IPv6 For Web Developers

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Web Development with PHP

September 29, 2014

The STEMulus Center
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Outline

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  - **ISPs**: staying on older IPv4 implementations
  - **End Users**: with aging, IPv6 incompatible modems & routers
  - **Software Developers**: writing software that are merely IPv4 aware

OSI Model

The **OSI Model** is a layered approach of all network traffic.

#	Layer	Example
7	Application	HTTP, SMTP, FTP, DHCP
6	Presentation	SSL/TLS, UTF-8, JSON
5	Session	PPTP, RPC, SMB
4	Transport	TCP, UDP
3	Network	IP, IPSec, ICMP
2	Data Link	PPP, AppleTalk, Ethernet, Wi-Fi
1	Physical	DSL, Cable, PSTN

Table 1: OSI Model

Table 1 lists the layers and examples. Most web development is at layers 6 & 7. Today's discussion will also focus on layer 3.

DHCP & SLAAC

IPv4 is primarily "autoconfigured" using **D**ynamic **H**ost **C**onfiguration **P**rotocol (DHCP). DHCP was originally designed as an extension to BOOTP, a network method of booting a diskless workstation from the network.

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IPv6 has two methods of configuring: DHCPv6, which is IPv6 DHCP and **S**tateless **A**ddress **A**uto**c**onfiguration (SLAAC). SLAAC essentially asks everyone around you for the gateway and network part of the IPv6 address. The large advantage of this is that there's no single point of failure (the DHCP server).

The IPv4 Address

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With 32 bits, the theoretical limit on IPv4 is $2^{32} \approx 4.2$ billion IPv4 addresses. With the world population currently at 7.2 billion, that is 1 IPv4 address per 1.67 people. [1]

The IPv6 Address

An IPv6 address is written in hexadecimal notation. For instance, `2001:470:4b:1f4:dee7:d16:9ec0:de72`. While this may look intimidating, hexadecimal was chosen because it can represent many more bytes in a smaller space.

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IPv6 addressing is not fundamentally different than IPv4 addressing is. Other than the obvious difference in the size & representation of the address space, the concepts remain exactly the same.

Subnetting

Each IPv*X* address consists of two sections: the network and host section. The division of the network and host sections are determined by the individual ISPs and systems administrators.

The canonical way of addressing and making the network/host boundary known is to use CIDR[1] notation. This indicates the number of bits for the network section of the IP address. Given the following 2 IPs:

`198.251.70.220/28`
`2001:470:4b:1f4:dee7:d16:9ec0:de72/96`

The IPv4 has 28 bits for the network section and 4 bits for the host section. Similarly, the IPv6 has 96 bits for the network section and 32 bits for the host section.

[1] **C**lassless **I**nter-**D**omain **R**outing

Common IPv4 & IPv6 subnets

The common IPv4 subnets are:

- /8: "Class A": $2^{24} = 16,777,216$ addresses
- /16: "Class B": $2^{16} = 65,536$ addresses
- /24: "Class C": $2^{8} = 256$ addresses

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The common IPv6 subnets are:

- /48: large site deployment $2^{80} \approx 1.209 \times 10^{24}$ addresses
- /64: end user deployment $2^{64} \approx 1.845 \times 10^{19}$ addresses
- /96: small end user deployment $2^{32} = 4,294,967,296$ addresses

Notice the "smallest" IPv6 subnet is enough to fully accomodate all possible IPv4 addresses.

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Need I go on!?

Regional IP Address Control

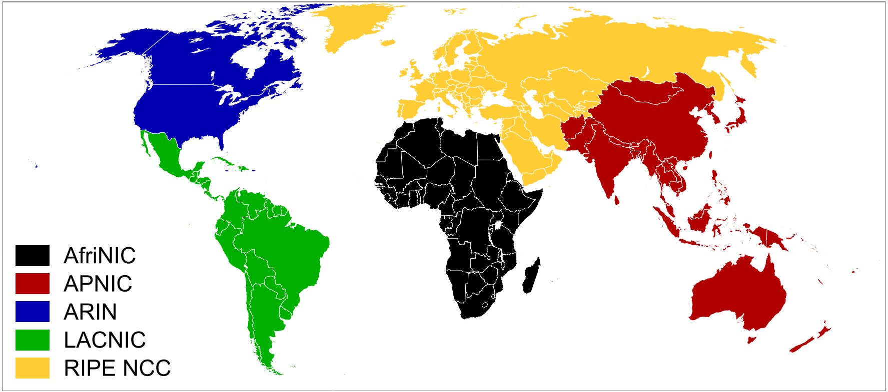

Figure 1: Regional Registries

Regional Statistics

Currently, the regional authorities are reporting the following number of IPv4 addresses: [2]

Region	**Remaining IPv4s**	**% Change Since April 2014**
Africa	50,525,282	-4.0657 %
Asia/Pacific	13,821,881	+3.7838 %
North America	11,410,384	-46.4627 %
Latin America	3,672,662	-71.61766 %
Europe	16,370,480	+17.8664 %

Table 2: Remaining IPv4s by Region

Asia/Pacific exhausted in April 2011. Europe exhausted in September 2012. North America exhausted in April 2014. [3] Latin America exhausted in June 2014. [4]

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  - ISP quality NAT, while it has delayed the inevitable slightly, breaks this end-to-end communication.
  - This problem has been exacerbated by the explosion in connected mobile devices.

The only true long term solution is IPv6.

IPv6 Improvements

The most obvious improvement in IPv6 is mind boggling number of addresses. $2^{128} \approx 3.40282 \times 10^{38} \approx 340$ trillion trillion trillion. That's still enough IP addresses to grant every grain of sand on the earth and every single cell on every single human an entire IP space the size of IPv4 and still have IP addresses to spare!

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In addition to the mammoth IP address space, IPv6 enjoys the following features:

- Built in security (IPSec)
- More efficient routing
- Easier auto-configuration

End Point Approaches

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Dual stack is by far the most efficient method and is easiest to setup. Where possible, dual stack is preferred.

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ISP	IPv6?
AT&T DSL	yes
AT&T Wireless	no
CenturyLink	yes
Comcast	yes
Sprint	no
T-Mobile	yes
Verizon Wireless	yes

Table 3: IPv6 Compatible ISPs

Tunnels

A **tunnel** is a service provided by a **broker**, an upstream ISP that has IPv6 access. Packets are sent from the endpoint to through the tunnel via IPv4, thus negating the necessity for native IPv6 at the end point. Many IPv6 enabled routers can be configured to use a tunnel out-of-the-box.

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Tunnelbroker & Sixx are the most popular brokers and are integrated into most end user's router configuration pages. Once the tunnel is created and configured, IPv6 will be enabled on the local network.

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That's right! Apache worked with IPv6 immediately! Ever since then, the dual stack web server has been chugging along transparently irrespective as to whether IPv4 or IPv6 clients are connecting.

Storing IP addresses

As just discussed, IP addresses are just numbers. To convert the ASCII (string) format, PHP has the `ip2long()` function for IPv4 addresses. The traditional wisdom was to use this function and store the IPv4 address as an `INTEGER UNSIGNED` in mySQL.

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The new way is to store IPv*X* addresses as raw binary data and store it in mySQL as `VARBINARY(16)` to effectively accommodate both IPv4 and IPv6 addresses. In PHP, use the `inet_ntop()` to retrieve IPs and `inet_pton()` to store IPs. This will create an efficient solution that is both IPv4 and IPv6 compatible.

IPv6 Application “Y2K” Problem

The real impact on web developers, and developers in general, is IPv6-enabling applications. The previous discussion about storing IPv6 addresses is only the beginning. After you're enabled with a dual-stack web server, code modifications abound. . .

- Changing mySQL table definitions
- Refactoring IP-based access lists to support IPv6
- Enhancing logic that deals with geolocation of IPs
- IPv6 enabling code that depends on DNS queries
- **Regression testing** a new IPv6 application

IPv4 will be around for some years to come. IPv6 will need to cooperate with IPv4 while the world is in transition. This cannot happen without great developers.

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