THE BROADBAND INCENTIVE PROBLEM, Part II

a follow-on white paper prepared by the

Broadband Working Group

MIT Communications Futures Program (CFP)

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The publication of the Broadband Working Group's first white paper on "The Broadband Incentive Problem" stimulated healthy debate among members of the press, industry, and advocacy communities. The most frequently asked questions were "On what data are you basing your arguments?" and "How does this paper relate to the network neutrality debate?" In this brief follow-on paper, we address these and other questions about the original paper, and update the discussion based on newer data that has since become available.

In September 2005, the Broadband Working Group issued a white paper entitled "The Broadband Incentive Problem."[1] Briefly, the white paper argued that prevailing business models for broadband Internet access give wired and wireless broadband operators a perverse incentive to throttle many innovative but high-bandwidth uses of the Internet. Under prevailing business models, high-usage applications, when unaffiliated with access providers, have the potential to raise an access provider's costs more than their revenues. The incentive to limit or shut down such applications is perverse because users value these applications, and because their adoption has the potential to stimulate beneficial growth in other parts of the broadband value chain, such as device manufacturing and content provision.

Particularly after Congressional hearings on "network neutrality" focused the public's attention on related issues, we have received numerous queries regarding our paper. In this short follow-on piece, we answer frequently asked questions about the original paper, and update the earlier discussion based on newer data that has since become available.

What was the paper really trying to say?

Put bluntly: flat revenues + rising costs would not add up to a healthy, sustainable broadband industry.

Put more grandly: if broadband access providers (both wired and wireless) experience costs that rise faster than revenues, they will be unlikely to invest in the ongoing stream of network capacity upgrades that would be required for broadband to follow a Moore's Law-style curve. If this happens, industries in other parts of the broadband value chain, such as content and consumer devices, will also suffer.

Is this scenario likely to happen? Why might costs rise faster than revenues?

The future can never be known with certainty, and we were not trying to claim that this scenario would definitely come to pass. However, we did want to make the point that **the scenario in which broadband access providers' costs rise faster than their revenues should not be categorically dismissed.**

In particular, this problematic scenario would result from the confluence of the following five trends. The first three trends would limit revenue growth, while the fourth and fifth would raise costs:

1. Penetration growth slows as broadband access markets saturate;

2. Network operators, both wired and wireless, continue to offer access pricing plans that provide unlimited data network usage (even if tiered by maximum burst rate) for a fixed monthly fee, otherwise known as "flat-rate" pricing;

[1] The original white paper is available at http://cfp.mit.edu/groups/broadband/docs/2005/Incentive_Whitepaper_09-28-05.pdf

3. Network operators are unable to capture as much "value-added services" revenue as their current business plans would appear to expect;

4. The average bandwidth used by each customer rises, perhaps significantly, because of changes to user capability (such as through fatter access pipes) and user habits (such as through adoption of peer-to-peer applications for video distribution); and finally,

5. Bandwidth costs do not decline fast enough to keep usage-based costs from rising.

What data can shed light on the likelihood of each of these trends?

We view the instigation of public and private discussions around this question as one of the successful outcomes of the original white paper. These discussions particularly highlight the dearth of credible data in discussions (and indeed in formulation) of broadband policy. By definition, no one has more than speculative data about the future, and extrapolating from current trends has well-known dangers. That said, data about current trends is better than no data at all. Here is what we know about each of the five potential trends outlined above.

Trend 1: Penetration growth slows

Market saturation is by nature a matter of when, not if. The timing of this development will differ by region and technology (for example, wireless broadband markets in Finland will probably saturate in a different year from fiber-to-the-home markets in Japan; and, as the discussion in the original white paper showed, DSL markets have already saturated in S. Korea). As a result, there is no universal answer to the question of "how soon is the problematic scenario likely to appear," although interested readers can certainly do their own extrapolations from broadband penetration growth curves available from market researchers.

Trend 2: Flat-rate access persists

In developing the original white paper, the group conducted a non-exhaustive review of broadband pricing policies around the world, as of winter 2005. This review found significant variety and experimentation, including ISPs in the UK and Australia that charged subscribers based on usage volume; ISPs in Iceland and Portugal that placed explicit limits on usage, with more stringent limits for international traffic; and an ISP in Austria that limited usage only during peak hours. However, our review also found that in the U.S. and Korea – the largest broadband markets at that time by number of subscribers and penetration, respectively – the dominant (though not universal) pricing model was a fixed monthly fee, often tiered by peak access rate, with no explicitly stated limits on any individual user's overall traffic volume. Limits were being implicitly enforced, however, by some providers; not surprisingly, these limitations were most often evident in networks with the most limited (and therefore the most contended-for) resources, such as satellite broadband. Also not surprisingly, similar implicit limits on usage volumes have subsequently been reported in U.S. cellular broadband networks with all-you-can-eat pricing, as these wireless services have grown in popularity [4].

Not all providers are sticking exclusively to flat-rate pricing, however, and some are experimenting with usage-based pricing. As [4] documents, Sprint and Cingular's new cellular broadband services in the U.S. offer usage-based pricing plans at entry price points lower than their flat-rate offerings. In the U.K. at the time of this writing, BT's retail consumer DSL service is offered at three price points, all featuring a common 8 Mbps peak access rate, but distinguished by usage volume caps of 2, 6, or 40 GB per month.[2] Their competitor Orange UK also offers three price points, distinguished by combinations of access speed (1 vs. 8 Mbps) and usage volume limits (2 vs. 30 GB per month).[3]

Our previous paper was not trying to "prove" that flat rate access would persist. Rather, it was arguing that if flat rate *did* persist, it could lead to problematic scenarios, and that recognition of this possibility would motivate providers to want to move away from flat-rate pricing for access. However, for that shift to happen in practice, providers must find alternative pricing mechanisms that can succeed in the marketplace. One of the intentions of the original white paper was to stimulate thinking about alternative pricing mechanisms and focus attention on the related marketplace experimentation that is already taking place.

Trend 3: Provider revenues from value-added services are limited

The original white paper discussed several reasons why provider revenues from value-added services (i.e. services beyond basic access) might have a more limited upside than many operators would appear to be expecting. Most importantly, not all of the activities that generate value for users will have a "service" component that generates revenues for operators; for example, consider peer-to-peer file sharing applications, which are increasingly being employed for legally obtained content [7]. We also argued that value-added services offered by providers face competition from third parties, and that aggressive attempts by providers to favor their own services would be kept in check by the threat (if not the actuality) of regulatory intervention. This last observation led many readers to ask whether our paper intended to take a position in the network neutrality debates currently raging in Washington, DC.

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[2] BT's "Total Broadband" pricing plans are described at http://www.bt.com/broadband/bb_info.jsp?BV_SessionID=@@@@1329527289.1153983892@@@@&BV_EngineID=ccceaddigmkhhilcflgcefkdffndflh.0&obsNoSee=Y&vStore=1128&obsPage=/index.jsp&obsType=LINK&obsOID=112066

[3] Orange's broadband pricing plans can be found here: http://www.orange.co.uk/time/broadbandaccess/default.htm?WT.hplink=D2&cd_source=arthuradel&linkfrom=Today&link=link_2&article=oukhomeorangeshopv4prospect The 30 GB limit for the "unlimited" Broadband Max plan is inferred from the Terms of Service available here: http://www.orange.co.uk/terms/6923.htm?linkfrom=terms_internet_default&link=link_title&article=termsofusebroadband. In contrast, Comcast in the U.S. recently announced its "PowerBoost" service, which preserves flat rates but automatically raises peak downstream burst rates when spare capacity is available; it is free to customers who already subscribe to the company's 6 Mbps and 8 Mbps (peak-rate access) services [13].

The short answer is no. However, the discussion in the original paper does provide a framework for analyzing some of the arguments swirling through this debate. Third-party applications or services that consume significant network resources, such as the bandwidth consumed by always-on file sharing, can impose noticeable costs on networks; these costs will need to be recovered from somewhere. As a group, we did not take a position as to where such costs should be recovered from; however, **one of the intentions of the original white paper was to stimulate research and industry experimentation on pricing schemes that would enable such cost recovery directly from users, in market-acceptable ways**. We viewed this alternative as preferable to the common practice of automatically throttling such traffic, without giving users a chance to pay more to get more.

Trend 4: Per-subscriber usage volumes increase, possibly significantly

We focus on per-subscriber usage volumes because of their connection to revenues. While multiple sources have documented the aggregate growth rates of Internet traffic in different places and periods (for example see [8], [10], and [11]), some portion of this growth is driven by the addition of new users and therefore involves the generation of new revenues. The problematic scenario of a cost-revenue growth mismatch arises when *existing* subscribers raise their usage, without adding new revenues into the system (i.e. assuming flat-rate pricing).

For the original white paper, our understanding of this possibility was informed primarily by public and private data about Korea Telecom's experience, in particular data from KT's 2004 annual report on growth in the number of users, and data from [6] on aggregate traffic volume growth. S. Korea provides a particularly interesting harbinger of broadband trends because its fixed-line broadband market is already saturated. A graph in the original paper illustrated rapid growth in KT's traffic per subscriber. Table 1 complements that presentation by showing the annual percentage growth rates for KT's traffic per subscriber. Compounded, the per-subscriber traffic volume more than quadrupled over the 3-year period, 2001-4:

Table 1: Growth in KT's traffic per subscriber

Period	Growth rate
2001-2	42%
2002-3	75%
2003-4	64%
Total (2001-4)	307%

We were also aware of preliminary results of a novel and rigorous study being carried out in Japan, involving seven Japanese ISPs, several Japanese Internet researchers, and the Ministry of Internal Affairs and Communications, and focusing on the characteristics of residential broadband traffic [1]. Subsequent to the publication of our original white paper, an expanded and updated version of this group's findings became available [2]. This updated version is particularly interesting because it breaks out differences in usage among DSL and FTTH users, possible because by September 2005, Japan had 4 million FTTH users, up by more than a factor of two from the year prior. The results of this study are not only quite interesting in their own right, but consistent with ideas we discussed in the original white paper regarding changes in user behavior and traffic variance that seemed likely as access pipes get fatter.

Specifically, the Japanese researchers found that aggregate traffic increased 45% from November 2004 to November 2005 for the 7 ISPs they observed.[4] Normalizing this increase by the growth rate in total Japanese broadband users over roughly the same period (from about 12m in September 2004 to 14m in September 2005), we estimate that traffic per subscriber grew 24%.[5] This figure is substantially lower than the Korean increases in the 2001-4 period (Table 1), illustrating an expected variability in per-subscriber traffic growth rates across different markets and time periods.

The study's deeper analysis of particular segments within the data provides numerous interesting insights. First, about 70% of the traffic appears constant within the pattern of diurnal traffic fluctuations, suggesting that machine-generated traffic is a significant component of overall usage as well as a significant driver of overall traffic growth. Second, the data clearly demonstrate that subscribers use bandwidth more symmetrically when they have the option. That is, subscribers to symmetrical FTTH services produced more symmetrical traffic patterns, while subscribers to asymmetric DSL services maxed out their upstream traffic capability.[6] Third, rural subscribers do not behave differently from urban ones; lower traffic volumes in rural regions simply reflect their smaller overall number of users, not the nature of usage within each region, which is markedly similar.

Of particular interest is the study's examination of so-called "heavy hitters," defined as users who upload (i.e. send to their ISP) more than 2.5GB per day.[7] The study found that heavy hitters' traffic was more symmetric, and that the top 4% of heavy hitters used 75% of the total upstream traffic, and 60% of the downstream. However, the study also demonstrated that despite the visible change in slope of the cumulative distribution curves, there were no visible gaps in usage patterns. The distribution of usage volumes among

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[4] Participants in the Broadband Working Group confirm a similar growth rate for aggregate traffic measured at an Internet exchange during 2004-5. Similarly, [5] estimates 50% annual increases in aggregate U.S. Internet traffic.

[5] This assumes that the growth rate of subscribers to the 7 ISPs is not substantially different from the country as a whole. Unfortunately, the growth rate in subscribers for these 7 ISPs is not reported in the paper.

[6] We use "upstream" to refer to data flowing from the user to the ISP; [2] however adopts the ISP's perspective and refers to such traffic as "inbound." As the authors write (p. 13): "The inbound and outbound rates are roughly equal throughout our data sets. Many access technologies employ asymmetric line speed for inbound and outbound based on the assumption that content-downloading is dominant for normal users. However, this assumption does not hold in our measurements."

[7] 2.5 GB per *day* is selected because it is the (rough) knee of the log-log cumulative distribution curves. See especially Figures 15 and 16 in [2]. We note that some provider experimentation with usage caps has involved cutoff values as low as 10 GB per *month*, which may partially explain their unpopularity with users.

users is heavy-tailed, with no clean delineation point between "light" and "heavy" users.[8] As we observed in our original white paper, such a distribution makes the design of tiered or capped volume-pricing schemes particularly difficult.

The study's authors interpret these and other aspects of their data to mean that there is no clear application profile for particular types of users; rather, their results reflect a diverse portfolio of application types (e.g. streaming or downloading, vs. file-sharing) within each user's activities. In their words ([2], p. 12): "[H]igh-volume traffic is generated not only by peer-to-peer file sharing but also by other applications such as content-downloading from a single server. A plausible explanation for the large variance is that the majority of users use both file-sharing and downloading with different ratios." Again, this result reinforces the supposition in our earlier white paper that the variance among users might well increase as access pipes get fatter, making one-size-fits-all pricing that much more difficult to sustain.

Finally, the study found that there were proportionally more heavy hitters among FTTH users than among DSL users. Unfortunately, the study methodology does not enable the authors to distinguish whether the heaviest DSL users are simply the first to migrate to fiber, or whether fiber users become heavy hitters because they can. As the authors write:

> We can no longer view heavy-hitters as exceptional extremes since there are too many of them, and they are statistically distributed over a wide range. It is more natural to think they are casual users who start playing with new applications such as video-downloading and peer-to-peer file sharing, become heavy-hitters, and eventually shift from DSL to fiber. Or, sometimes users subscribe to fiber first, and then, look for applications to use the abundant bandwidth. The implication is that, if a new attractive application emerges, a drastic change could occur in traffic usage. ([2], p. 13)

This last point is especially worth noting in light of the fact that the huge leaps in usage occasioned by the original Napster's popularity were largely unforeseen by ISPs. Of course, no one can predict with certainty whether some new application or service involving video over the Internet will take ISPs by storm in the same way, but given the ferment in the video-over-IP space at the moment, and recent announcements such as Warner Bros.' use of Bittorrent's peer-to-peer video distribution technology, it is not improbable to imagine scenarios in which per-user traffic volumes grow rapidly.

Trend 5: Aggregate cost of bandwidth rises

This speculation generated a good deal of controversy, particularly from readers who argued that providers will simply be able to "overprovision" themselves out of rising usage

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[8] In their words: "Note that the difference is only in the slope of the distribution, and the boundary between the two groups is not clear. In other words, users are distributed statistically over a wide traffic volume range, even up to the most extreme heavy-hitters. There is no typical daily traffic volume per user that can be identified by a concave in the slope." See [2] p. 8.

scenarios. Overprovisioning was one of the commonly proposed solutions described in the original paper. Its advocates contend that (1) bandwidth costs are declining so fast that usage would have to grow much more than anyone expects in order to cause a problem, and (2) even if that did happen, bandwidth costs are starting from a negligible proportion of major ISP's expenses in any case.

We have no public data with which to confirm or deny contention (2), so we do not discuss it further here, other than to note that the scale and location of an ISP clearly affect the validity of this assumption.[9] Contention (1), however, we were able to examine based on two public sources of data. The results are mixed.

One data set consists of the rates of bandwidth price decline published by the market research firm TeleGeography, in sample reports freely available on their web site (in particular [10] and [11]). Figure 2 of [10] and Figure 3 of [11], reproduced for convenience below, illustrate several salient points. First, bandwidth prices and their rate of change vary considerably by geography; from 2003 to 2004, price declines ranged from about 15% on trans-Atlantic routes to about 40% on intra-Asian routes. Such variability helps explain why pricing policies vary so considerably in different parts of the world.

Second, evidence is accumulating that at least in the more developed parts of the world, price declines had leveled off considerably by 2005, suggesting that the extremely rapid rates of decline that characterized the first half of the decade may in fact have represented somewhat of a historical anomaly.[10] Figure 4 of [10] suggests a 2006-7 end to the capacity overhang from the telecom bubble; the report predicts that this factor will combine with ongoing growth in aggregate demand and industry consolidation to lead to a closer balance between supply and demand in the future, as capacity is added by incremental lighting of already installed fibers, rather than by onslaughts of new construction.

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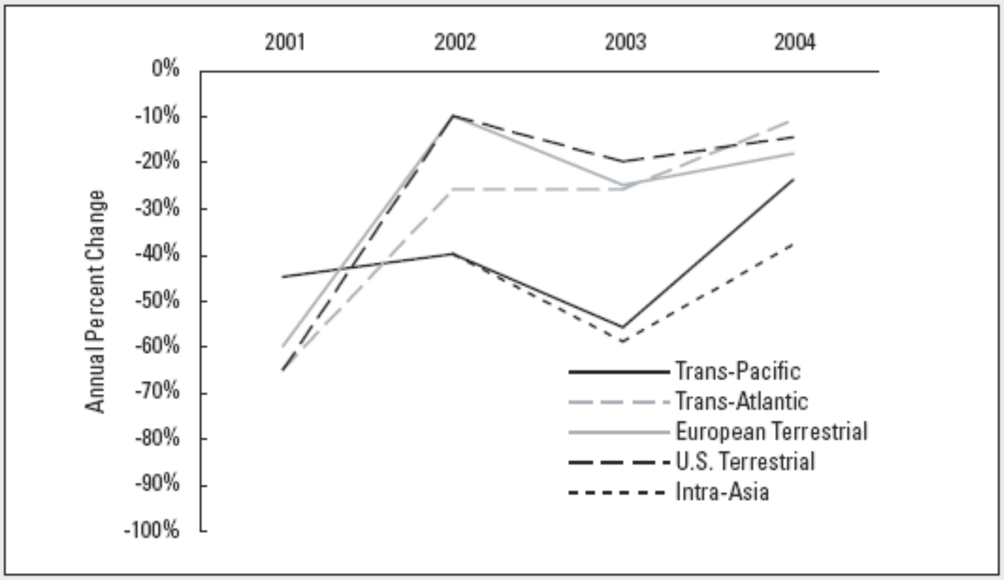
[9] In particular, Dave Burstein, author of the DSL Prime Newsletter (http://www.dslprime.com/), claims the validity of contention (2) based on private data.

[10] This conclusion is consistent with the analysis in [14] which infers the unsustainability of such rapid rates of price decline based on historic learning curve data for networking equipment.

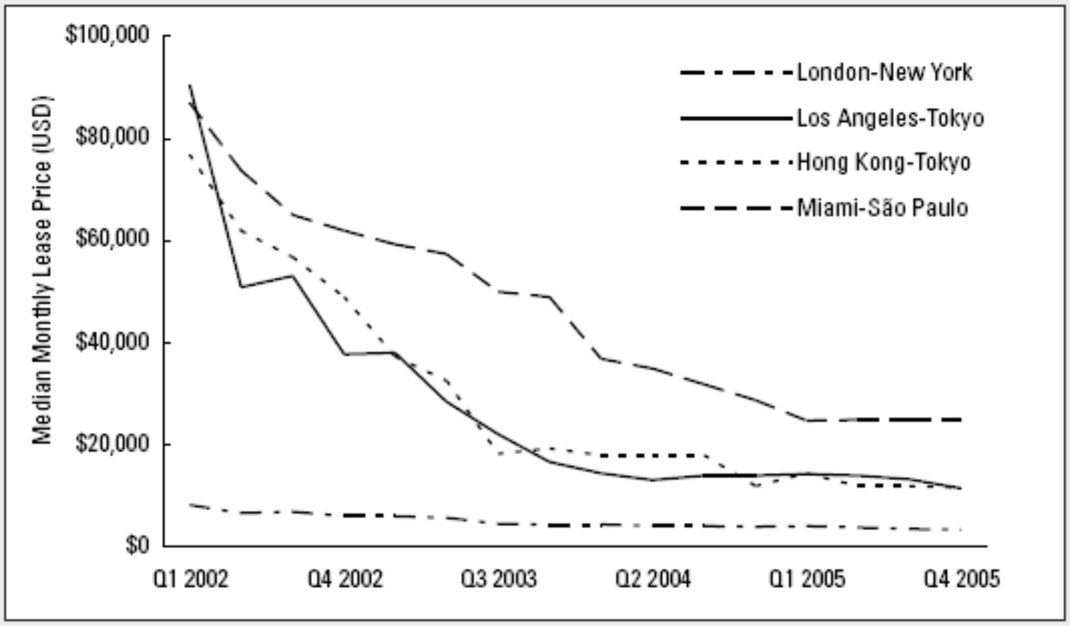
Figure 2. OC-3/STM-1 Pricing Trends, 2001-2004



Notes: Data reflect median OC-3/STM-1 monthly lease price changes between the fourth quarter of each year, exclusive of installation fees. Price changes on Intra-Asian routes in 2001 were unavailable.

Source: TeleGeography research

Figure 3. STM-1 Price Trends, 2002-2005



Notes: Price reflects median STM-1 monthly lease prices, exclusive of installation fees.

Source: TeleGeography research

The working group also assembled its own data set, consisting of estimated transit prices available at major Internet exchange points for a 1 Gbps commitment, as shown in Table 2. From these data we estimated a 35% annual price decline for transit bandwidth prices during the 1999-2005 period.[11] Because the underlying data are gathered from different sources, this rate is not necessarily representative of any particular route or carrier's offering. However, its consistency with the range of price declines shown in the TeleGeography data reinforces the credibility of that data.

[11] The 2002-3 data points are inferred based on the price decline computed from the 1999 and 2005 endpoints. Put another way, we solve 20.73 = 281.01*(1-r)^6, and find r = 35.2%. The rate of price decline is a better way to characterize bandwidth price trends than the absolute price quotes shown in Table 2. Absolute prices are known to vary considerably based on the term and size of the circuit purchased, as well as by region (see [10] and [12]). In addition, the prices shown in Table 2 represent marginal prices available at bandwidth exchanges; a provider seeking to balance costs and revenues, however, would concern itself with average costs, which are typically higher.

Table 2: Price Declines for Transit Bandwidth

Year	Price ($/Mbps/mo based on purchase of 1 Gbps)
1999	$281.01
2000	$182.09
2001	$118.00
2002*	$76.46
2003*	$49.55
2004	$32.11
2005	$20.73

*inferred, see note **Error! Bookmark not defined.**

Sources:

1999-2001: [3], Figure 7 (p. 49);

2004: http://www.merit.edu/mail.archives/nanog/2004-08/msg00178.html;

2005: http://www.nanog.org/mtg-0505/norton.html

If bandwidth prices were to continue declining in the range of 5-40% annually, how fast could traffic grow each year such that a broadband providers' overall expenditures on bandwidth would remain constant? Figure 1 aids such sensitivity analysis by illustrating the constant traffic cost frontier for usage growth rates from 5 to 100%, and price decline rates from 5 to 50%.[12] The frontier itself represents constant expenditures on bandwidth, while points above or below it represent increasing or decreasing overall expenditures on bandwidth, respectively. From Figure 1 it can be seen that for the 5-40% range of annual price declines, annual usage can grow 5-65% (respectively) without raising traffic costs.

[12] The computation proceeds from the assumption that the product of price and quantity of bandwidth used (the total bandwidth cost) remains constant from year-to-year. For example, for a 35% annual price decline, the intuition for the corresponding supportable 54% traffic increase can be gotten by observing that if the price in year 2 is 2/3 of the price in year 1, then the quantity can increase by 3/2. Algebraically, $Q_2 = (1+r) * Q_1$, where r is the rate of bandwidth growth shown on the x-axis in Figure 1, and $P_1*Q_1 = P_2*Q_2$. Therefore, $P_2/P_1 = Q_1/Q_2 = 1/(1+r)$. For the graph's y-axis, this ratio is expressed in percentage terms by subtracting 1 from the result. The graphical presentation of this computation was inspired by [11], Figure 4, p. 16.

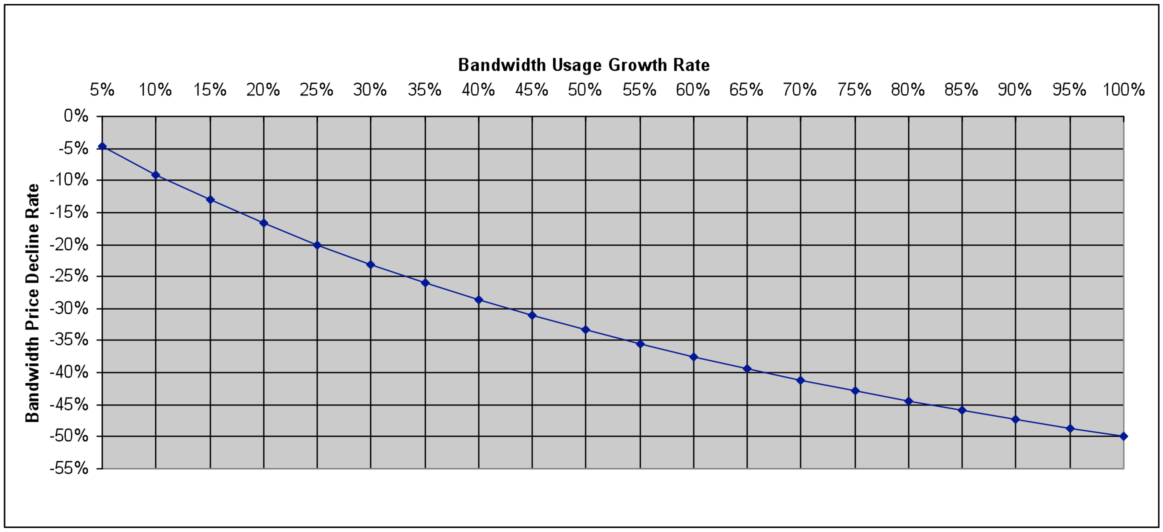


Figure 1: Constant Traffic Cost Frontier

The challenge posed by this large range is the wide margin of uncertainty it creates. If future price declines are closer to the 5-15% annual rate, then continued per-subscriber growth at the rates estimated in the previous section (24% for Japan, and see Table 1 for Korea) would be quite problematic. If on the other hand future price declines are in the 30-40% range, usage growth would appear problematic in some years and not in others. As the Japanese data discussed above illustrate, the introduction and adoption of new applications and services is an unpredictable process that leads to correspondingly unpredictable fluctuations in usage levels. Since carriers do not want their margins to be equally unpredictable, they are likely to respond quickly to constrain usage growth if it appears to be even heading towards the problematic range.

Conclusions

The data presented above suggest that, as subscribership and per-subscriber usage continue to grow, broadband operators' overall traffic costs may very well increase. Whether that increased spending is a problem or not obviously depends on revenue-side factors as well, underscoring the importance of per-subscriber analyses, particularly as a broadband market approaches saturation.

With so much uncertainty surrounding their costs, it should hardly be surprising that broadband providers would seek ways to increase their revenues, in particular through differentiated pricing. As [9] discusses, the motivations for network operators to find market-acceptable ways to offer price and quality-differentiated services are very strong; however, the ISP industry has so far not converged on models that work beyond the bounds of a single provider. Such models would need to address not only the technical aspects of quality-differentiated interconnection, but also any pricing and public policy issues. In addition, agreements would need to involve not only traditional network operators, but also the end-user-mediated and ad-hoc networks that additionally comprise the Internet.

Enabling differentiated service quality across multiple network providers has been the focus of CFP's inter-provider QoS working group. We expect these efforts to continue, whether within that working group or a follow-on. To the extent these efforts help providers differentiate services and associated pricing on an end-to-end basis, they can thus be viewed as progress towards solutions to the broadband incentive problem.

As with our original white paper, our motivation in exploring this topic further has been to stimulate experimentation with a broader range of approaches and experiments, in search of mechanisms that customers find acceptable. The time has come for the broadband industry to think seriously about alternative pricing mechanisms that can remove the perverse incentive for network operators to throttle bandwidth-hungry innovations that they do not "own," but that are nevertheless an essential component of the broadband Internet's appeal and value to users.

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Comments on this white paper should be directed to William Lehr, wlehr “at” mit.edu, and John Watlington, john.watlington “at” francetelecom.com.

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