

Competition in IPv6 Addressing: A Review of the Debate

Concept Paper by the
Internet Governance Project

www.internetgovernance.org

5 July, 2005

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1. Introduction

To be connected to the Internet, any computer or other device must have a unique IP address assigned to it. Without globally unique addresses and robust methods of routing data packets based on those addresses there is no communication, no Internet.

The IP address space, like the telephone numbering space, the electromagnetic spectrum or the domain name space, is a virtual resource that must be carefully managed to preserve its economic value. Unlike the domain name space, the IP address space is not hierarchically structured and has no “root.” However, the allocation and assignment of addresses to Internet users is structured in a hierarchical manner and thus has a “top level” from which delegations originate. Currently, top-level delegations are administered by ICANN. Second-level delegations are controlled by Regional Internet Registries (RIRs), who assign blocks of addresses to Internet Service Providers and (in IPv4 only) end users. Most of the hard policy decisions in IP addressing are made by RIRs.

Last year a debate began over competition in IP addressing. The debate was fueled by political rivalries between the International Telecommunication Union (ITU) and the Internet Corporation for Assigned Names and Numbers (ICANN). Nevertheless, important questions about the future of IP address policy have been raised. Initially, the RIRs claimed that any change in current methods will result in disaster. A more objective analysis of the economic and technical aspects of address allocation and assignment, however, shows that there is room for significant policy variation in address space management. Introduction of a responsible, competing IPv6 allocation authority below the top level would permit experimentation with different policies and governance systems. This might make addressing more responsive to the needs of users. While the creation of 200+ uncoordinated national addressing authorities probably would not be a good idea, global forms of competition should be investigated further. Proposals to introduce economic incentives into addressing by permitting transferability or pricing should also be explored and developed.

In this author’s opinion the current RIR addressing regime is working adequately. The RIRs are technically proficient, reasonably transparent and open, and their leaders are responsible. Most importantly, their mechanisms for allocating and assigning Internet addresses have evolved organically with the growth of the Internet itself, through a largely voluntary association of IETF, IANA, and Internet Service Providers. Such organic, working institutions – and the expertise behind them – deserve respect. This debate is not about tearing down the RIRs as organizations or people, any more than it is about supporting (or opposing) the ITU as an institution. It is (or should be) about finding the optimal public policy.

2. What are the Stakes?

IP addressing policy is indirect in its effects on end users, but its impact is substantial. Understanding the effects of IP address allocation and assignment policies requires a good understanding of how the supply of addresses affects the Internet industries, and how the industry's uses of the addresses in turn affect users. We can quickly summarize the areas of impact as follows:

- a. **Competition policy.** Address allocation and assignment policies strongly affect competitive entry into the Internet Service Provider (ISP) industry. Address availability is a significant gatekeeper into the industry. It is possible that addressing policies may reinforce the advantages of larger ISPs over smaller ISPs, or favor incumbents over new entrants. For example, South Korea's assertion of national control over IP addresses is widely agreed to be a product of pressure from its dominant telecommunication company, KTA, to protect KTA's broadband infrastructure from competing service providers.
- b. **End user costs.** Address allocation and assignment policies powerfully affect the distribution of costs and benefits between ISPs and end users. Current policies make IP addresses non-portable across ISPs. Indeed, IPv6 addressing policies will not permit address blocks to be given to end users at all. This imposes major costs on users when they switch ISPs, and may also create stronger incentives to "dual home" or rely on duplicate ISPs. In the U.S., there has already been at least one lawsuit around this issue.
- c. **Equitable distribution.** The global imbalance in the distribution of IPv4 addresses is so severe as to be embarrassing. These imbalances were not directly caused by the current ICANN-RIR system. They are a legacy of the early days of the Internet when it was not a public system and the US military, defense-linked corporations, research universities and US technology companies had privileged access and no real restraints. One could contend, however, that current policies have failed to address this problem adequately (see point d immediately below).
- d. **Efficient use.** Current policies employ mechanisms to conserve address resources for future consumption and make sure that those who get allocations are actually using them. Existing policies may or may not be the optimal methods of promoting efficient use of the address space. A number of economic and management techniques could be used to promote efficient use and to prevent over-consumption. Current policies make it "illegal" for holders of IP addresses to transfer or trade them in a secondary market. It also offers companies that have been assigned address blocks no economic rewards for returning them to the pool. These policies are largely responsible for the system's inability to modify or correct the huge imbalances in the distribution of IPv4 addresses created in the early days of the Internet.
- e. **Route aggregation.** The main constraint governing address allocation today is the attempt to avoid a "routing table explosion" that could cripple the Internet. Every packet that moves through the Internet must be individually routed. To know how to route a packet, a router must check the prefix of the packet's address against a stored table of routes. As the number of networks connected to the Internet expands, the number of possible routes grows exponentially. At some point limits

on the processing capacity of routers are reached, at which point there might be disastrous effects on the Internet's performance. As the number of routes grows, there are also limits on the routing systems' ability to negotiate and reflect the constant changes in announced routes ("route flux"). To put it bluntly and simply, the current system restricts access to abundant IPv6 addresses in order to conserve scarce router resources. This is known as "route aggregation." Current policies may or may not be the optimal method of promoting route aggregation. Very little is known about the optimality of this tradeoff or alternative methods of achieving the same goal. Because this tradeoff and its terms are dictated and controlled by suppliers, the costs imposed on users are basically unanalyzed and unknown.

3. Competition in Addressing

How feasible is "competition" or alternative administrative agencies in making address policy and allocating and assigning addresses? This section of the paper discusses three things: a) the emerging debate over competitive addressing; b) models of competition, and c) how competing addressing authorities might affect the economic incentives of address registries.

The current system of address management is, in theory at least, coordinated and noncompetitive. Applicants for addresses are supposed to get them only from the RIR with responsibility for their territory. The RIRs "sell" memberships, and are sustained economically primarily by membership fees, although they also derive some revenue from address fees as well. End users and ISPs have little real choice but to pay these memberships if they want addresses. Instead of choice of supply, the RIR regime offers them a chance to formulate the monopoly policy for their region by participation in RIR meetings.

If there were two or more addressing authorities operating in parallel, and users were able to pick which one to ask for addresses, what would happen? The main effect is that there would be more room for policy variation. With no monopoly, RIRs would not be able to dictate the terms of address allocation and assignment to ISPs and users. If their policies were not consistent with user and industry needs, they would lose memberships and revenues.

3.a The Evolving Debate over Competition

It is useful to review the debate over competition in addressing as it has progressed so far. In October 2004, the director of ITU's Telecommunication Standards Bureau, H. Zhao, proposed assigning IPv6 address blocks of unspecified size to countries "at no cost" for their own management. (Zhao, 2004) In a brief, one paragraph section of a paper on "ITU and Internet Governance," he referred to "competition between the country registration agency and the regional registration agencies" and expressed his belief that it will give people "a good choice." Zhao also recognized that technical issues related to route aggregation needed to be discussed.

In November 2004, the Number Resource Organization (NRO) expressed their opposition to a “single uniform administrative model” based on national states. (NRO, 2004) The RIRs accommodate diversity by regional rather than national segmentation, allowing “regional and national communities to determine what is in their best interests in terms of structure of participation.” The NRO noted that past imbalances in IP address allocation and assignment cannot be blamed on the current system. The paper suggested that Zhao’s proposal would have negative impacts on address space routability, but did not elaborate any argument as to why or how significant the problem would be.

In December 2004, Zhao responded to the NRO by noting (correctly) that he did not propose a uniform system of exclusively national allocation. He proposed to add an alternative and give users a choice. The NRO was forced to admit that they had mischaracterized Zhao’s proposal. However, in email list discussions among civil society it became evident that many people in industry and civil society do not consider the ITU’s commitment to competitive addressing to be sincere. They fear that any role of national governments in address management will result in laws such as those passed in South Korea, which attempts to force everyone in the jurisdiction to get addresses exclusively from the national authority. Thus, a political dimension to the debate was raised.

In January 2005, the European Telecommunications Network Operators (ETNO) issued a short statement supporting the NRO, RIRs, and ICANN and criticizing the ITU proposal. Addressing plans, ETNO claimed, must be consistent with the structure of networks, which are not national in scope. Attempts to implement national addressing – even as a choice – would have “a highly negative impact both at technical level (via a dispersion of blocks according to a logic which is not that of the networks) and in terms of the resulting management complexity.” No details were supplied.

In April 2005, the Internet Governance Project (IGP) issued a paper calling for “coordinated competition” between ITU and the ICANN/RIR regime. (Klein and Mueller, 2005) IGP proposed that IANA should allocate a block of the IPv6 address space to the ITU. But it conceived of ITU as a *global* not regional or national allocation/assignment authority. The IGP specifically rejected the option of basing the alternative system around national addressing authorities. The object of this proposal was to create policy alternatives for ISPs and end users and so improve the accountability and performance of both ITU and the RIR regime. This proposal, too, was relatively brief.

In mid-April 2005, APNIC director Paul Wilson released a paper on “The Geography of Internet Addressing” which discussed APNIC’s experience with national Internet address registries (NIRs). In one of the more factual contributions, Wilson described how lack of coordination among NIRs led to fragmentation of address blocks and the eventual adoption of a “shared address pool” model of address space management by NIRs and APNIC. According to Wilson, national allocation would lead to 200+ different policy regimes and “excessive consumption and subdivision” of the address space which would undermine route aggregation. National allocation might also lead to further national

intervention in the Internet, such as national gateways, traffic aggregation points and inter-provider settlement schemes.

A few days later, Paul Wilson and Geoff Huston (Wilson and Huston 2005) released a paper on “Competitive Addressing.” Starting from the premise that competitive differentiation could only be based on relaxing conservation policies, the paper asserted that the mere existence of competition (of an unspecified and unanalyzed sort) would lead directly to the elimination of *all* address conservation policies. Competing authorities would rush to give out all their addresses to users eager to hoard and speculate. This would lead, he asserted, to the quick and complete exhaustion of the vast IPv6 address space.

To summarize the debate we can say the following:

- The debate is in an early stage. Little is known about many of the key issues and very little serious policy and economic research exists.
- Technical objections can be raised about a nationally-based addressing scheme. Experience in the AP region seems to suggest that they do fragment address blocks, although more research on this should be conducted. Also, sovereignty protection might lead to uncoordinated global policies, or even a “rogue” national authority that sells addresses to spammers or phishers for profit.
- There are also important political concerns about NIRs. Even if choice did exist formally, there are fears that choice would be eliminated by governments seeking more power over the Internet.
- Most of the debate has been preoccupied with the issue of NIRs. The Internet Governance Project’s proposal for global competition via the ITU has not been widely discussed.
- The one generalized attempt to debate competition in addressing (Wilson and Huston, 2005) was more akin to a scare tactic than a serious analysis. It presented the world with a stark but not very realistic choice between the present regime and a frenzied, speculative land rush. In so doing, it failed to develop realistic analysis of policy incentives under a regime of coordinated competition. For example, if address space is so valuable that everyone would be eager to hoard it, why would the competing agencies be so willing to give all of it away? How would these competing entities sustain themselves if they gave all of their assets away? Why would n’t a viable secondary market develop?
- There is an unexplored tension between the current RIR regime’s opposition to competition and its reliance on semi-autonomous regional authorities. RIRs as regional entities are supposed to provide opportunities for more participation by more localized constituencies. However, the only reason to have such diversified, localized participation is to allow these different constituencies to produce policies uniquely tailored to their own needs. If local input cannot produce policy variation, what good is it? If it does produce policy variation, why can’t we give users a choice among these various policies? As a matter of fact, currently the IPv6 addressing regime seems to reveal no significant difference between the policies of the various RIRs.¹ Do RIRs have real policy development functions, or

¹ There were, on the other hand, significant differences in policy for IPv4 among RIRs.

are they just “branch offices” of a global regime? Or are they just ways of giving broader political constituencies a piece of the pie? If the latter is true, can this logic be extended further – should policy and representational diversity be taken beyond the RIRs?

3.b Models of Competition

From the discussion above, it is clear that there are at least 4 distinct models of address management on the table:

Model 1. What the RIRs do now (IANA + 5 RIRs) no competition

Model 2. What the ITU wants: the RIRs compete with 200-odd National Internet Registries who provide address allocation and assignment functions on a national basis.

Model 3. What the Internet Governance Project proposed: the RIRs compete with another global address allocation and assignment entity administered by the ITU.

Model 4. A free market alternative that would transform IP addresses and/or routing table entries into priced, transferable commodities.

Rule number one in any debate about “competition in addressing” is that any criticism or discussion of such competition must make it clear which of the three institutional alternatives they are discussing. Each of them would have radically different effects on IP address management incentives.

3.c Effects of Competition on Route Aggregation

As noted earlier, any system of address management must be consistent with route aggregation, so that the Internet’s routing tables don’t reach a size that exceeds the capacity of the technology. The choice of aggregation methods, however, is not purely binary: either accept the present system, or get no route aggregation at all. Different policies will produce different levels of route aggregation and different incentives to aggregate. It is important to know how big the difference would be.

First, it must be noted that the current system does not do a perfect job of route aggregation. According to the CIDR Report, major Western ISPs could make up to 90% improvements in their route aggregation. Among other methods, the technical community relies on publication of such “lists of shame” to enforce aggregation.² It is apparent that stronger economic incentives might produce better results.

As far as I can tell, the main mechanism used by RIRs to promote aggregation in the IPv6 space is the introduction of hierarchy and large scale in the initial allocation. If that is true, it is difficult to understand, without more analysis, why the addition of one more global source of these initial allocations (as proposed in Model 3) would cause serious aggregation problems.

² “Aggregation summary,” June 4, 2005, CIDR Report, <http://www.cidr-report.org/>. As far as I can tell, this report indicates that major ISPs such as Time Warner Telecom, Covad, and Comcast could improve aggregation by 80%, 99% and 97% respectively.

Considered as a resource pool, IP addresses are largely homogeneous, undifferentiated items. This has caused Wilson and Huston (2005) to contend that all competition would be limited to policy variation. However, like real estate or spectrum, contiguity affects the value of IP addresses. That is, an unbroken band of contiguous IP addresses is worth more than the same number of IP addresses scattered across a wide numerical range. Contiguous address blocks are more likely to be routable, and unless addresses show up in the routing table they are worthless. So if competing RIRs are responsive to demand, they have an incentive to try to deliver aggregated, contiguous address blocks to their members as well.

To conclude, while route aggregation may militate against more extreme forms of diversity, such as 200+ NIRs, there is no real support for the idea that the need for aggregation precludes all forms of competition.

3.d Effects of competition on conservation incentives

In assessing the effects of competition on conservation, we need to distinguish carefully between different models of competition. We also need to keep in mind that the need for IPv4-type conservation policies in the IPv6 space is open to serious question. Although most would agree that some conservation is prudent, the current bias toward over-conservation must be recognized.

Model 2 – a NIR-based approach to competition – would sacrifice efficiency in some respects, in that blocks of addresses would be devoted to national territories regardless of how much use there was within a country. In other respects, a national regime might prove to be more conservative than the present system. Each national entity would perceive its address assets as something to be carefully managed in conformity with national policies, just as it manages its radio spectrum. Government agencies typically have a conservationist bias because they are not subject to market pressures and they are more likely to retain political power and budget allocations if they retain control over important assets. Also, one nation would be unlikely to give away its national addresses to other nations, making the system somewhat rigid.

It seems likely that Model 3 – the global competitor approach proposed by IGP – would produce changes in conservation policies, but it is not clear how far they would go or how far conservation would be relaxed, if at all. In order to attract IPv6 address users away from the RIR system, it is likely that an ITU system would have to vary their initial allocation policies in ways favored by users of IP addresses. On the other hand, ITU is a traditional intergovernmental organization, and in particular often reflects the views of developing countries which are not in a position to put to immediate use large quantities of IPv6 addresses. ITU might in this respect favor policies that reserve blocks for developing countries, and thus be more conservative than the RIR's. Also, ITU must achieve consent among its member states before it can take any action, so the prospect of radical innovations is not large. If anything, ITU might also have too conservationist a bias.

At any rate, the opportunity to experiment with alternative policies in this area is what we consider to be one of the virtues of the IGP proposal. Given the relatively slow pace at which the Internet industry is migrating to IPv6, the prospects for a land rush seem slim to none. It should be noted that both RIRs and the ITU have long term relationships with constituencies that would need IP addresses in the future as well as at present, and thus would have incentives to retain a supply for the future. It is hard to conceive of how or why either competing entity would suddenly give away all of their assets. And in this respect, competition might strengthen some conservation incentives. An RIR with no addresses to hand out becomes a significantly less important actor on the Internet's stage than one with additional supply. The same goes for the ITU. In general, Wilson and Huston's argument that all conservation incentives would be eliminated by the existence of an alternative addressing entity are entirely unconvincing.

The impact on conservation of Model 4 – a free market – depends on how the market was implemented in the initial stages. Subject to strong initial allocation limits, markets could improve conservation significantly by making consumers of address space pay the full opportunity cost of holding addresses, and/or by giving them incentives to transfer addresses to those who need it or release address space they didn't need. A poorly implemented market, however, might produce speculation and facilitate market concentration.

The preceding analysis is a just a first step. A lot more analysis and research could be done – and needs to be done – around these issues. Specifically, we need to investigate more carefully the effects of address transferability on both conservation and aggregation incentives. If permitted, transferability can solve many supply availability issues, but may also create incentives for hoarding and speculation and may have to be purchased at the price of some loss of aggregation. It is useless to categorically reject transferability – one must look at the details of how it would work in specific applications and contexts.

3.e Effects of competition on national control

Champions of national control and national sovereignty in the Internet need to face facts. The Internet resists “nationalization.” Competition between national IRs and the existing RIRs might increase national governments' ability to integrate addressing policies with national policies, but it would *not* increase their overall control over Internet addressing or Internet governance. By leaving open the choice to use the existing RIR regime, NIRs would be subjected to some discipline. If they tried to impose on their ISPs or users addressing policies that were more restrictive than the RIRs, and these restrictions had no beneficial effects, users would simply avoid them. The more restrictive, regulatory and nationally unique an NIR's policies were, the more likely they would be avoided by ISPs and users. And if NIRs try to eliminate choice, or if people believe they will try to eliminate choice at some point in the future, they will only succeed in galvanizing global opposition to giving national governments *any* role in addressing, or at best diminish the viability of any alternative they offer.

More broadly, national governments need to move beyond the idea that they can push the toothpaste of the global Internet back into the tube of a national/territorial governance

model. Those days are gone. The more time nation-states invest in efforts to recreate the “good old days” of national jurisdiction, the more time they will waste and the farther they will fall behind the advanced economies which have embraced and thrived on the transnational information economy. If national governments want to play a role in the Internet, they will have to do so by *adding value*, not by restricting alternatives.

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