Buying numbers: An Empirical Analysis of the IPv4 Number Market

Milton L. Mueller
Syracuse University
Mueller@syr.edu

Brenden Kuerbis
Syracuse University
and University of Toronto
bkuerbis@gmail.com

Abstract

The emergence of a trading market for previously allocated Internet number blocks is an important change in Internet governance. Almost all of the Internet's 32-bit address space has been given out, and we have not migrated to a new internet protocol, IPv6, with a larger address space. IP addresses are therefore being commoditized, as organizations with surplus numbers sell address blocks to organizations that want more. Though controversial, we know little about this phenomenon. This paper quantifies the number of address blocks that have been traded as of July 2012 and analyzes the scant information that exists about the pricing of these resources, discovering the emergence of a billion dollar market. The paper then shows how this factual information relates to key policy debates, in particularly the role of needs assessment and property rights in IPv4 number blocks.

Keywords: Internet governance, IP address markets, IPv4 scarcity, IPv6 migration, property rights

Introduction

One of the most important but least-studied aspects of Internet policy is the emergence of a trading market for previously allocated Internet number blocks. Without unique Internet protocol numbers for the networks and devices attached, the Internet simply doesn't work. The original Internet Protocol standard, known as IPv4, specified a 32-bit numbering space, which provided slightly less than 4 billion unique numbers that could be used as addresses (Postel, 1981). A large part of that number space has already been handed out to organizations. The available supply is dwindling. The Asia-Pacific region is already reduced to rationing its last /8 in tiny 1024-address chunks, one to an organization. The European region is only a few months from that status.

Recent market developments and policy changes by Internet number registries now allow organizations with more numbers than they want to sell them to another organization. In other words, a market for IPv4 numbers is now possible. This is a major change in the political economy of Internet governance. IP numbers were considered common pool resources and registry contracts allocating number blocks to users made them foreswear any property rights in their blocks. It is likely that the commercial forces unleashed by number markets will have far-reaching consequences for Internet businesses, users and governance institutions. Certainly domain name registration was transformed by the emergence of a commercial market, leading to the growth of a domain name industry and major changes in policies and institutions, such as the formation of ICANN, the separation of registries and registrars and the new gTLD program.

Number markets are controversial. Many Internet traditionalists resist the commoditization of what they view as a "community resource." Others see it as diverting progress toward IPv6. Still others predict that "a functioning market won't form at all, or will break down very quickly after it forms" (van Beijnum, 2011). This paper makes a much-needed empirical contribution to the literature on the economics and institutions of IP addressing. While several papers already discuss IP number markets in theoretical or

Mueller, M. L., & Kuerbis, B. (2013). Buying numbers: An empirical analysis of the IPv4 number market. *iConference 2013 Proceedings* (pp. 27-37). doi:10.9776/13129

policy terms, no one has actually compiled and analyzed the transactions themselves. This paper draws on the records of the RIRs to compile as much information about traded IP number blocks as possible, and then conducts some very basic analysis of stocks, flows and proportions to assess the nature of this emerging market and explore some of its implications for Internet governance.

Background: The Controversy and the Policy Changes

This section explains the significance of what are known as “legacy” or “historical” allocations in the emerging market, and then describes the policies the RIRs passed authorizing market transfers and the date they were passed.

Legacy Number Allocations

Prior to 1991, there were no regional registries with formal policies for allocating number resources. There was only a central registry known as the Internet Assigned Numbers Authority (IANA), run by USC’s Information Sciences Institute (Cerf, 1990). Upon receipt of number resources from IANA, organizations did not have to sign contracts governing their use. Conservation was not a major consideration in this early period of Internet development. More than 40% of the IP address space was given away as universities, the U.S. military and major corporations involved in data networking projects received large allocations simply by asking for them. Many of them retain those allocations to this day. Organizations that received IP number blocks prior to 1991-1999[1] are considered “legacy” or “historical” holders, and their number holdings are usually not subject to RIR contracts created later.

IPv4 Scarcity and the IPv6 Transition

As Internet usage increased, and after the RIRs assumed responsibility for managing IP numbers, increasingly stringent conservation policies were applied (Hubbard, Kosters, Conrad, Karrenberg, & Postel, 1996). To receive an allocation one had to “demonstrate need,” which meant providing the RIR with confidential business and technical information about how the requested numbers would be used. To gain new allocations one had to demonstrate a specific utilization level of one’s existing allocation. In theory, numbers that were not needed were supposed to be given back to the RIR. In practice, few number blocks were returned. Those holding number blocks had no incentive to return them, and the RIRs lacked the institutional capacity or authority required to take them back (Mueller, 2010). The combination of weak-to-nonexistent reclamation and the delegation of 40% of the IPv4 numbers to legacy holders meant that despite the apparent scarcity of IPv4 numbers, there were many unused or underutilized number blocks (Mueller, 2008; Perset, 2007).

Some say that the whole problem of IPv4 scarcity will go away because there is a new Internet protocol with an expanded address space. This is a half-truth, at best. It is true that by 1998 Internet engineers had developed a new Internet protocol, IPv6, with a gargantuan, 128-bit address space. But in one of the most fateful and questionable design decisions in the IETF’s history, the IPv6 protocol was not made backwards compatible with IPv4. The incompatibility means that to implement IPv6, one must either abandon communication with everyone else running IPv4, or run both protocols at the same time. And running both protocols in parallel (known as ‘dual stacking’) does not reduce the demand for IPv4 numbers. So the migration from IPv4 to IPv6 does not involve an incremental reduction in the demand for IPv4 numbers as networks adopt IPv6. Rather, it involves *parallel growth* of the IPv4 and IPv6 Internets until such time as a huge tipping point is reached. When almost everyone is running IPv6 then, and only then, can the networks running IPv6 shut off IPv4.

[1] The date varies because RIRs were established in different regions at different times. ARIN wasn’t created until 1997, whereas in Europe RIPE-NCC was established in 1991 and had a contractual governance scheme in place by 1994.

Transfer Policies

Beginning in 2005 the Internet technical community began to notice that the supply of unallocated IP numbers was nearing exhaustion (Hain, 2005). Migration to the new IPv6 protocol still seemed years away (Colitti, Gunderson, Kline, & Refice, 2010; Dell, Kwong, & Liu, 2008; Elmore, Camp, & Stephens, 2008). That is when the idea of number markets began to be seriously considered. So controversial was the idea of trading address blocks that the terminology used by the RIRs studiously avoided explicitly stating that numbers would be bought and sold. They were called "transfers to specified recipients" or "transfers of allocations." Advocates claimed that market transfers would provide incentives for blocks holders with underutilized allocations to make them available to companies that needed them. The rising price of increasingly scarce IPv4 blocks would encourage a gradual and economically rational migration to IPv6. Others feared that markets would be so successful at extending the life of IPv4 that it would become a roadblock on the path to IPv6. This debate is covered in other literature and will not be recounted here (Edelman, 2008; Hofmann, 2010; Lehr, Vest, & Lear, 2008; Mueller, 2008). Suffice it to say that in most regions market transfer policies were passed after long, rending debates.

RIPE-NCC, the RIR for the European region, was first to approve a policy authorizing commercial transfers of IP address blocks in 2008. The RIPE NCC also runs a "Listing Service" that allows holders of IP address blocks to advertise numbers available for "exchange."[2] ARIN, the RIR for the North American region, implemented a market transfer policy in June 2009, and also runs a listing service.[3] APNIC, which serves the Asia-Pacific region, was one of the first to propose a transfer policy, but debate and controversy prevented its adoption until February 2010. The other two RIRs have not yet authorized market transfers of IPv4 address blocks. Table 1 below summarizes the situation and contains links to the relevant policy documents governing market transfers.

Table 1
RIR Market Transfer Policies

Region	Transfer policy	Date passed
RIPE NCC (Europe)	http://www.ripe.net/ripe/docs/ripe-553#-----transfers-of-allocations	December 2008
ARIN (North America)	https://www.arin.net/policy/proposals/2009_1.html	June 2009
APNIC (Asia-Pacific)	http://www.apnic.net/policy/transfer-policy	February 2010
LACNIC (Latin & Carib)	No transfer policy in place	
AFRINIC (Africa)	No transfer policy in place	

Market and Non-market Transfers

We define *market transfers* as those transfers authorized by the new transfer policies listed above. More generically, they are an agreement between separate organizations to transfer the registration of a specified IP number block from the holder to the recipient in exchange for money. Market sales are not the only way to transfer IP address allocations from one organization to another. Transfers also occur through mergers and acquisitions. There are also specified methods by which organizations with multiple subsidiaries or business units with different corporate accounts with the RIR transfer number resources among themselves (internal transfers). We refer to internal transfers and transfers arising from mergers and acquisitions as "non-market'' transfers. In order to study the emerging transfer market, it is necessary to differentiate records of non-market transfers from records of market transfers. Some RIR data regarding transfers, notably APNIC, combine logs of non-market transfers and market transfers and do not differentiate between them (see Data and Method section below).

---

[2] RIPE NCC Listing service: https://www.ripe.net/lir-services/resource-management/listing. As of August 1, 2012 it showed 4 /21s (8,192 numbers) available.
[3] ARIN specified transfer listing service: https://www.arin.net/resources/transfer_listing/index.html

Data and Method

There is no single source of data about market transfers of IPv4 number blocks. This section describes how the authors cobbled together the data used in this paper, drawing on bankruptcy court records, RIR statistics, Whois records, and RIR lists of transferred blocks.

The IP address Whois is a database that shows the general public which organization is holding which IP address block(s). Each RIR operates its own Whois database. It provides a tool for network operators and others to discover which number blocks are allocated or assigned to which organization. Using web-based interfaces, one can type the name of an organization and see a list of the IP number blocks registered in its name, or one can type in an IP address and see which organization has registered the block containing it. It may also be possible for an organization to obtain "bulk access" to the Whois records of an RIR, which means that the entire database is downloaded and can be processed and analyzed automatically. At least one RIR also maintains a "Whowas" database, showing which organization held a number block at specified dates in the past.

The 3 RIRs with transfer policies take entirely different approaches to recording number transfers. RIPE publishes no information whatsoever about events that occur under its market transfer policy. ARIN publishes a list of *IP Address Blocks Transferred per NRPM 8.3.* The list, updated weekly, shows the IPv4 block numbers that have been traded using Section 8.3 of ARIN's Number Resource Policy Manual.[4] The list contains nothing but IP address block numbers. Using the list of *IP Address Blocks Transferred per NRPM 8.3* in combination with ARIN's Whois and Whowas databases, one can determine the organizations involved, the date of the original registrations and the date of the transfer.

APNIC provides the most information. It maintains a public log of all IPv4 transfers that includes the name of the releasing organization, the name of the acquiring organization and the effective date of the transfer. The problem with the APNIC list is that it includes both market transfers and non-market transfers, and provides no basis for distinguishing between them. Utilization of this data, therefore, involved additional work to see if the organizations involved were part of a merger, or whether they were subsidiaries of the same corporation. In some cases no strong confirmation of the status of a transfer as non-market could be found. In those cases, the transactions were presumed to be market transfers. It is possible that some of those presumptions are wrong, and that we slightly overstate the number of market transfers in the AP region.

Using the methods and data sources described above, we assembled a spreadsheet of all market transfers (including IP numbers transferred as a result of bankruptcy asset sales). Each row contains data showing the region, the IP address of the block traded, the name of the releasing organization, the name of the acquiring organization, the transfer date, the traded block's prefix, the original registration date of the block, the status of the /8 prefix according to IANA records (legacy or allocated), and the contract type (RSA or LRSA). This data will be made public on the Internet Governance Project web site.[5]

Counting IP Number Trades

In quantifying and analyzing IP number trades, three different units of analysis are relevant: i) the number of transactions, ii) the number of blocks, and iii) the total quantity of IP numbers.

The most obvious metric is the total amount of IP numbers involved. This gives a good overall sense of the dimensions of the trading market. However, for reasons related to routing efficiency, no one sells or buys individual IP numbers; in that respect numbers should not be discussed as if they were homogenous, interchangeable commodities that come in single units.

IP numbers are almost always assigned and allocated in contiguous blocks of various sizes.[6] RIR policies dictate that the smallest block that can be traded is a /24, which consists of 256 unique

---

[4] ARIN NRPM, Section 8.3, Transfers to specified recipients. https://www.arin.net/knowledge/statistics/transfers_8_3.html
[5] http://internetgovernance.org
[6] Based on technical aspects of routing and network management, one would expect larger contiguous blocks to command higher per-address prices than smaller blocks. Put simply, the larger the block of contiguous numbers a network has, the easier it is for a network operator to manage addressing and routing.

contiguous numbers. The largest allocated block, known as a /8, consists of approximately 16.78 million unique contiguous numbers. Thus, it is also relevant to count and analyze the number of blocks involved in trades, while recognizing that blocks vary widely in size. (Table 4 provides a list that maps the /X notation to specific quantities of IP numbers.)

Finally, one can count transactions. A single market transaction can involve one or more blocks. Generally if the same two organizations are involved in a transfer of multiple blocks on the same date, we count it as one transaction. We found evidence of what may be complicated three-party and four-party transfers of address blocks which may not meet these assumptions, but there are only a few of them.

Number Block Use

Our research also performs some analysis of whether traded address blocks were used before and after the transaction. The lookups were performed using a Python library written by Asghari called PyASN. It takes as input a BGP dump file first. The website Routeviews archives these dumps for many years. Using a script, the IPv4 address space was enumerated, and for each /24 IP block, an ASN lookup is performed using the Routeviews data. We tested at 6-month intervals from January 2010 to July 2012, inclusive.

The Number Market Data

Summary statistics for the period from November 2009 to the end of June 2012 indicate that there were 83 distinct transactions, 204 distinct blocks traded, and a sum total of 6,034,688 unique IP numbers exchanged in the transfer market. Most of the prices are not known, but based on known prices from bankruptcy court records, the overall value of this market is in the tens of millions of dollars at least, and probably around US$ 60 million in total. There was minimal activity in 2009 and 2010, but in 2011 and 2012 the number of transactions, blocks traded and IP numbers began to increase rapidly (Table 2). If the data for the first 6 months of 2012 are extrapolated forward, the number of transactions and IP numbers traded is on pace to increase by a factor of 4 and 10, respectively, from 2011 to 2012, while the number of blocks traded is projected to increase by 60%.

When # *IP numbers* is used as the metric, North American activity dominates the market, whereas if the metric is # *blocks* or # *transactions* the Asia Pacific region is more active. Ninety of the 204 traded blocks making up 5.057 million IP Numbers were in the ARIN region. The # *IP numbers* traded in the ARIN region is 84% of the total amount traded, whereas ARIN accounts for only 37% of the # *blocks*. While there seem to be more transactions in the AP region (52 out of 83, or 63%), they generally involve smaller blocks and thus a much smaller quantity of IP numbers in total.

Table 2
Accelerating pace of market transfers (all regions)

	2009	2010	2011	2012 1st H	Total
# transactions	3	2	27	52	83
# blocks traded	8	3	109	84	204
# IP numbers	11,264	10,240	1,013,248	4,999,936	6,034,688

Note that *ARIN has not yet run out of IPv4 numbers.* At the end of July 2012, ARIN still had 52.6 million numbers available for allocation. The Asia-Pacific region, on the other hand, reached its last /8 on April 15, 2011 and now hands out only small allocations, one to an organization. In other words, North American organizations are turning to the market for IPv4 numbers when they could get numbers from ARIN. Like ARIN, RIPE-NCC still has numbers available; as of July 30, 2012, its website shows 27.38 million in stock. While there have been some parties willing to list blocks for sale in the RIPE region, there have been no buyers and no known transactions in Europe.

Table 3
Quantitative comparison of ARIN allocation and market allocation

	2009	2010	2011	2012 1st H
IP numbers allocated by ARIN	41,317,376	45,266,688	22,471,424	16,077,056
# IP numbers allocated by market in ARIN region	11,264	10,240	1,150,976	4,221,184
% market of total allocations	0.03%	0.02%	5.12%	26.26%

The market constitutes a substantial portion of total allocations in the North American region. Table 3 shows the quantity of IP numbers allocated by ARIN in the normal way from 2009 to the first half of 2012, and compares it to the quantity of IP numbers allocated via market transfers. The quantity of IP numbers involved in market allocations went from 3.6% of administrative allocations in 2011 to 26% in the first half of 2012. If the quantity of numbers involved in market transfers in the ARIN region continues to increase at the pace of the last two years, market transfers could equal administrative allocations in 2013.

Table 4 breaks down market transfers by address block size. It shows that the old Class C (/24) address blocks are the most commonly traded, with 69 transferred blocks, but due to their small size, they account for a tiny portion of the traded numbers. The old Class B (/16) blocks, which contain 65,536 numbers, are also popular objects for trades, with 26 of them changing hands. Twenty-seven /20s were traded as well. Overall, the 35 largest blocks that were traded, from /16 up to /12, account for 91% of all the numbers traded. Still missing from this picture is a /8, the largest unit of allocation. If and when one or more of those blocks trade, all the other trades will shrink to insignificance in relative terms.

Table 4
Address blocks traded

/ Notation	Number of blocks this size traded	Numbers per block size	Total number of traded numbers per block size	Percent of all traded numbers
/8	0	16,777,216	0	0%
/9	0	8,388,608	0	0%
/10	0	4,194,304	0	0%
/11	0	2,097,152	0	0%
/12	2	1,048,576	2,097,152	33.0%
/13	1	524,288	524,288	8.2%
/14	3	262,144	786,432	12.4%
/15	3	131,072	524,288	8.2%
/16	26	65,536	1,900,544	29.9%
/17	5	32,768	163,840	2.6%
/18	4	16,384	65,536	1.0%
/19	14	8,192	114,688	1.8%
/20	27	4,096	110,592	1.7%
/21	14	2,048	28,672	0.5%
/22	20	1,024	20,480	0.3%
/23	16	512	8,192	0.1%
/24	69	256	17,664	0.3%
Sum	204	--	6,034,688	100.0%

The Reallocation of Legacy Blocks

The blocks in play in this market are overwhelmingly comprised of legacy allocations. Of the 6.03 million IP numbers that have been traded, 5.33 million, or 88 percent, were from allocations made before July 1997. 5.36 million, or 89%, were classified as 'legacy' allocations in IANA or RIR records. 100% of the larger blocks sold (/15 and up) were legacy allocations, and 21 of the 26 /16s traded (81%) were legacy blocks. Further, while the releasing organizations are corporations of a highly varied type, the recipients are almost entirely Internet access providers (both mobile and fixed), online service providers such as Amazon and Microsoft, smaller VoIP providers and telephone cooperatives, and hosting companies. This indicates that market transfer policies are succeeding in re-allocating the inefficiently allocated legacy blocks from entities with an unneeded surplus to growing Internet businesses that need them more.

Three of the larger trades of legacy allocations involved bankruptcies in which number blocks were sold to creditors as assets: Nortel, Borders[7] and Teknowledge. The other large legacy block transaction involved pharmaceutical company Merck. In 1992 it was given a /8 and from that original allocation it sold two /12s (roughly 2.1 million numbers) to Amazon early in 2012. Borders and Teknowledge sold off legacy /16s as part of their bankruptcy proceeding.

In March 2011, it was announced as part of Nortel's U.S. bankruptcy proceeding that Microsoft would be acquiring 666,624 IPv4 numbers from Nortel for $7.5 million. Microsoft bought 38 number blocks that had been accumulated since 1989 by Nortel from IANA or from corporate acquisitions. Included in the package were sixteen /24s, four /23s, one /22, two /21s, four /20s, nine /16s, and one /17 and /18 each. A second tranche of Nortel IP numbers, sold as part of the Canadian bankruptcy process, went to Vodafone, Salesforce.com, Bell Aliant, and two smaller ISPs. The Canadian court has refused to release any information about the price of these transactions. The Teknowledge /16 sold for $590,000, or $9.00 per address.[8]

The Merck-Amazon deal was not a bankruptcy but a straight legacy transaction, so we do not know the price. But it illustrates the market's success at moving IPv4 address stock from legacy holders with excessive allocations to expanding, network-intensive industries. According to our tests, both of the /12 blocks went from being unrouted (i.e., not used on the Internet) to publicly routed within a year of the transaction.

Some Policy Issues

The previous material set out the basic parameters of the transfer market. A solid empirical outline of the transfer market is intended to provide a stronger basis for discussion of the many interesting and important policy questions raised by the future of IP addressing. In this section, we introduce briefly some of those policy issues.

Why ARIN/North America?

One would expect market transfers to take place in APNIC's region, where the RIR has almost nothing to give out to applicants, and one would *not* expect to see a lot of market transfers in Europe, where the RIR still has unallocated numbers to give out. Both of those expectations hold up. But North America is the anomaly; ARIN still has numbers to give – more than twice as many as RIPE – and lots of market activity. From a research standpoint, this is an interesting puzzle.

In explaining this puzzle, the Microsoft-Nortel deal is especially revealing. By paying $7.5 million, Microsoft invested about $11.25 per IPv4 address. Using ARIN's fee schedule for numbers available in its free pool, Microsoft would have paid only $87,250 per year or about 13 cents per address per year in

---

[7] Some of the relevant court documents in the Borders case are available here: http://www.internetgovernance.org/wordpress/wp-content/uploads/Bankr.S.D.NY_.-2233_merged.pdf

[8] The court order approving the sale is available here: http://www.internetgovernance.org/wordpress/wp-content/uploads/Bankr.N.D.Cal_.-034022138232.pdf

ARIN fees. To pay ARIN $7.5 million in annual fees, Microsoft would have had to hold the address blocks and pay ARIN fees for 86 years, an unlikely eventuality. The disjunction between what Microsoft paid Nortel and what it would have paid ARIN for perfect substitutes indicates that there are factors governing firms' economic calculations regarding IPv4 numbers that may not be obvious to casual observers.

The explanation for this puzzle, we believe, can be found in two policy factors. One is the large gap between the restrictiveness of ARIN's "needs assessment" policies when applied to its remaining free pool allocations and when applied to transfer markets. The other explanation lies in the disjunction between the *de facto* property rights enjoyed by legacy holders, and the far more limited use rights of non-legacy holders.

Needs Assessments

A critical policy issue in the IP number market is the role of administrative needs assessment in the market transfer process. All the transfer policies in place require buyers of number blocks to justify their acquisition by providing technical and business data showing that they "need" the numbers. While market transfers introduce price signals and economic incentives into IPv4 number allocations, the commoditization of the resource is severely limited by the retention of needs assessment. Data from ARIN indicate that in 2011, one third (33%) of all attempts to conduct market transfers via the 8.3 process were blocked or modified due to needs assessments. In 2012 the percentage was 28%. Need assessments thus restrict willing sellers from transacting with willing buyers in about 30% of the cases.

A key variable in the application of needs assessment is the time horizon employed. Proving that one "needs" X numbers tomorrow because one's network is overloaded is a fairly straightforward technical-operational calculation. Proving that one needs X numbers over the next three years in order to accommodate growth and/or implement new business plans is more like an investment decision than a network engineering decision. In free pool allocations, ARIN and the other RIRs have reduced the time horizon for needs assessments as the pool dwindles and exhaustion nears. The time horizon for demonstrating need is now only three months. To qualify for needs assessments in ARIN's 8.3 transfer process, on the other hand, the time horizon for assessing need was one year from 2009 – 2011, and was extended to two years starting in February 2012. Forward-looking companies that want to secure access to IPv4 numbers over a commercially relevant time frame would obviously opt for the transfer market over a free pool allocation – even if the apparent cost of the transferred numbers is much higher.

Property Rights

There is another explanation for the existence of a market prior to the depletion of the free pool in North America. Transactions with legacy holders can provide buyers with more secure property rights – although this issue is partially unsettled. The prominent role of legacy holders in the number market has raised important legal and policy questions about the legal rights of the transacting parties. If legacy holders have no binding contract with ARIN, they are not obligated to transfer their IPv4 number holdings via the Section 8.3 transfer policy. This means that legacy holders could transact with buyers regardless of whether the buyers can "demonstrate need." It would also mean that the buyers of legacy numbers would hold them free and clear of ARIN contracts, just as the seller did.

Fearing that such transactions would undermine its authority over a substantial portion of the IPv4 number space, ARIN has agitated to keep transfer market participants within its process. It has even gone so far as to publish advice in a bankruptcy law journal (Ryan & Martel, 2012). As it lacks any contractual leverage over legacy holders, however, it has had to grasp for other forms of influence over legacy sellers and prospective buyers. Specifically, it is attempting to use its control of the Whois database as a strategic lever. ARIN is now warning buyers of legacy resources that it will not update its Whois records to reflect transfers that take place outside of its 8.3 process. It is unclear what the effect of excluding transactions from the Whois will be. It could undermine the value of purchased number blocks, if their absence from the Whois prevented network operators from considering the buyer to be the legitimate holder of the block. This might cause ISPs to refuse to route traffic to the affected number blocks. On the other hand, it is possible that buyers will discount this threat and purchase the block anyway. If the transaction involves a major, reputable corporation and a large block such as a /8 or /16, it seems unlikely that the entire Internet would filter out the number block simply because ARIN didn't approve of the trade. If other ISPs routed to the “illicitly” traded block anyway, ARIN’s database would lose its status as an authoritative, reliable guide to who holds which number blocks. Thus, ARIN’s attempt to gain leverage over the transfer market through the use of the Whois database is like a game of chicken; if neither side gives in there could be a collision.

The MSFT-Nortel deal brought these issues to a head. Nortel and Microsoft bypassed ARIN’s 8.3 transfer process and transacted independently to exchange their property rights over the number resources in bankruptcy court. A last-minute intervention by ARIN, and private appeals to Microsoft, led to a compromise solution. Microsoft agreed to sign a special contract for legacy holders, known as a LRSA, and ARIN agreed that the transaction gave Microsoft the same de facto property rights held by the prior legacy holder, Nortel. The specific terms of the LRSA Microsoft signed have not been disclosed.

ARIN claims that it performed a "needs assessment" prior to the Microsoft-Nortel transaction to ensure it was compliant with its policy. Others have disputed ARIN’s claim, dismissing the assessment as a face-saving exercise to make it appear as if it was applying its policy and retaining some authority over legacy address transactions. The evidence supports the more cynical view. By tracing the routing of prefixes, we can see which of the Nortel blocks Microsoft is actually using a year after the trade was approved. We find that as of July 2012, only 7 of the 38 Nortel blocks, totaling only 10,496 numbers, are now being routed by MSFT (Table 5). Indeed, three of the larger /16 blocks transferred went from being routed to being *unrouted*. Thus, only 18% of the blocks involved in the Nortel - MSFT transaction were routed within a year of the transaction, and due to the withdrawal of the /16s from use there was a net *decrease* of 186,112 in the quantity of routed IPv4 numbers.

In what sense did Microsoft “need” these IPv4 numbers? From a technical point of view, it clearly did not need to put them into service within the short (one-year) time horizon contemplated by ARIN’s policy. But from a business point of view, it makes perfect sense for an Internet-dependent firm with a market capitalization around $260 billion to spend a paltry $7.5 million to secure long-term access to a resource so critical to its ongoing operations.

Conclusions

There is a thriving and growing market for IPv4 number blocks. Not only does the market exist, but it seems to be doing precisely what its advocates said it would do, namely provide access to additional IPv4 resources after the free pool is depleted, while reallocating number resources more efficiently by moving them out of unused or underutilized allocations and toward organizations who need them to grow.

An additional, partly unintended consequence of the transfer market has been to provide liberalized access to IPv4 numbers relative to the stringent needs assessment and documentation procedures required to get numbers from the RIRs. Companies have shown that they are willing to pay substantially more for IP number resources via the transfer market, if it allows them to extend their time horizon and/or avoid the needs assessment process. Thus the market provides a check on ARIN’s policy process. But due to the confidentiality of the needs assessment and contracting process, it also introduces potential discrimination in the RIR’s contracting process. It may be that there is one set of rules and contracts for smaller, less influential firms and quite another set for larger players whose defection from the ARIN regime might have a large impact. As technical needs assessments become less relevant, there is also the question of how a rising price for numbers will affect competitive entry into the market, and whether price manipulation through hoarding will occur.

It is too early to assess the impact of the transfer market on the migration to IPv6. However, the growth of IPv4 markets occurred simultaneously with what Huston (2012) has characterized as a “fourfold increase in the penetration of IPv6.” Huston’s research recognizes that that rate of IPv6 adoption will not be fast enough to “avoid some of the major pitfalls associated with encountering IPv4 exhaustion.” In other words, here again the market seems to be doing exactly what its advocates said it would do, namely provide a bridge over a period of scarcity that is of indefinite duration while Internet operators gradually come to terms with the costs and technical issues associated with IPv6 implementation, and wait for the great tipping point. To conclude, it is time to stop debating the merits of IPv4 address markets; the issue now is how to make them work better.

Table 5
Utilization of Nortel blocks by Microsoft

Blocks purchased	Jan 2010	July 2010	Jan 2011	July 2011	Jan 2012	July 2012
131.253.1.0/24	ASN 19952	Unrouted	Unrouted	Unrouted	Unrouted	Unrouted
131.253.3.0/24	ASN 19952	Unrouted	Unrouted	Unrouted	Unrouted	Unrouted
131.253.5.0/24	ASN 19952	Unrouted	Unrouted	Unrouted	Unrouted	Unrouted
131.253.6.0/24	ASN 19952	Unrouted	Unrouted	Unrouted	Unrouted	Unrouted
131.253.8.0/24	ASN 19952	Unrouted	Unrouted	Unrouted	Unrouted	Unrouted
131.253.12.0/22	ASN 19952	Unrouted	Unrouted	Unrouted	ASN 8075	ASN 8075
131.253.16.0/23	Unrouted	Unrouted	Unrouted	Unrouted	Unrouted	ASN 23468
131.253.18.0/24	Unrouted	Unrouted	Unrouted	Unrouted	Unrouted	ASN 8075
131.253.21.0/24	Unrouted	Unrouted	Unrouted	Unrouted	Unrouted	Unrouted
131.253.22.0/23	Unrouted	Unrouted	Unrouted	Unrouted	Unrouted	Unrouted
131.253.24.0/21	Unrouted	Unrouted	Unrouted	Unrouted	Unrouted	Unrouted
131.253.32.0/20	Unrouted	Unrouted	Unrouted	Unrouted	Unrouted	ASN 8075
131.253.61.0/24	Unrouted	Unrouted	Unrouted	Unrouted	Unrouted	Unrouted
131.253.62.0/23	Unrouted	Unrouted	Unrouted	Unrouted	Unrouted	Unrouted
131.253.64.0/18	Unrouted	Unrouted	Unrouted	Unrouted	Unrouted	Unrouted
131.253.128.0/17	Unrouted	Unrouted	Unrouted	Unrouted	Unrouted	Unrouted
132.245.0.0/16	Unrouted	Unrouted	Unrouted	Unrouted	Unrouted	Unrouted
134.170.0.0/16	Unrouted	Unrouted	Unrouted	Unrouted	Unrouted	Unrouted
134.177.0.0/16	ASN 7099	ASN 7099	ASN 7099	ASN 7099	Unrouted	Unrouted
137.116.0.0/16	Unrouted	Unrouted	Unrouted	Unrouted	Unrouted	Unrouted
137.117.0.0/16	Unrouted	Unrouted	Unrouted	Unrouted	Unrouted	Unrouted
137.135.0.0/16	Unrouted	Unrouted	Unrouted	Unrouted	Unrouted	Unrouted
138.91.0.0/16	Unrouted	Unrouted	Unrouted	Unrouted	Unrouted	Unrouted
141.251.0.0/16	Unrouted	ASN 7099	ASN 7099	Unrouted	Unrouted	Unrouted
192.32.0.0/16	ASN 7099	ASN 7099	ASN 7099	Unrouted	Unrouted	Unrouted
192.48.225.0/24	Unrouted	Unrouted	Unrouted	Unrouted	Unrouted	Unrouted
192.84.159.0/24	Unrouted	Unrouted	Unrouted	Unrouted	Unrouted	Unrouted
192.84.160.0/24	Unrouted	Unrouted	Unrouted	Unrouted	Unrouted	Unrouted
192.84.161.0/24	Unrouted	Unrouted	Unrouted	Unrouted	Unrouted	Unrouted
198.49.8.0/24	Unrouted	Unrouted	Unrouted	Unrouted	Unrouted	ASN 8075
198.200.130.0/24	Unrouted	Unrouted	Unrouted	Unrouted	Unrouted	Unrouted
198.206.164.0/24	Unrouted	Unrouted	Unrouted	Unrouted	Unrouted	Unrouted
199.30.16.0/20	Unrouted	Unrouted	Unrouted	Unrouted	Unrouted	Unrouted
199.74.210.0/24	Unrouted	Unrouted	Unrouted	Unrouted	Unrouted	ASN 8075
199.242.32.0/20	Unrouted	Unrouted	Unrouted	Unrouted	Unrouted	Unrouted
199.242.48.0/21	Unrouted	Unrouted	Unrouted	Unrouted	ASN 8075	ASN 8075
204.152.140.0/23	Unrouted	Unrouted	Unrouted	Unrouted	Unrouted	Unrouted
205.174.224.0/20	Unrouted	Unrouted	Unrouted	Unrouted	Unrouted	Unrouted

References

Cerf, Vinton. (1990). IAB Recommended Policy on Distributing Internet Identifier Assignment (Vol. RFC 1174): Internet Engineering Task Force.

Colitti, Lorenzo, Gunderson, Steinar, Kline, Erik, & Refice, Tiziana. (2010, April 7-9). *Evaluating IPv6 Adoption in the Internet.* Paper presented at the PAM 2010: Passive and Active Measurement Conference, Zurich, Switzerland.

Dell, Peter, Kwong, Christopher, & Liu, Ying. (2008). Some reflections on IPv6 adoption in Australia. *Info - The journal of policy, regulation and strategy for telecommunications, information and media, 10*(3), 3-9.

Edelman, Benjamin. (2008). *Running Out of Numbers: The Impending Scarcity of IP Addresses and What To Do About It*. Harvard Business School. Cambridge, MA.

Elmore, Hillary, Camp, L Jean, & Stephens, Brandon. (2008). *Diffusion and Adoption of IPv6 in the ARIN Region.* Paper presented at the Worskhop on the Economics of Information Security, June 25-28, 2008, Hanover, NH.

Hain, Tony. (2005). A Pragmatic Report on IPv4 Address Space Consumption. *Internet Protocol Journal, 8*(3).

Hofmann, Jeanette. (2010). Before the sky falls down: a 'constitutional dialogue' over the depletion of Internet addresses. In Bridget Hutter (Ed.), *Anticipating Risks and Organising Risk Rregulation* (pp. 46-67). Cambridge: Cambridge University Press.

Hubbard, K., Kosters, M., Conrad, D., Karrenberg, D., & Postel, J. (1996). Internet Registry IP Allocation Guidelines *Network Working Group* (Vol. RFC 2050). Reston, VA: Internet Engineering Task Force.

Huston, Geoff. (2012). The End of IPv4, Part 2. *The ISP Column*. Retrieved from The ISP Column website: http://www.potaroo.net/ispcol/2012-08/EndPt2.html

Lehr, William, Vest, Tom, & Lear, Elliot. (2008). *Running on Empty: The challenge of managing Internet addresses.* Paper presented at the 36th Annual Telecommunications Policy Research Conference, September 27, 2008, Arlington, VA.

Mueller, Milton L. (2008). Scarcity in IP addresses: IPv4 Address Transfer Markets and the Regional Internet Address Registries. *Internet Governance Project*. Retrieved from http://internetgovernance.org/pdf/IPAddress_TransferMarkets.pdf

Mueller, Milton L. (2010). Critical resource: An institutional economics of the Internet addressing-routing space. *Telecommunications Policy, 34*(8), 405-416.

Perset, Karen. (2007). Internet Address Space: Economic Considerations in the Management of IPv4 and in he Deployment of IPv6 *Organization for Economic Co-operation and Development (OECD), Ministerial Background Report, DSTI/ICCP*. Paris.

Postel, J. (1981). Internet Protocol (Vol. RFC 791). Arlington, VA: Defense Advanced Research Projects Agency.

Ryan, Steven, & Martel, Mathew. (2012). Internet Protocol Numbers and the American Registry for Internet Numbers: Suggested Guidance for Bankruptcy Trustees, Debtors-in-Possession, and Receivers. *BNA's Bankruptcy Law Reporter, 24*, 32-37.

van Beijnum, Iljitsch. (2011). Trading IPv4 addresses will end in tears. *Ars Technica*. Retrieved from http://arstechnica.com/tech-policy/2011/08/trading-ipv4-addresses-will-end-in-tears/