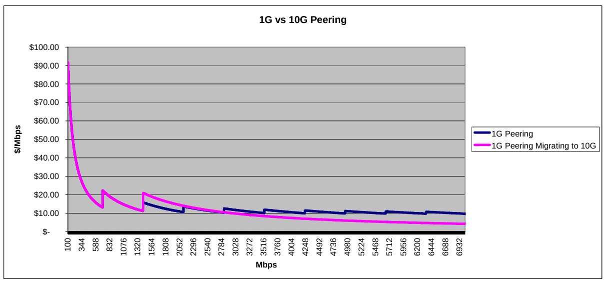
14 Wild guess here, since we haven't seen 10gigE offered at major exchange points in the US.

15 Wild guess here since we don't see many 10GigE local loops yet in the U.S.

16 We assume also that we can recover the approximate street market price for the old equipment, so we assume that we don't incur a loss from the sale of the old equipment.

Model I : Monthly 10-gigE Peering Costs			
Transport	10000 Mbps	$	16,000.00
IX Fees (Port + 1/2 rack)	10000 Mbps	$	12,000.00
Base IX Participation Peering Costs		$	28,000.00
Amortized Cisco 6509, 4*10G, 4xXENPAK			$1,527.78
Total Monthly Cost of 10000M Peering		$	29,527.78

Figure 31 – Cost Model for Peering at 10gig Levels



Summary Stats for Model I Peering 10000M w/new 6509

Effective Peering Bandwidth				7,050.0	Mbps
Minimum Cost of Peering (at 7050Mbps)			$	4.19	per Mbps
Peering Breakeven Point (20% Peering)				306.48	Mbps
Effective Peering Range	306.5	until		7050.00	Mbps

Figure 32 - Peering Metrics for Peering at 10G

Summary. Peering clearly makes sense financially at the upper end of the peering spectrum. If you can peer more than 306 Mbps in today's environment, then you can get better performance at a lower cost by peering.

Next we will consider peering when there is already a network presence at the IX. In this case, it is assumed that the network capacity, equipment and collocation fees are already covered.

Model II – Company already collocated at IX

In this model, we assume that the ISP or Content Provider is already collocated at the IX, so these expenses are already covered. For example, an ISP may be installed at an IX in order to sell transit, to meet the peering prerequisites of some other network, or perhaps the company is installed to participate in a Financial Exchange. In any case, we will assume that sufficiently large equipment, network access, and rack space suitable to handle peering tasks are already available. What is the *incremental* cost to start peering if you are already there?

If a company wishes to start peering, they will purchase an interface card at 100M, 1000M or a complete 10Gig peering kit with the corresponding costs below.

10GE Peering Equipment		
Cisco 6509 w/4*10GE Ports, 4*XE	$55,000	
3yr Straight Line Depreciation	$1,527.78	per month
Router Interface Cards		
Fast E Interface Card	$100	
Amortized over 3 yrs	$2.78	per month
GigE Interface Card	$1,500	
Amortized over 3 yrs	$41.67	per month

Figure 33 - Router Interface Card Price Models

They will also need to purchase a peering port from the IX, assumed to be priced as shown below:

IX Peering Port Only		
100 Mbps Peering Port	$1,500	per month
1000 Mbps Peering Port	$4,000	per month
10000 Mbps Peering Port	$12,000	per month

Figure 34 - Cost Model for IX Port Fees

Amortized over 36 months, we see the interface card costs represent a negligible component of the cost of peering.

Model II - 100M Peering

We assume that there is a router like the BigIron 4000 with up to 24 fastE ports available for peering. With the local loop and equipment costs eliminated, the Minimum Cost of Peering is $21.28 per Mbps, which lies nicely below the cost of the 100M and 1000M Commit prices of $45/Mbps and $30/Mbps respectively.

Model II : Monthly 100M Peering Costs		
Transport		$ -
IX Port Fees (rack present)	100 Mbps	$1,500.00
Base IX Participation Peering Costs		$1,500.00
Equipment present		
Assume 24 Fast Ports already installed		
Total Monthly Cost of 100M Peering		$1,500.00

Figure 35 - Cost model for Model II Peering at 100M

The sawtoothed graph below shows the incremental 100M Peering ports being purchased and trunked together. We assume no discounts on multiple ports, although most IXes would provide multi-port discounts.

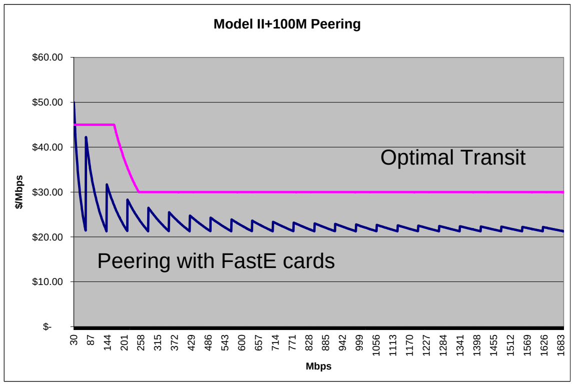


Figure 36 - Peering at 100M by trunking FastE Ports together

At 70.5Mbps we add a second FastE Peering port and again we see a Minimum Cost of Peering of $21.28 per Mbps. At the point the second 100M port is added but not utilized, so the unit price of peering is $42.55 , so at this point, peering is slightly more expensive until the second FastE port gets used. When the second FastE is at 70.5 Mbps, we approach the point where gigE peering needs to be considered.

Summary Stats for Model II Peering 100M

Effective Peering Bandwidth			70.5	Mbps
Minimum Cost of Peering (at 70.5Mbps)		$	21.28	per Mbps
Peering Breakeven Point (20% Peering)			33.33	Mbps
Effective Peering Range	33.33	to	70.5	Mbps

Figure 37 - Summary Peering Metrics for Model II 100M Peering

Summary. Peering at FastE when one is already at an IX should be a no brainer.

Model II - 1000M Peering

If the company is already collocated at an IX, the costs of peering at 1000Mbps are simply the gigE line card and a gigE port on the peering fabric. Again, assuming that sufficient capacity and equipment is already present, and using the prices outlined before, we see a Peering Breakeven Point of about 134.7 Mbps, where peering is less than Transit of $30 per Mbps. From there on, peering gets less expensive until it reaches the Effective Peering Bandwidth of 705 Mbps and the unit cost is $5.73 per Mbps. Again, we see the cost of peering is very much less expensive than the cost of purchasing transit.

1000M Peering Equipment				
Router already in IX	Add 1G card + Port		Add 2nd card+IX Port	
	$4,041.67	per month	$8,083.33	per month
MinCostofPeering	$5.73	per Mbps	$5.73	per Mbps

Once 705 Mbps is reached, the company will probably add a second gigE peering port to continue to grow peering. When we purchase a second gigE card, we see a blip in the graph where 705Mbps costs $8,083.33 per month, resulting in a unit cost of $11.47 per Mbps. Of course the good news is that this is still substantially below the cost of transit, and from here on down to 1410 Mbps we see the unit cost of peering approach $5.73 per Mbps.

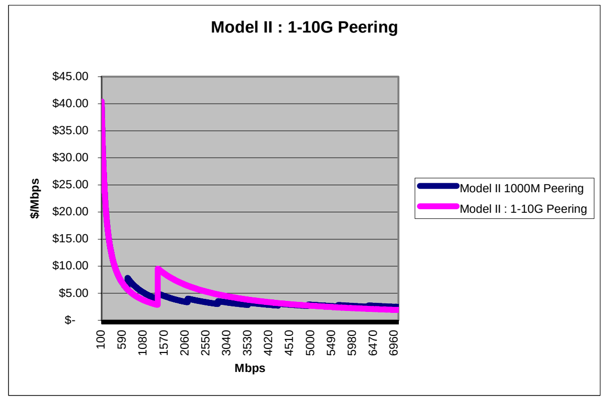


Figure 38 - Peering trunked gigabit ethernets vs 10GigE

When we get to 1410 Mbps, we expand the peering connection to a 10GigE peering.

If we assume the 10gigE peering requirements will require a new Cisco 6509 with the 4 port 10G card, we see a cost again of and can be amortized over 3 years at $1,527.78 per month, and we assume that the 10gigE peering ports are available at 3 times the cost of gigE ports, we see a total monthly cost for 10G peering of $13,527.78 per month. At the point where the gigE peering cards are replaced with the 10GigE peering equipment, the unit cost for peering is $9.59 per Mbps. From here, the cost of peering approaches the Effective Peering Bandwidth of 7050Mbps where the unit cost for peering is **$1.92 per Mbps**.

Note that we are assuming that the local loop capacity is already there, perhaps to provide transit sales or bandwidth for hosting.

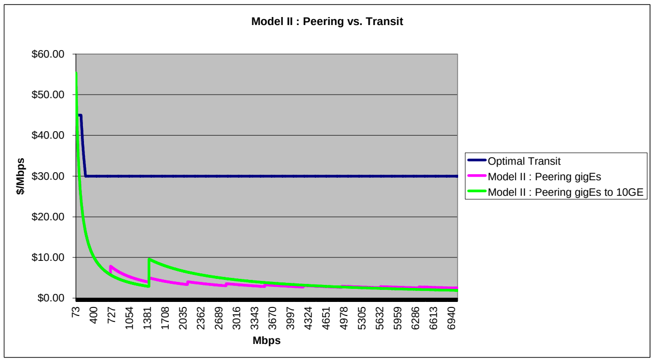


Figure 39 - Peering gigabit ethernets vs 10GigE vs. Optimal transit

Summary. We have clearly found the sweet spot for peering – if a company is already at an IX (or a collocation company also supporting interconnection), traffic exchange can be accomplished for less than $2 /Mbps.

Next Steps

We focused on peering models focused on peering with varying amounts of peering traffic as a percentage of transit load. It would be interesting to demonstrate the differences in peering metrics as one goes from 10% peering to 50% peering. This would spotlight the effectiveness of the Peering Coordinator and the financial benefits of hiring expertise in this role.

It would also be interesting to focus some attention on peering in multiple locations in order to meet peering prerequisites and pick up additional peering traffic. For example, Peering Coordinators pointed to the initial peering of 33% of ones traffic at a peering point as being unrealisitci with a single peering point, but easily obtainable if multiple peering points are used. But one has to factor in the cost of the trans-continental circuits and additional interfaces, etc. When does it make sense to peer at multiple locations to pick up additional peering traffic?

Conclusion

In 2004, Peering still provides a significant strategic advantage. At the lower end of the spectrum, we demonstrated that peering at 100Mbps levels is not a financially viable solution, but is more often motivated by the non-financial motivations for peering.

We shared market research that shows the transit prices at their lowest prices ever, and identified a heuristic for minimizing the cost of transit further through early adoption of the next level of commits. We called this “Optimal Transit” and used it as the basis to compare transit against peering.

We identified two broad cases for the comparison of Peering and Transit. Model I is where the ISP or Content Player needs to build into an IX in order to take advantage of peering. Thus, the cost of the local loop, the IX rack and port fees, and the equipment required are taken into account. In Model I we consider several configurations – used equipment for peering at 100Mbps levels, and both used and new equipment for peering at the 1000Mbps level. We also explore a hypothetic migration up to the 10G level.

Model II assumes that the ISP or Content Player is already at the IX for other reasons (e.g. for selling transit, for participating in a Financial Exchange separate from peering, etc.). here we only take into account the incremental line card and IX peering port. In this scenario we also drive the traffic volume up to the 10G level, and identify the unit costs for Peering in this scenario to be significantly below the current market prices for transit.

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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.`

10. **A Business Case for Peering in 2004** redevelops the Business Case for Peering with a slightly more comprehensive comparison of Peering and Transit using market prices for local loops, transit, peering ports, equipment costs, etc. This paper compares peering against "Optimal Transit", a heuristic that guarantees the lowest transit price given commit levels and transit break points. This is a must-read for anyone comparing the plummeting price of transit against peering solutions.

10G Peering Equipment Specifications

Courtesy of Richard A Steenbergen ras@e-gerbil.net, http://www.e-gerbil.net/ras

Remembered I never sent you this... Here are some example 10GE router configs for your numbers. The problem with these kinds of models and configs is that there is a massive number of gear combinations possible, each with their own specific advantages and disadvantages, and which one is appropriate for a specific company is highly dependant upon not only their current business models, but where they plan to be in the future.

Also note that these configs don't include the cost of connecting the routers "to" something, such as an existing network, or to customers, or even servers. These costs are easily the same as the cost of a border router, but they are impossible to model in a one size fits all scenerio. I've tried to at least pick mid-range models that are scalable too, so you won't have to throw the entire router away when you want to do more than 1x10GE. As such, the prices could probably be a tiny bit lower, but not significantly.

At the very least, this gives you a rough idea of the ballpark costs.

New enterprise-class 10GE platform, 4x10GE, around $50-60k

Used enterprise-class 10GE platform, 4x10GE, around $30k

New carrier-class 10GE platform, 1x10GE, around $250k

Also, the incremental costs for new capacity including all the associated card/optics costs divided by the number of ports (remember this is very simplistic, a larger network would probably have a minimum of 10x 10GE interfaces for every 10Gbps of traffic that goes through it):

New enterprise-class 10GE platform, $9,000 per port - 35% = ~ $6,000

Used enterprise-class 10GE platform, $3,500 per port

New carrier-class 10GE platform, $185,000 per port - 35% = ~ $120,000

Low end 10GE (non-carrier solution) new

Cisco 6509 w/SUP720, 4-port 10GE, 4xXENPAK

Part	Description	Price
WS-C6509	Cat 6509 Chassis, 9slot, 15RU	$9,500
WS-C6K-9SLOT-FAN2	Catalyst 6509 High Speed Fan Tray	$495
2xWS-CAC-2500W	Catalyst 6000 2500W AC Power Supply	$3,000
WS-SUP720-3BXL	Catalyst 6500/Cisco 7600 Sup 720 MSFC3 PFC3BXL	$40,000
WS-X6704-10GE	Cat6500 4-port 10 Gigabit Ethernet Module	$20,000
4xXENPAK-10GB-LR	10GBASE-LR XENPAK module	$4,000
Total	**With 35% (Conservative Discount)**	**$50,047**

Low end 10GE (non-carrier solution) used

Cisco 6509 w/SUP720, 4-port 10GE, 4xXENPAK

Used Part	Description	Price
WS-C6509	Cat 6509 Chassis, 9slot, 15RU	$3,000
WS-C6K-9SLOT-FAN2	(new)Catalyst 6509 High Speed Fan Tray	$495
2xWS-CAC-2500W	Catalyst 6000 2500W AC Power Supply	$1,000
WS-SUP720-3BXL	Catalyst 6500/Cisco 7600 Sup 720 MSFC3 PFC3BXL	$15,000
WS-X6704-10GE	Cat6500 4-port 10 Gigabit Ethernet Module	$10,000
4xXENPAK-10GB-LR	10GBASE-LR XENPAK module	$1,000
Total		**$30,495.00**

High end 10GE (carrier solution) new

Juniper M320 w/1 port 10GE PIC on FPC3, XENPAK

Used Part	Description	Price
M320BASE-DC	M320 DC Base Unit w/4xSIB RE-1600-2048 4xDC	$145,000
M320-FPC3	Flexible PIC Concentator, Type 3	$80,000
PC-1XGE-XENPAK	1-port 10 Gigabit Ethernet LAN PIC	$141,000
XENPAK-1XGE-LR	XENPAK 10GE Optics Module, 10GBASE-LR	$4,000
Total	**w/35% discount**	**$240,000**