

# Internet Access Pricing in a Post-IPv4 Runout World

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Lee Howard, Time Warner Cable

## Abstract

*The American Registry for Internet Numbers (ARIN) will no longer be able to allocate IPv4 addresses in 2013<sup>1</sup>, forcing North American Internet Service Providers (ISPs) to consider how they will support customers following IPv4 runout. IPv6 is the long-term solution, but many consumers will continue to have IPv4-only home electronics, and may want to reach IPv4-only Internet content. Various strategies, including Carrier-Grade NAT (CGN) and purchasing allocated but unused addresses, may cover the transition to all IPv6, but since they have different costs to ISPs and quality for consumers, pricing may vary among alternatives. This paper will examine costs, possible pricing models for CGN, an IPv4 market, and native dual-stack.*

## Introduction

During the transition to IPv6, consumers will continue moving, switching providers, and adding Internet service. This paper attempts to model the costs of Carrier-Grade NAT (CGN) and of buying IPv4 addresses on an IPv4 transfer market. Based on cost models, one can predict what rational ISPs will do, and may be able to make some predictions about the shape and time of the transition.

This paper is U.S.-centric, using dollars and U.S. ISPs as examples. However, the models should be applicable in other markets. Numbers given are approximations based on public data wherever possible, but costs, prices, margins, and so on, will vary for any particular ISP. Any variance in local conditions may change the exact outcome, but the general conclusions should still apply. Mobile wireless carriers already have significant CGN deployments, but those connections are used differently than fixed wireline access providers. Fixed wireless implementations, whether microwave or LTE, may tend to have the same problems as wireline providers, and therefore the same additional costs.

Many consumers will have devices that only support IPv4. In the U.S., 120 million households<sup>2</sup> have 80 million IPv4-only game consoles such as Microsoft Xbox<sup>3</sup>, Sony PlayStation<sup>4</sup> or

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<sup>1</sup> <http://www.potaroo.net/tools/ipv4/index.html>

<sup>2</sup> <http://quickfacts.census.gov/qfd/states/00000.html>

<sup>3</sup> [http://en.wikipedia.org/wiki/Xbox\\_360](http://en.wikipedia.org/wiki/Xbox_360)

<sup>4</sup> [http://en.wikipedia.org/wiki/PlayStation\\_3](http://en.wikipedia.org/wiki/PlayStation_3)

Nintendo Wii<sup>5</sup>. In addition, some 60 million other IPv4-only Internet-capable devices have been sold, including such devices as TiVo<sup>6</sup>, Blu-ray players<sup>7</sup>, and Apple TV<sup>8</sup>. None of these companies have committed to support IPv6 on these devices.

ISPs signing up new users have few options to support these consumers once IPv4 addresses are no longer nearly free from ARIN:

- Declare that Xbox, PS3, Wii, TiVo, Blu-ray, and video devices are not supported.
- Use their last few IPv4 addresses for Carrier-Grade NAT.
- Buy IPv4 addresses on the address market.

Unless the cost is very high, it is unlikely that ISPs will choose to declare that common consumer electronics will not work on their networks. In evaluating the other options, ISPs will consider both the cost to the ISP and the cost/experience to the consumer.

### Carrier-Grade NAT

Carrier-Grade NAT (CGN) is also referred to as Large-Scale NAT (LSN), and commonly understood as meaning NAT44, or sharing one IPv4 address among many IPv4 customers. In most cases, Dual-Stack Lite (DS-Lite) is equivalent in costs and problems.

The costs of a CGN include the direct capital outlay for the appliance and associated logging system. Further, one of the greatest concerns about CGNs is that law enforcement will be unable to track criminal activity to a specific subscriber (since many will share the same IPv4 address); the ISP will have to update software used to look up users based on subpoena information. Finally, all of these systems will require staff to maintain them, which is a recurring operational expense.

<b>\$70,000</b>	CGN hardware <sup>9</sup>
<b>\$10,000</b>	Logging systems <sup>10</sup>
<b>\$10,000</b>	Software development <sup>11</sup>
<b>\$90,000</b>	CAPEX per 10,000 users

<sup>5</sup> [http://en.wikipedia.org/wiki/Wii#System\\_sales](http://en.wikipedia.org/wiki/Wii#System_sales)

<sup>6</sup> <http://investor.tivo.com/phoenix.zhtml?c=106292&p=irol-newsArticle&id=1567404>

<sup>7</sup> [http://bluray.highdefdigest.com/news/show/High-Def\\_Retailing/Industry\\_Trends/Blu-ray/Blu-ray\\_Players/Research/Data\\_Points\\_to\\_a\\_Strong\\_Year\\_for\\_Blu-ray/6829](http://bluray.highdefdigest.com/news/show/High-Def_Retailing/Industry_Trends/Blu-ray/Blu-ray_Players/Research/Data_Points_to_a_Strong_Year_for_Blu-ray/6829)

<sup>8</sup> [http://en.wikipedia.org/wiki/Apple\\_TV#Sales](http://en.wikipedia.org/wiki/Apple_TV#Sales)

<sup>9</sup> An estimate based on list price from multiple CGN vendors. These devices are often simply interface cards in existing routers, so portion of the chassis cost may be included. Note that ISPs may negotiate better than retail.

<sup>10</sup> Assuming use of bulk port assignment or similar algorithm, so a typical server with significant disk array, and data retention for 12-24 months is sufficient.

<sup>11</sup> Software development is a one-time cost for an ISP, which can be scaled across the entire user base. However, smaller ISPs have less automation and simpler systems, so the cost is the same order of magnitude per ten thousand. Assumes a 100,000-user ISP spends 6 labor-months developing, testing, and deploying software.

<b>\$10,000/year</b>	Space, power, cooling, support contract, monitoring, monitoring, maintenance, staff support
<b>\$10,000</b>	Annual OPEX per 10,000 users

**Table 1 – Capital and Operational Costs for CGN per 10,000 Users**

Table 1 shows a simplified list of CGN costs, estimated for each 10,000 users. The initial costs may be depreciated over several years. At the end of its service life as a CGN, the device may be used as an application server, load balancer, or firewall.

In addition to higher cost of goods sold, CGN has been documented to provide a poorer user experience<sup>12</sup>. In particular, users who communicate directly with other users, rather than with web content providers, tend to have problems with shared addressing. These applications include peer-to-peer file sharing, head-to-head gaming, and some forms of voice-over-IP service.

It must be assumed that some of the affected users will call the ISP for support, but some will simply cancel service and switch to another ISP. Since ISPs will feel pressure from IPv4 exhaustion at different rates, for a consumer in a market where two or more ISPs compete, the first ISP(s) to deploy CGN may lose customers. Of course, if many consumers in a market suddenly switch, the other ISP may find increased pressure on its available IPv4 addresses. If all ISPs in a market have deployed CGN, then there is no outlet for frustrated consumers.

Given 80 million Xbox and PlayStation consoles in 120 million households, three quarters of potential customers could potentially have problems. Peer-to-peer applications are used by approximately 15% of Internet users.<sup>13</sup> In addition, Netflix is one of the most common content sites, used by nearly 10% of American Internet users<sup>14</sup>. Not all of these consumers will use the applications in ways or environments that are problematic, of course (for instance, not all Xbox owners use online gaming, and not all Netflix users have gateways that have trouble with CGN). If we suppose that half of potentially affected users actually see problems, and that among those, 25% will call ISP tech support, 25% will change ISPs, and 50% will suffer in silence<sup>15</sup>, then for every 10,000 users:

Use	Number of Potential Users	Number Affected	Number of Support Calls	Number of Lost Users
<b>Xbox</b>	2100	1050 <sup>16</sup>	262	262
<b>PS3</b>	1100	550 <sup>17</sup>	137	137

<sup>12</sup> <http://tools.ietf.org/html/draft-donley-nat444-impacts-02>

<sup>13</sup> 9% of Internet users use p2p, according to IFPI Digital Music Report 2010, [www.ifpi.org/content/library/DMR2010.pdf](http://www.ifpi.org/content/library/DMR2010.pdf)

<sup>14</sup> 24 million users, per Netflix letter to shareholders: [Guidance\\_Update\\_Sept\\_2011\\_final.pdf](#) or 11%.

<sup>15</sup> There is no reference for these numbers.

<sup>16</sup> Assumes 50% of Xbox users play online and will have problems.

<sup>17</sup> Assumes 50% of PS3 users play online and will have problems.

<b>P2P</b>	1500	1200 <sup>18</sup>	300	300
<b>Netflix</b>	1200	60 <sup>19</sup>	15	15
<b>Misc.</b>	800 <sup>20</sup>	800	200	200
	6,700	3,660	914	914

**Table 2 –Cost of Service Impact for CGN per 10,000 Users**

For an ISP whose typical support call cost is \$20<sup>21</sup>, the increased support cost of CGN is \$18,280 per 10,000 users. For an ISP whose average revenue per unit (ARPU) is \$400/year<sup>22</sup>, the total revenue lost to CGN is \$365,600 per year per 10,000 users.

Year 1	Year 2	Year 3	Year 4	Year 5	
\$18,000	\$18,000	\$18,000	\$18,000	\$18,000	CAPEX (depreciation)
\$10,000	\$10,000	\$10,000	\$10,000	\$10,000	OPEX
\$18,280	0	0	0	0	Customer support
\$365,600	\$365,600	\$365,600	\$365,600	\$365,600	Lost revenue
\$411,880	\$393,600	\$393,600	\$393,600	\$393,600	TOTAL: \$1,986,280

**Table 3 –Cost of Service Impact for CGN per 10,000 Users**

Thus, the total cost of CGN is \$200 per user, over five years; about \$40 per year.

The use of CGN does require some unique IPv4 addresses, to be shared among the users behind the CGN. At a sharing ratio of 10-100 users per address, the cost per ten thousand users is 0.1 or 0.01 times the price per address. The next section contains a discussion of address pricing. An additional cost of \$0.40 - \$7.00 per user should therefore be applied; because this estimate is so broad, it is not included in the table above.

It should be noted that some problems can be resolved with a new home gateway (which should support IPv6). That option is not available for users who do not complain, or silently switch, of

<sup>18</sup> Assumes 80% use BitTorrent or similar client, which enforces a upload-to-download ratio. “Leeches” are not permitted to download any more content is their ratio falls below a certain threshold, and “seeding” is not possible behind CGN. Thus, all BitTorrent (and similar) users will be affected.

<sup>19</sup> As documented in draft-donley-nat444-impacts, a few popular home gateways have a problem with Netflix when behind CGN. Here, we assume 5% of gateways are so affected.

<sup>20</sup> Includes additional problems from draft-donley-nat444-impacts, and allows for some unknown problems.

<sup>21</sup> (ASP) Says \$36.14, but possibly lower (\$5-10) with offshoring.

<sup>22</sup> An average, rounded to the nearest hundred, based on the quarterly reports for 3Q-2011 of Comcast, Verizon, and Time Warner Cable.

course. It is possible that other users can be saved by offering them globally unique IPv4 addresses, which will be considered in the next section.

It should further be considered that companies responsible for these systems may add IPv6 support, and indeed are likely to, if their customers find no ISPs without CGN.

## Buying IPv4 Addresses

The American Registry for Internet Numbers (ARIN) has a policy allowing organizations to transfer addresses directly between each other, within certain limits.<sup>23</sup> The purpose of the policy is to allow organizations that need IPv4 addresses to motivate organizations with an abundance of address space to make surplus address space available.

As of this writing, two major address transfers have been made public: address space sold from Nortel's bankruptcy proceedings to Microsoft for \$11.25 per address<sup>24</sup>, and address space sold from Borders's bankruptcy for \$12.00 per address<sup>25</sup>. Both of these transfers are remarkable, not just for the price paid, but for the fact that they occurred at a time when ARIN still had enough address space to meet the need for a fraction of the cost<sup>26</sup>. There are some unusual attributes to these cases: they covered "legacy," or pre-ARIN space, and the transfer occurred out of bankruptcy, which might have special legal properties. However, brokers have expressed a reluctance to accept a significantly lower price, at least for large blocks of IPv4 addresses.

Based on (Edelman, 2011), since prices include an expectation of the future value of a product, market prices for addresses will be at their highest just as ARIN nears run-out. At this writing, ARIN exhaustion was predicted for early 2013<sup>27</sup>. A few constraints on the price of addresses can be assumed. There will be pricing support at \$12.00 per address, a well-known existing price. After run-out, more address holders may become aware of the possibility of transferring space for a fee, which could result in further downward pressure.

The sale price is also unlikely to exceed the profit value of an individual subscriber. For a typical \$400 per year subscriber at an ISP with a 35% profit margin<sup>28</sup>, the annual profit would be \$140 per address.

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<sup>23</sup> ARIN requires the receiving organization to demonstrate that it needs the addresses; that is, will use them within 12 months. This is to prevent addresses from being bound up by speculators.

<sup>24</sup> [http://www.theregister.co.uk/2011/03/24/microsoft\\_ip\\_spend/](http://www.theregister.co.uk/2011/03/24/microsoft_ip_spend/)  
<sup>25</sup> [http://www.theregister.co.uk/2011/12/05/borders\\_flogs\\_ipv4\\_addys/](http://www.theregister.co.uk/2011/12/05/borders_flogs_ipv4_addys/)

<sup>26</sup> ARIN does not charge per address, but assesses fees by size. The fee for ISPs generally works out to well under \$1 per address.

<sup>27</sup> <http://www.potaroo.net/tools/ipv4/index.html>

<sup>28</sup> An average of the margins reported by Comcast, Verizon, and Time Warner Cable, for their Internet service, in Q3-2011.

This ceiling assumes ISPs maintain their current prices; as long as customers will pay higher prices to cover the cost of addresses and margin, there is no ceiling. That is, the ceiling for addresses is only as high as consumers are willing to pay for them.

The option of CGN will also limit the amount ISPs are willing to spend. An ISP would not spend more than it would save. CGN is not a perfect substitute, but will suffice in many cases. At a \$200 cost, though, a significant portion of the \$700 profit is eroded.

The ceiling may in fact be much lower, since ISPs are unwilling to surrender all, or usually even most, of their profit margin. Absorbing \$40 for a \$400 customer will reduce margins from 35% to 25%. When the price of an IPv4 address exceeds half of the profit of a customer, it is more profitable to sell the address than to provide service to the customer. For instance, once an ISP has run out of IPv4 addresses, when the price of addresses reaches \$71, if ISPs maintain prices, the annual profit from a \$400 customer is only \$69, or 17% margin. At this point, the ISP that can sell addresses for \$71 would be more profitable (in the one-year time frame) than the ISP buying addresses to activate new customers. This profit line of around \$70 provides one more layer of resistance to IPv4 market prices.

If an ISP expects to retain its customers for two or more years, this price ceiling may be higher, although the return on investment of the IPv4 address is longer than a year.

Thus, until addresses reach \$40 per IPv4 address, there is no reason to deploy CGN. At that point, market price increases will slow, as CGN provides an alternative. If fragmentation of address space drives operators to filter routes based on prefix length, affected address space will be less desirable. Once addresses exceed \$70 per address, ISPs will give native IPv4 to fewer users; most new users will have IPv6-only, or maybe IPv6+CGN. Beyond that point, the value of addresses will stabilize or decline generally, as ISPs can realistically convert more users to IPv6-only service (or possibly IPv6 plus CGN) than their net new subscribers.

## **Pricing Models**

An ISP could reasonably determine that above \$40 per address, the best path forward is to provide CGN service where possible, and unique IPv4 service where needed to prevent the loss of disgruntled customers from CGN.

There are two ways to determine whether a customer needs unique IPv4 addresses. First, an ISP can use deep-packet inspection (DPI) to search an existing customer's traffic for applications known to fail behind CGN, and if none of the known-problematic traffic is seen for a sufficient period of time, the customer could be converted to CGN without interrupting service. This method has the drawbacks that DPI is expensive, individual users' traffic profiles are sensitive information that ISPs may not want to keep, and it assumes that a user will never change how they use their service.

The second method is to allow users to select the service appropriate to them. For instance, at sign-up or renewal time, an ISP could present options:

1. Basic Internet. Provides web and email only. This service is behind a CGN, and gaming consoles and peer-to-peer file sharing may not work behind it.
2. Advanced Internet. Provides access to all Internet services. Includes a globally-unique IPv4 address (the user may not be guaranteed that this address will remain the same).

In a cost-recovery pricing model, the Basic Internet service would cost \$40 per year more than existing Internet service (the cost of the CGN), and Advanced Internet service would recover the \$40-70 that addresses cost on the market. Self-selecting Basic (CGN) users will be less likely to complain or cancel; if 10% as likely Pricing the Advanced Internet service, however, includes the risk that prices for addresses will rise. This risk is compounded by the fact that since it provides a better experience, all users might choose it over a comparably-priced Basic service.

However, an ISP does not necessarily want to drive users toward a CGN service, which is more complicated to build and operate, and has a short operational life (it should no longer be needed once IPv6 is ubiquitous). The CGN service only makes sense if it is cheaper than buying addresses, which is when the price is above \$40 per address. An ISP pursuing a pricing strategy based on this model would need to track IPv4 market prices closely, which is problematic since transactions may not be made public.

To provide pricing stability, therefore, an ISP considering these options would need to price Basic service at least \$40 above its previous service, and Advanced service above that. It may not want to establish any price distinctions before market prices exceed the CGN threshold. Of course, to preserve margins, ISPs are likely to mark up their additional costs. Given the 35% margin above, Basic would be an additional (\$40+35%) \$54, and Advanced would be (\$70+35%) \$94.50 per year:

Price before scarcity	Basic Internet (CGN)	Advanced Internet (status quo)
<b>\$33/month</b> <b>\$400/year</b>	\$37.83/month \$454/year	\$40.88/month Up to \$495/year

**Table 4 – Pricing Model**

Margin before scarcity	Basic Internet (CGN)	Advanced Internet
<b>\$140 on \$400 ARPU</b> <b>35%</b>	\$100 on \$400 ARPU 25%	\$70 on \$400 ARPU 17.5%

**Table 5 – Effects on Margin if Prices Do Not Change**

Consumers can be expected to be unhappy with price increases for the same service, or for lesser service. ISPs may instead elect to trim their margins, to continue remaining price-competitive.

The exact point where any given ISP would stop selling IPv4 service would depend on the total lifetime profit value of the customer; beyond that profit, it becomes more profitable to sell IPv4 addresses than to provide service. Thus, ISPs with “stickier” or higher-priced services may continue offering Advanced service, but only for as long as their customer lifetime. The ISP may want to offer IPv6+CGN or IPv6-only service, even when the Advanced service is unprofitable.

### **Life Span of CGN and IPv4**

The window where CGN makes sense is only while address prices are between about \$40 and \$70.

It could be concluded that when addresses reach \$40, the average lifetime for native IPv4 service will be equivalent to the average lifetime of an Internet access contract. After that time, ISPs will adjust pricing to sort customers into native and CGN services. By the time of the following contract renewal, enough of the Internet will have moved to IPv6 to make IPv4 redundant.

The earliest that address prices will reach such a level is three months following ARIN run-out. Prior to ARIN run-out, addresses are essentially free, for any amount an ISP needs in the next three months. Assuming ARIN run-out in early 2013, and postulating an average customer lifetime of 18 months, the earliest date when IPv4 service is no longer viable is late 2014. To ensure interoperability, ISPs should ensure that all of their customers and services are running IPv6 before the end of 2014.

The actual date may be much later. The rate of increase of Internet users in North America may be low enough in comparison with available addresses that the inflection point does not happen for several more years. If that is the case, and ISPs have deployed IPv6 to all customers (not just new customers, since customers expect to communicate between each other) before then, it may be possible to avoid CGN altogether.

### **Encouraging IPv6**

Regardless of whether an ISP uses CGN or an IPv4 address market to extend their local run-out crisis, they will have to provide IPv6 connectivity eventually. IPv6 provides the only long-term solution. It is considerably cheaper than extension options, since nearly all modern networking hardware can support it, with software upgrades. Hardware or software updates be done during normal upgrade or replacement cycles, which is a good use of the time gained by CGN or address markets.

Many ISPs provide a modem and gateway to their customers. They will need to retire old equipment through attrition, and eventually actively reclaim devices, to effect the transition. For ISPs who do not provide equipment, further pricing options could be presented to encourage customers to upgrade their own equipment to support IPv6.

The cost of deploying IPv6 depends on the speed at which it needs to be deployed. Assuming a five-year hardware replacement cycle, then a five-year plan to deploy IPv6 means there is no hardware cost. A four-year deployment plan has a hardware cost equivalent to the last year of depreciation on the hardware (thus, 20% of hardware costs for straight-line depreciation). Of course, since most modern hardware does support IPv6, it may be that even a two-year deployment plan incurs little or no hardware cost, as the previous generation already works (possibly with a software upgrade). ISPs with older hardware, including customer premise equipment, will be at a disadvantage, since older equipment will have to be replaced.

Most operations support systems, including monitoring and management systems, support IPv6 in their current versions. ISPs may find they have to upgrade their software, but most software is updated every few years. A shorter deployment schedule means great cost to deploy IPv6.

Most ISPs have some systems developed in-house. These systems are often updated at about the same cycle as off-the-shelf software, and these updates can incorporate IPv6 changes for a marginal increase, generally about 10-15% of the cost of the software. A shorter deployment will have the same cost, but a high opportunity cost, since other projects will have to wait for IPv6 development to complete.

In short, an ISP with a five-year IPv6 deployment plan has very little cost (assuming it does not have to buy IPv4 addresses or deploy CGN due to its long transition time). The longer an ISP waits to start its deployment, the more expensive it will be.

Ongoing operational cost of a dual stack network will include operations, routing troubleshooting, routing policy, security policy, and traffic engineering, and of which could increase significantly (probably no more than double) in a dual stack network. Engineering and operations personnel costs may increase, since new features have to be designed, tested, and implemented in both address families. This additional cost may be 5% or less, since most new features are not specific to IP addressing, and for those that are, once a test is set up, running it again on the other address family is generally fast. Troubleshooting is most common at the data link layer, so once an IPv4 address is pingable, adding a ping6 test is a small increment.

One may attempt to align revenues with costs by billing customers in proportion to the IPv4 traffic they send or receive. With appropriate bit-counting techniques, an ISP could bill IPv4 bits at a higher rate than IPv6 bits. The rate difference could reasonably be set at the cost difference between IPv4 and IPv6, which--at the point of deploying CGN--is about 30% (see Table 4). Given the overall costs of CGN and the IPv4 address market, avoiding them altogether would be preferable. An ISP may consider that it could avoid those significant additional customer acquisition costs if IPv6 is in wide use before addresses hit the CGN threshold. It may make

sense to spend a fraction of that CGN per-customer cost for each of the new subscribers it expects in an effort to encourage ubiquitous industry adoption of IPv6, so that IPv4 can be reclaimed and used for limited cases only. For example, an ISP expecting to spend \$200,000 for CGN in 2014 may prefer to spend \$40,000 now on IPv6 encouragement, if it could be assured that the encouragement would prevent the need for CGN.

## Conclusions

As shown in the CGN discussion the total cost per user of CGN is about \$200, or \$40 per year. This price presents an upper resistance level on the likely price of IPv4 addresses in a transfer market. A second ceiling is provided by the marginal value of a subscriber, about \$70. These results provide a matrix of guidance to ISPs.

	\$0 - \$12	\$12 - \$40	\$40 - 70	\$70+
ISP Action	Business as Usual	Buy IPv4 Addresses as needed.	Drive customers to CGN. Charge more for Native IPv4.	Provide IPv6-only service, sell IPv4 addresses.

**Table 5 – Action to Be Taken at Various IPv4 Price Points**

ISPs are able to negotiate prices for CGN hardware, logging systems, support calls, and so on, so these numbers are not precise. The variance is small enough that even where the numbers change, the conclusion is the same: begin deploying IPv6 now.

## Works Cited

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## Acknowledgements

I would like to thank Ben Edelman of Harvard University for his generous review and advice.