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IPv6: it's time to make the move



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WHEN ENGINEERS DEPLOYED IPV4 IN 1981, four billion IP addresses seemed like plenty. As the world caught on to the commercial possibilities of the Internet, though, engineers realized that the number of IP addresses simply wasn't enough for all the laptops, mobile devices, Web servers, routers, and other devices coming online. IPv6, the new numbering system, enlarges the address pool drastically, but it is unfamiliar and relatively unused so far. In this article, we show that, with only about 16% of the IPv4 address space remaining, the world will run out of IPv4 address blocks within a few years, and we suggest what you can start doing now to prepare for the transition to IPv6.

IPv4 History

In the late 1960s, various U.S. universities and research centers needed a way to connect their computers together to access each other's resources. At that point, all interconnection technologies were proprietary, required homogeneous equipment, and were very expensive to deploy.

The Advanced Research Project Agency, a U.S. government organization, developed a network called ARPANET, incorporating interconnection and the ideas of the design, implementation, and use of network techniques in general and packet-switching in particular. The company Bolt, Beranek and Newman (BBN) had ARPANET operational by 1971, but two years later the existing lower-layer protocols had become functionally inadequate. The improvement goals were to be independent from underlying network techniques and from the architecture of the host; to have universal connectivity throughout the network; to provide end-to-end acknowledgments; and to standardize application protocols.

TCP/IP (IP version 4) was fully implemented in 1983. The success of TCP/IP has been based largely on three factors: (1) the 1983 University of California at Berkeley implementation of TCP/IP placed into the public domain, leading to free implementations others could use; (2) the National Science Foundation's interconnections of various U.S. educational institutions and international players; and (3) decreased interconnection costs.

By 1992, the world was beginning to realize the advantages of the Internet. More and more companies and users wanted to connect to the Internet, leading to increased demand for IP addresses. Until 1992, sites that connected to the Internet received allocations based on class: class A (16,777,214 maximum possible addresses), Class B (65,534 maximum possible addresses), and Class C (254 maximum possible addresses). For many, Class A was too big and Class C was too small, leading to a large demand for Class B addresses. This particular scheme promoted a lot of waste, and engineers consequently created the Classless Inter-Domain Routing (CIDR) scheme, allowing allocations to be based on bit boundaries. For example, a Class C is now considered a /24, a Class B is now a /16, and a Class A is now a /8. This allowed IP allocation agencies to hand out “right-sized blocks” to ISPs who requested space. If an ISP required a /19, they could get it—not a /16, as was happening in the classful days [1].

IPv4 Depletion

Although the introduction of CIDR slowed the consumption of IPv4 address space, continued global demand still makes IPv4 depletion inevitable. Figure 1 shows the global depletion of IPv4 address space over the past three years. The Internet Assigned Numbers Authority (IANA) allocates address space blocks in /8 increments to the five Regional Internet Registries (RIRs) [2] that manage the distribution of address space to Internet Service Providers (ISPs), large organizations, universities, and other entities. There are 256 /8s in the entire IPv4 pool. As of December 2007, there are 42 /8s remaining, or 16.4%.

The Regional Internet Registries have collectively allocated about 10 /8s of IPv4 address space each year, on average. If that trend continues unchanged, IPv4 address space will be fully depleted by 2011. This scenario assumes that demand does not increase, which is unlikely, given the ever-increasing number of Internet-enabled devices. This scenario also assumes no industry panic (hoarding, withholding, etc.), no IANA or RIR policy changes, and no other external factors influencing address space allocations, any of which could push the IPv4 depletion date earlier.

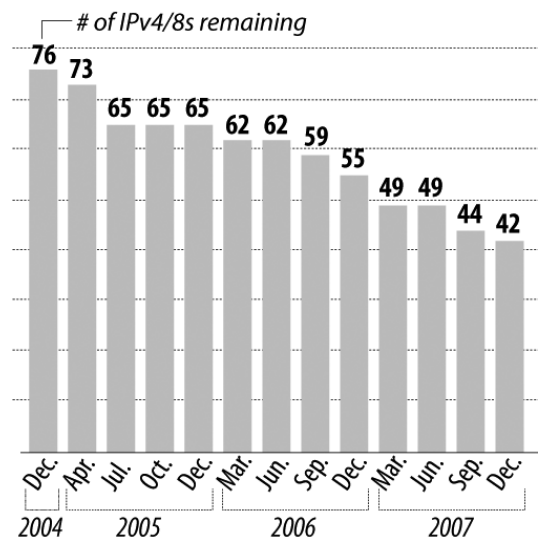


FIGURE 1: IPV4 ADDRESS BLOCK DEPLETION FROM DEC. 2004 TO DEC. 2007

Figure 2 shows allocations from RIRs to ISPs and other large entities by year. APNIC (Asia Pacific), ARIN (North America), and RIPE NCC (Europe) have allocated the most space to date. LACNIC (Latin America) and AfriNIC (Africa) follow, as newer RIRs are growing the infrastructure in their regions. The 2007 data in Figure 2 is as of 30 September, putting the numbers on track to exceed allocations from 1999 through 2006.

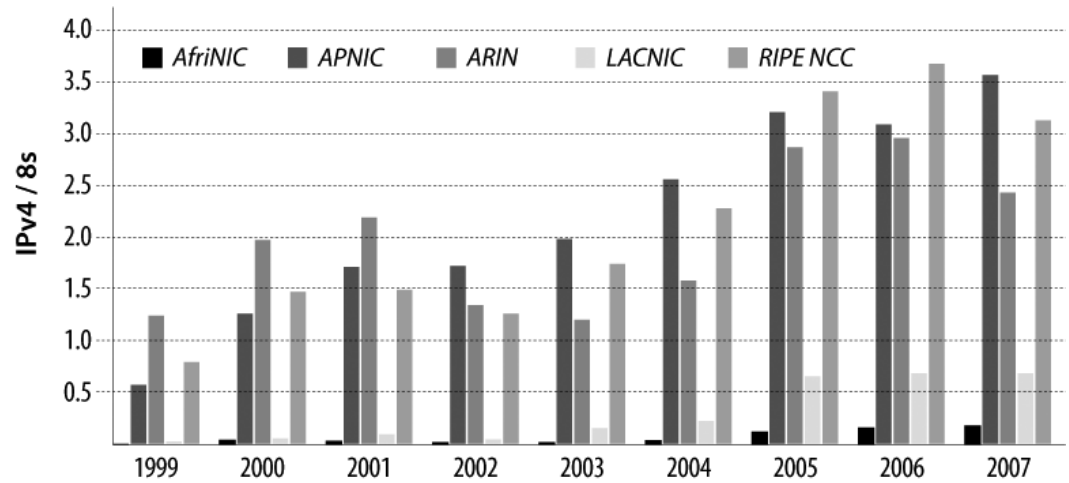


FIGURE 2: IPV4 ALLOCATIONS FROM REGIONAL INTERNET REGISTRIES

IPv6 Arrives

Once the Internet became a commercial success, demand for IP address space increased dramatically. Based on increased demand, various technologists in the Internet Engineering Task Force (IETF) studied demand and possible depletion of IPv4 addresses. From those studies, the IETF started looking at a replacement for IPv4 called IPng (IP next generation).

Debates over various technologies within IPng resulted in IPv6 as the replacement technology to supersede IPv4. IPv6 promised many things, many of which were back-ported to IPv4. The biggest issue IPv6 solves is the growth of the address space—from 32 bits, or four billion addresses, to 128 bits, an astronomical 16 billion-billion addresses. Although still a finite space, IPv6 should provide enough addresses for a very long time.

With available /8 address blocks diminishing and annual allocations increasing, the American Registry for Internet Numbers (ARIN) is now actively advising the Internet community that transitioning to IPv6 is necessary for any applications that require ongoing availability of contiguous IP address space.

ARIN, the Regional Internet Registry that manages the distribution of IP addresses in Canada, many Caribbean and North Atlantic islands, and the United States, cannot and will not force anyone to transition to IPv6. However, soon organizations that require larger contiguous blocks of IP address space will only be able to receive them in IPv6. In the meantime, ARIN will continue to issue IPv4 address space as available; its distribution practices will change only when its community creates or revises policies.

Recognizing the inevitability of IPv4 depletion, on 7 May 2007 the ARIN Board of Trustees passed a “Resolution on Internet Protocol Number Resource Availability” [3]. In addition to advising the community on IPv6 transitioning, the resolution directs ARIN staff to heighten its efforts to verify the authenticity of IPv4 resource requests and asks that ARIN’s elected pol-

icy body, the Advisory Council, consider working with the community on policy changes to encourage transition to IPv6.

To implement this resolution, ARIN has reviewed its internal resource request procedures, sent progress announcements to the community, produced new educational documentation, and focused on IPv6 in many of its general outreach activities, such as speaking engagements, trade shows, and technical community meetings.

Current Allocation Policies

ARIN and the other RIRs have community-defined policies that dictate how they distribute IPv4 and IPv6 address space within their regions. In the ARIN region, these community decisions are recorded as policies in the Number Resource Policy Manual [4].

Table 1 shows ARIN's current allocation policies for IPv4 and IPv6, for both ISPs and end users. This table is current as of December 2007 but is subject to change. See the Policy section on the ARIN Web site for the most up-to-date policy set.

<p>Initial allocation varies from a /22 (1,024 addresses) to a /20 (4,096 addresses); larger amounts are possible in some cases.</p> <p>Eligibility is as follows:</p> <p>For a /22: efficient utilization of a /23 from upstream; intent to multihome; agree to renumber</p> <p>For a /21: efficient utilization of /22 from upstream; intent to multihome; agree to renumber</p> <p>For a /20: efficient utilization of /21 from upstream; intent to multihome; agree to renumber</p> <p>Efficient utilization of /20 from upstream (no renumbering required)</p>	<p>Minimum initial allocation is a /32 (296 addresses); larger amounts are possible in some cases.</p> <p>Eligibility requires:</p> <p>being an ISP</p> <p>routing the aggregate</p> <p>having a plan to make at least 200 /48 assignments to other organizations within five years</p>
<p>Minimum assignment is a /22 (1,024 addresses); larger amounts are possible in some cases.</p> <p>Eligibility is based on:</p> <p>Current and planned utilization (25% immediate utilization and 50% utilization within one year)</p> <p>Multihoming state</p>	<p>Minimum assignment is a /48 (280 addresses); larger amounts are possible in some cases.</p> <p>These assignments come from a distinctly identified prefix and are made with a reservation for growth of at least a /44.</p> <p>Eligibility is based on:</p> <p>Being an end user</p> <p>Qualifying for an IPv4 assignment or allocation from ARIN under current IPv4 policy</p> <p>In other words, if you could get IPv4 space, then you can get IPv6 space.</p>

TABLE 1: IPV4 AND IPV6 ALLOCATION CRITERIA

Getting an initial allocation of IPv6 address space from ARIN is a relatively simple and straightforward process.

- Step 1: Review the requirements for IPv6 in ARIN's Number Resource Policy Manual [5].
- Step 2: Complete and submit the appropriate forms, including contact and organization identifiers (if new to ARIN) and the IPv6 Network Request Template [6].
- Step 3: Correspond with ARIN's Registration Services Department to obtain answers to any questions or required documentation.
- Step 4: Receive approval from ARIN.
- Step 5: Pay any required fees and sign the Registration Services Agreement.
- Step 6: Receive allocation from ARIN.

IPv6 Implementation

ARIN and the other Regional Internet Registries have distributed IPv6 address space since 1999. As shown in Figure 3, as of 30 September 2007 RIPE NCC in Europe is responsible for nearly half of the IPv6 prefixes that have been allocated; APNIC in the Asia-Pacific region and ARIN in North America are responsible for just under one-quarter each; and AfriNIC in Africa and LACNIC in South America handle the remainder.

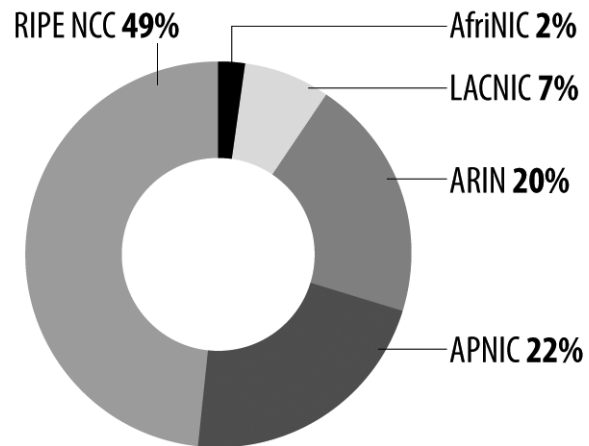


FIGURE 3: IPV6 ALLOCATIONS FROM REGIONAL INTERNET REGISTRIES

IPv6 has not yet really taken hold, with only a few hundred prefixes allocated globally. Over the past three years, the IPv6 routing table has grown from 400 independent address blocks with announced routes to around 1,000. In comparison, there are nearly 250,000 IPv4 routes.

Lack of education, ubiquitous use of NATs, and uncertainty about the costs involved in transitioning have all made IPv6 slow to deploy. Specific transition needs and costs vary based on many factors, but may involve:

- Obtaining IPv6 addresses and connectivity
- Upgrading operating systems, software, and network management tools
- Updating routers, firewalls, and other hardware that is “middleware”
- Training IT staff and customer service representatives

Why Should You Begin the Transition Today?

IPv6 IS READY

IPv6 is stable and well tested and already deployed in locations across the globe. Because both IPv4 and IPv6 will coexist and work simultaneously for years to come, applications that currently work with IPv4 will continue to work in a dual-stacked network. Transition costs vary by situation, but planning ahead by getting IPv6-ready equipment in regular purchasing cycles will help minimize costs.

IMPENDING IPv4 DEPLETION

Only about 16% of the IPv4 address pool remains, and that percentage gets smaller every month. As IPv4 demand increases and available address space decreases, organizations will soon have no choice but to continue network operations in IPv6. The sooner you learn and deploy IPv6, the farther ahead of your competition you will be.

CUSTOMER REACH

Right now, people are trying to reach you through IPv6. At this point, the user is choosing to use IPv6 and will use IPv4 by default when the IPv6 query fails. Once the IPv4 address pool is depleted, people will try to reach you through IPv6 only. In a few years, if a user's IPv6 query fails, that user will not be able to communicate with you and you will lose business.

Your Next Steps

There are several practical steps you can take toward the transition to IPv6.

Replace any outdated equipment and software with IPv6-ready devices and applications. Encourage vendors to support IPv6, and specifically include IPv6 support in RFPs and contracts.

Send your IT staff to IPv6 training seminars and encourage them to read forums such as the ARIN IPv6 Wiki or to get involved in organizations such as the IETF or the North American Network Operators' Group (NANOG) to learn from other engineers already deploying IPv6 in their networks.

Talk to your ISP about getting IPv6 service. If it cannot provide such service, experiment with tunneling IPv6 over IPv4 with tools such as Teredo or TSP. Start by looking at listings of freely available tunnel brokers: There are multiple brokers on the Internet that can cater to specific needs. For example, one user-friendly broker that has helper applications and configurations packaged for various platforms is go6 [7]. The service is free and has client applications that completely automate tunnel configurations on Windows, Linux, FreeBSD, and OS X.

Additionally, you may have had to undergo the excruciating exercise of renumbering in IPv4—moving from one set of IP addresses to another. These renumbering exercises have been and continue to be painful, especially in networks that are poorly documented and have hidden address dependencies. Although in some ways IPv6 has made renumbering easier, ARIN recommends that organizations design their networks to allow for easy renumbering, as you will have a clean slate to build upon. ARIN also recom-

mends that upstream providers who receive a /32 prefix directly from the RIR enter into contractual arrangements with their customers stipulating that the address space may have to be returned, requiring all end-sites to be renumbered.

Summary

With the IPv4 address space decreasing and demand for IP addresses increasing, now is the time for you to begin the transition to IPv6. Getting IPv6 address space from ARIN is a simple process, and the faster you learn about IPv6 and prepare your network, the further ahead of your competition you will be and the better prepared you will be to handle requests from *all* of your customers well into the future.

More Information

ARIN hosts an IPv6 Wiki site [8] to facilitate discussion and information-sharing on IPv6 topics and issues. Its purpose is to provide interested individuals with an opportunity to collaborate on IPv6, with specific focus on implementation and migration to IPv6 in the ARIN region.

More information about IPv6, including general educational materials, specific registration services information, and contact information, is available from the IPv6 Information Center [9]. You can also visit the main ARIN Web site at www.arin.net or email us at info@arin.net.

ABOUT ARIN

The American Registry for Internet Numbers is a nonprofit corporation that distributes Internet number resources, including both IPv4 and IPv6 address space, to Canada, many Caribbean and North Atlantic islands, and the United States.

REFERENCES

- [1] A chart showing the number of unique IP addresses possible in classful addressing, IPv4, and IPv6 is available at http://www.arin.net/education/IP_Address_Block_Size_Equivalents.pdf.
- [2] More information on the Regional Internet Registry system is available at <http://www.arin.net/community/>.
- [3] The ARIN Board Resolution is available at <http://www.arin.net/v6/v6-resolution.html>.
- [4] The Number Resource Policy Manual is available at <http://www.arin.net/policy/nrpm.html>.
- [5] IPv6 policies are available at <http://www.arin.net/policy/nrpm.html#six>.
- [6] All templates are available at <http://www.arin.net/registration/templates/index.html>.
- [7] <http://www.go6.net>.
- [8] <http://www.getipv6.info>.
- [9] <http://www.arin.net/v6/v6-info.html>.