the Availability Digest

www.availabilitydigest.com

The IPv4 Doomsday

August 2009

Remember the Year 2000 Doomsday? As it turned out, we survived that one well. Though potentially a worldwide disaster, the Y2K problem only affected individual systems; and massive efforts by system developers avoided most problems.

But what if instead the problem had affected the entire Internet? Not only might these individual systems have been taken down, but *all* systems except those few that lived in isolation might have been lost. Without the Internet, much of today's global commerce would come to a halt.

Well, we are facing just that problem. The issue is the Internet Protocol (IP) that interconnects systems and users all over the world via a global packet-switching network. The current version of IP, Version 4, known as IPv4, has an address space that seemed inexhaustible when the Internet was first being specified. After all, IPv4 used a 32-bit address field that provided over four billion unique addresses. Since there are about 6.7 billion people on the earth, this would provide an Internet address for more than half of all men, women and children around the globe. This should be enough, right? Wrong!

Various estimates now indicate that the IPv4 address space will be exhausted in the next two years or so. What now? The planned answer is a massively extended address space that is made available in the next version of IP, IPv6. But is IPv6 ready for prime time? Let's look at this issue.

What Happened to IPv4?

IPv4 was the fourth version of the Internet Protocol and was introduced in 1981.[1] Growing out of the ARPANET (Advanced Research Projects Agency Network), a joint venture of the U.S. Department of Defense and several universities and laboratories, the primary use of the Internet was expected to be for the exchange of scientific papers and studies for academia (a related network, the MILNET, served the military's needs).

The Internet was opened to commercial use in 1989.[2] At the same time, Tim Berners-Lee introduced his new invention, the World Wide Web.[3,4] No longer was the Internet used only by academic and government users. It was now useful for everybody on the planet Earth. It is estimated that in 2009, 25% of the world's population is using Internet services. That accounts for

[1] IPv4*, Wikipedia.*
[2] Internet, *Wikipedia.*
[3] World Wide Web, *Wikipedia.*
[4] Interestingly, Tim Berners-Lee argued against the support of graphics on the Web, saying that it would bog down the Internet with its high bandwidth demands. Fortunately, he lost that argument. Isn't the rapid advance of technology wonderful?

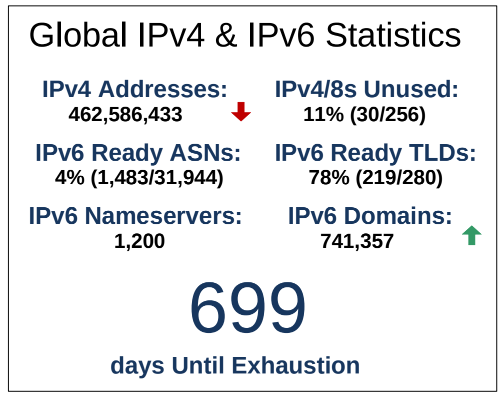
half of all Internet addresses in the IPv4 address space (assuming that all users have their own Internet address, which is probably not quite true).

Furthermore, the number of users of the Internet appears to be doubling every year. This dooms IPv4 sometime in the next year or so.

Doomsday Predictions

There are a number of efforts to predict when the IPv4 address space will be exhausted based on the current rates of deployment. In 2003, it was estimated that the address space would be suitable for two decades. In 2005, Cisco predicted that the address space would dry up by 2009.[5]

Hurricane Electric, an Internet backbone provider, has introduced an iPhone application that counts down the number of days to exhaustion.[6] On Wednesday, July 22, the count was 699 days. A similar estimate by Asia-Pacific Network Information Centre (APNIC) was surprisingly close, at 701 days. This puts exhaustion day in early to mid-2011.



These estimates are all based on the current rate of IP address assignments. Of course, if there should be a "land rush" for the last addresses, the address exhaustion could come somewhat earlier.

IPv6 to the Rescue – Maybe

In response to this problem, the Internet Engineering Task Force (IETF) released the specifications for Version 6 of the IP protocol, IPv6, in late 1999.[7] IPv6 quadruples the size of the IP address field from 32 bits to 128 bits. This increases the IP address space from four billion ($4x10^9$) addresses to $3.4x10^{38}$ addresses (a googolplex, or a 1 followed by a googol of zeros – a term coined by a nine-year old in 1938[8]). This is enough addresses to assign almost five quintillion addresses (10^{15} – almost a googolplex) to every observable star in the known universe![9]

Is this enough? We would certainly hope so. However, the intent in creating such a large address space was not to combat address exhaustion but rather to make the assignment of addresses much more flexible. The current IPv4 32-bit address uses the first one to three octets (an octet is network-speak for an eight-bit number) to specify a network address and the remaining octets to specify a subnet and host address according to a subnet mask.[10] The expanded IPv6 address, with 64 bits for each, provides a sparsely-filled address space that will allow a better systematic and hierarchical allocation of addresses.

How complex is the transition from IPv4 to IPv6? It is not trivial. Not only are the protocol stacks different, but the packet headers are different. In addition, IPv6 requires the Internet Protocol Security (IPsec), which is optional in IPv4, to be supported. Furthermore, IPv6 routers no longer do fragmentation. It is up to the host to query the route to determine the maximum transmission

[5] Tony Hain, A Pragmatic Report on IPv4 Address Space Consumption, *The Internet Protocol Journal*; September, 2005.
[6] Stephen Lawson, iPhone app predicts IPv4 doomsday, *Infoworld*; July 22, 2009.
[7] The new IP version could not be named Version 5 since this version number had been assigned to an experimental streaming protocol to support video and audio.
[8] Googolplex, *Wikipedia.*
[9] IPv6, *Wikipedia.*
[10] W. Richard Stevens, pg. 8, *TCP/IP Illustrated, Volume 1: The Protocols*, Addison-Wesley; 1994.

unit (MTU) and to fragment its messages into packet sizes that are no larger than the MTU. Four-gigabyte jumbo-sized packets, called jumbograms, can be transmitted via IPv6 if the link allows.

Fortunately, IPv6 allows IPv4 addresses to be encapsulated in IPv6 addresses. The four-octet IPv4 address occupies the low-order four octets of the IPv6 address, with the upper twelve octets set to a defined value.

Transition Help

For a while, IPv4 and IPv6 networks will coexist. How long is a while? How long have flat files coexisted with SQL tables? How long have COBOL applications coexisted with C++ or Java applications?

While these networks coexist, several mechanisms will be available to provide interoperability.

- Dual-Stack IP Implementations: IPv6 is, in fact, an extension of IPv4. Therefore, it is straightforward to write a dual protocol stack that supports both IPv4 and IPv6 while using a great deal of common code. Most IPv6 stack implementations today provide a dual stack.

- Address Mapping: IPv4 addresses can be mapped to IPv6 addresses. Mapping is accomplished by setting the first 80 bits of the IPv6 address to zero and the next 16 bits to one. The remaining 32 bits hold the IPv4 address. When opening an IPv6 socket, IPv4 addresses will appear as appropriately-mapped IPv6 addresses.

- IPv4 to IPv6 - Tunneling: An IPv4 host or network can reach the IPv6 Internet by encapsulating IPv6 packets within an IPv4 packet. This is the IPv4 protocol 41.

- IPv6 to IPv4 - Header Translation: This is still an area of concern. How can a new IPv6 host talk to a legacy IPv4 host? One way is to use a dual-stack application-layer proxy such as a web proxy. IPv6 traffic is sent to the proxy, which will retransmit it over IPv4 to its destination.

How Is IPv6 Deployment Going?

Not well. Even though IPv6 has been around for a decade, there are many impediments to its adaption. These impediments include:

- networks that use equipment obtained from manufacturers that have since gone out of business.
- manufacturers that refuse to provide IPv6 upgrades or that charge excessively for them.
- IP stacks in ROM that cannot be upgraded.
- insufficient memory in routers to implement the IPv6 stack.
- performance problems in older routers caused by IPv6.

In addition,

- Manufacturers must provide new equipment with sufficient resources for IPv6.
- Manufacturers must invest in developing new software for IPv6 support.
- End users must be educated in issues concerning IPv4 obsolescence.
- End users must be educated to upgrade their current equipment.
- ISPs must invest technical resources to upgrade their networks for IPv6.

Most manufacturers have been responsive to the need to support IPv6. Most servers, routers, and operating systems marketed today support IPv6. However, the other issues still stand in the way of wide-spread adoption of IPv6.

A 2008 study by Google[11] found that less than 1% of Internet-enabled hosts used IPv6. The leader was Russia, with 0.76%. The U.S. had a penetration of 0.45%. The Mac OS X operating system led all operating systems with a penetration of 2.44%. Linux followed with a penetration of 0.93%. Windows Vista had a penetration of 0.32%. None of these numbers bode well for an explosion of use of IPv6 in the next couple of years.

Though China trailed with a penetration of 0.24%, it may be the furthest ahead. All of the network operations for the 2008 Summer Olympic Games held in Beijing were conducted using IPv6. China must make a commitment to IPv6. While the U.S. has gobbled up one-third of the available IPv4 addresses (over one billion addresses for 300 million people), China has more high-speed Internet users than assigned addresses. The rapid adoption of IPv6 is its path to Internet stability.

Summary

We will survive this transition as we did the Y2K crisis, though it may be painful. Daniel Bernstein wrote a paper in 2002 entitled the "The IP Mess" in which he criticized what he considered to be fundamental design flaws in IPv6. One of his points was that the IPv6 specification did not have a transition plan. We may be painfully aware of this in the next few years when new hosts that can only obtain an IPv6 address must work over the IPv4 Internet.

This is not the last doomsday we will face. We've just gone through a couple of them.[12] The Y2K7 bug confused many systems when the dates of Daylight Savings Time were changed in the U.S. in 2007 – an impact that is still felt today in systems that automatically adjust for this time change.[13]

The Z2K9 bug disabled all of Microsoft's 30-gigabyte Zune MP3 players when the 2008 leap year ended at midnight, December 31, 2008.

Up and coming is the Y2K38 bug. Unix systems storing date/time as a 32-bit signed integer will roll over to zero.

But there is no problem with doomsdays of the future. As long as it won't happen on our watch – as long as we will have been retired for a while when it comes – don't take it out of our budget. Leave it for the next guy to figure out. That's how we handled the Y2K doomsday, and that's how we're handling the IPv4 doomsday. After all, that's the I.T. way.

[11] S. H. Gunderson, Global IPv6 Statistics – Measuring the current state of IPv6 for ordinary users, *Google White Paper*; October, 2008.

[12] J. Di Giacomo, What Time Is It In Your Test Bed?, www.tandsoft.com (to be published in *The Connection*; September/October, 2009).