**Beginner's Guide to**

INTERNET PROTOCOL (IP) ADDRESSES

ICANN

This is one of a series of guides about issues of importance to Internet users. Educating new users about Internet issues is part of ICANN's mission to ensure a stable, secure, globally interoperable Internet. ICANN prepared this guide at the request of the At-Large Advisory Committee, the voice of the individual Internet user at ICANN. We sincerely hope you find it helpful.
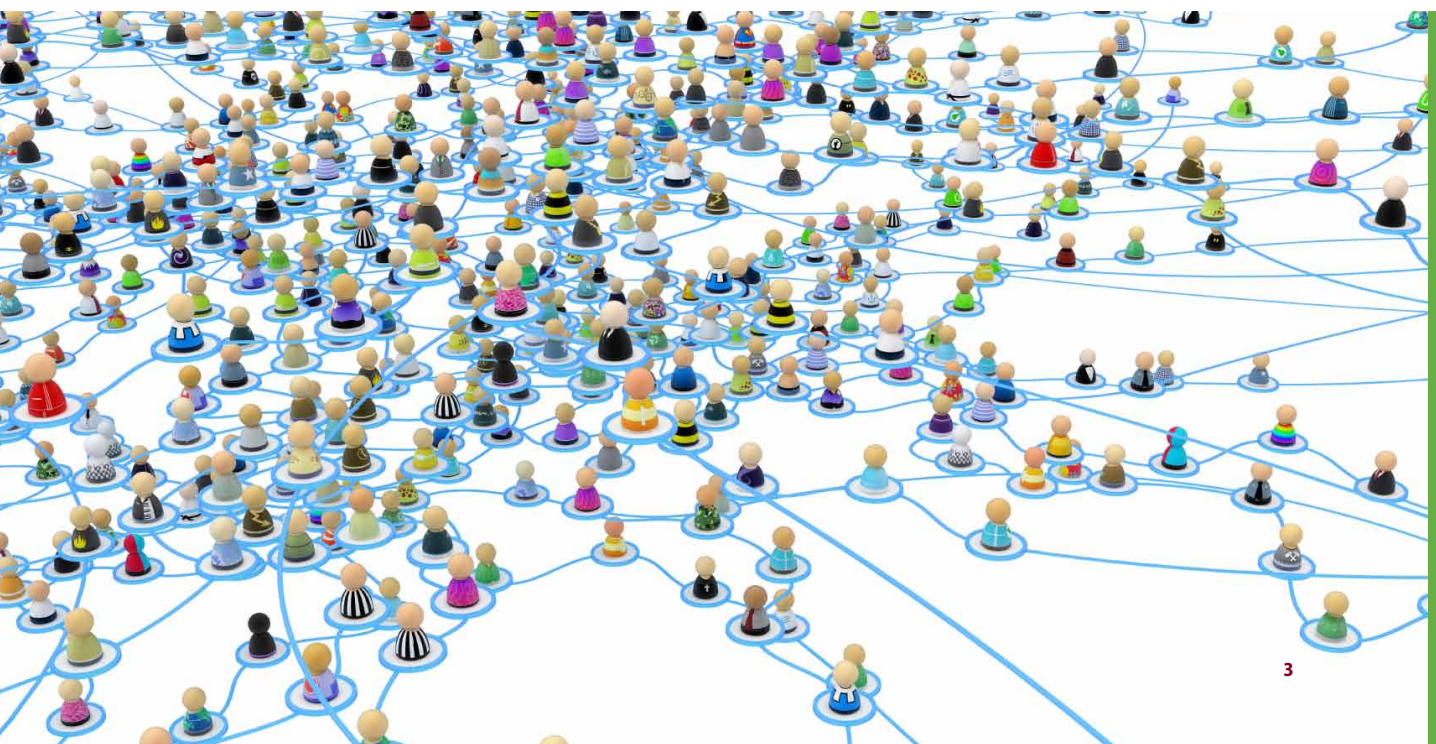
INTRODUCTION

Internet Protocol (IP) addresses are the unique numbers assigned to every computer or device that is connected to the Internet. Among other important functions, they identify every device connected to the Internet, whether it is a web server, smartphone, mail server, or laptop. After years of rapid Internet expansion, the pool of available unallocated addresses for the original Internet Protocol, known as IPv4, has been fully allocated to Internet Services Providers (ISPs) and users. That's why we need IPv6, the next generation of the Internet protocol that has a massively bigger address space than IPv4.

IPv4 Capacity
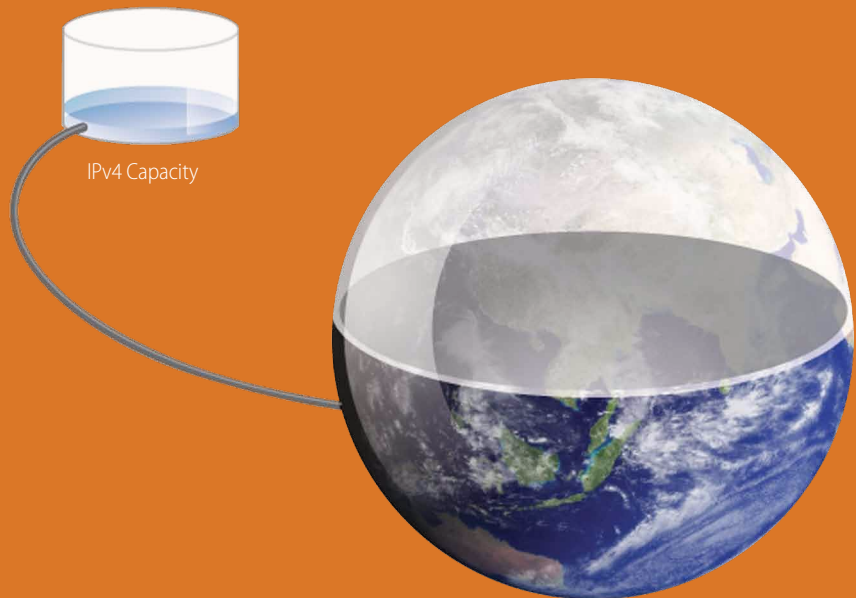
There are 7 billion people on Earth, but IPv4 only offered about 4.3 billion IP addresses. IPv6 offers enough for everyone.

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WHAT IS AN IP ADDRESS?

"IP address" is a shorter way of saying "Internet Protocol address." IP addresses are the numbers assigned to computer network interfaces. Although we use names to refer to the things we seek on the Internet, such as *www.example.org*, computers translate these names into numerical addresses so they can send data to the right location. So when you send an email, visit a web site, or participate in a video conference, your computer sends data packets to the IP address of the other end of the connection and receives packets destined for its own IP address.

WHY DO WE NEED IP ADDRESSES?

IP addresses are the numbers that enable our computers, servers, telephones, cameras, printers and sensors to communicate with each other. Without IP addresses, we would have to copy data from device to device manually, using CDs, DVDs, hard disks or flash storage, such as a USB drive. But more importantly, our devices could not send data to each other without human intervention. Without the IP addresses assigned to our computers, we would have to send paper letters and memos instead of sending emails. There would be no streaming video sites. Instead, we would have to send each other discs and tapes. Worst of all, we would not be able to order items online and would have to go to stores to buy them in person. It would be horrific, like the 1970s all over again.

WHAT IS THE DIFFERENCE BETWEEN A PRIVATE IP ADDRESS AND A UNIQUE IP ADDRESS?

Private addresses are the addresses people use on private networks, such as many home and office networks. At a protocol level there is no difference between the addresses, but organizationally, private addresses are distinct because they can only be used within a single administration and not on the wider Internet. This is because private addresses are set aside for use by anyone without any global coordination. You can know an address is from a block of private addresses if it:

- Begins with 10. (i.e. 10.0.0.0 through 10.255.255.255)

- Begins with 172.16. through 172.31.

- Begins with 192.168.

These addresses are the defaults used in a lot of plug'n'play networking equipment, like that sold to residential Internet users. Unique addresses are different only in that their distribution is managed by a set of registries. Because the registries manage the distribution of the other addresses, it is possible to know who an address is assigned to and how to get in contact with them. These types of addresses allow data to be routed across the whole Internet.

If your computer is assigned a private address, but you can still access services over the Internet, then your computer is probably behind a Network Address Translator (NAT), which lets lots of computers share a single unique IP address.

HOW MANY IP ADDRESSES DO I USE?

Typically, a residential Internet connection is assigned one unique address and uses a block of private addresses to number each computer, printer, video game console, or smartphone connected to it. But while this address is assigned to the connection we use, the services and peers we communicate with on the Internet also have addresses. There are approximately 3.7 billion addresses available for ordinary Internet connections, and about 1.6 billion people used the Internet in 2009. So, very roughly, each user requires a little over two unique addresses.

WHAT DO IP ADDRESSES LOOK LIKE?

There are currently two different versions of IP addresses in use—IPv4 and IPv6. The two versions look quite different from one another.

IP addresses are actually just long strings of numbers, like 3221226037, but to make it easier for people to read them, we write them down in a special way. IPv4 addresses are written as a string of four numbers between 0 and 255, separated by dots. A typical IPv4 address looks like this: 192.0.2.53.

IPv6 addresses are considerably longer strings of numbers, so they are written using hexadecimals, which can fit more information into fewer digits. Colons separate the segments of IPv6 addresses instead of dots; for example, 2001:0db8::53. In fact, when you see two colons side by side in an IPv6 address, you know that all the segments between them contain only zeros. Without those colons, the example address expands to its fully-written version, 2001:0db8:0000:0000:0000:0000:0000:0053.

WHAT IS IPv4'S HISTORY?

IPv4 has just over four billion unique IP addresses. It was developed in the early 1980s and served the global Internet community for more than three decades. But IPv4 is a finite space, and after years of rapid Internet expansion, its pool of available unallocated addresses has been fully allocated to Internet services providers (ISPs) and users.

Only 3.7 billion IPv4 addresses are usable by ordinary Internet access devices. The others are used for special protocols, like IP Multicasting. Almost three and a half billion addresses was enough for the experiment that the Internet started as in the 1980s, but it is not enough for a production network in today's world, with its population of almost seven billion people.

WHAT IS IPv6'S HISTORY?

Standardized in 1996, IPv6 was developed as the next-generation Internet Protocol. One of its main goals was to massively increase the number of IP addresses available. The first production allocations were made to ISPs and other network operators in 1999, and by June 2006, IPv6 was successful enough that important test networks shut down. They were no longer needed.

Over the past year, major content providers and access networks have started offering IPv6 services to ordinary Internet users. Because IPv6 is so much larger than IPv4, it should last us considerably longer than the 30 years IPv4 has given us so far. But just how large is IPv6?

IPv6 is significantly bigger than IPv4. Compared to IPv4's 32-bit address space of four billion addresses, IPv6 has a 128-bit address space, which is 340 undecillion addresses. That's not a number you hear every day!

Using IPv6, ISPs generally assign many thousands of network segments, called a /64, to a single subscriber connection used in places such as a home, classroom, or business. Giving every person on Earth a connection with a /64 would barely dent the available IPv6 address space. In fact, while the Earth's orbit around the Sun is only big enough to contain 3,262 Earths put side by side, it would take 21,587,961,064,546 Earths to use all the addresses in the part of the IPv6 space we now use.

What happened to IPv5?
It was an experimental protocol and is no longer used, although some of the concepts it developed have been incorporated into other protocols.
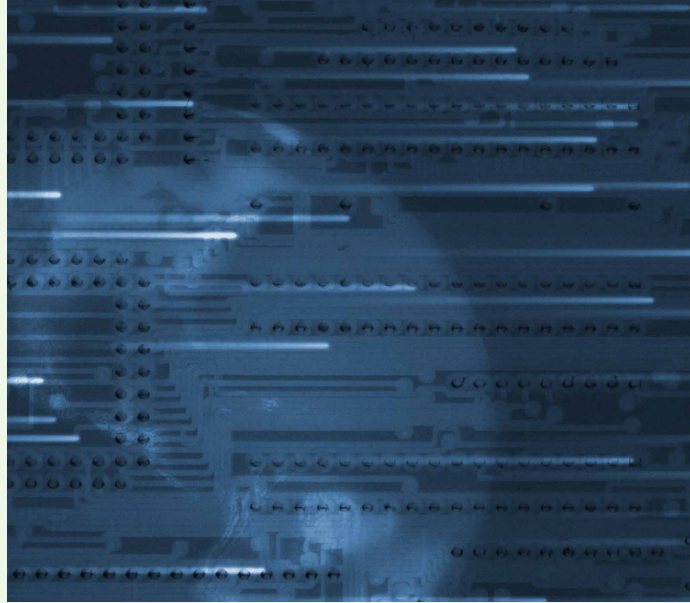
HOW ARE IP ADDRESSES DISTRIBUTED?

IP addresses are distributed in a hierarchical system. As the operator of Internet Assigned Numbers Authority (IANA) functions, ICANN allocates IP address blocks to the five Regional Internet Registries (RIRs) around the world. (The "regions" of the Regional Internet Registries are roughly continental in size.) The RIRs then allocate smaller IP address blocks to ISPs and other network operators. From there, the ISPs and other Internet operators assign the addresses to the individual Internet connections you are probably accustomed to.

HOW WERE IPv4 ADDRESSES DISTRIBUTED?

IANA assigns addresses based on globally agreed-upon rules, or policies. The key policy elements for IPv4 were:

- RIRs received IPv4 blocks in /8 units from IANA.

- RIRs could receive an additional block when they had just one half of a block left.

- The number of /8 units RIRs received was based on a formula established by IANA.

Two policies governed the allocation of IPv4 addresses to the RIRs. The regular policy was called the ***Policy for Allocation of IPv4 Blocks to Regional Internet Registries*** and governed how IPv4 addresses were allocated to RIRs since April 2005. The second, called the ***Global Policy for the Allocation of the Remaining IPv4 Address Space***, governed how the last five IPv4 /8s were allocated. It was ratified in March 2009.

The regular policy

The regular policy contained a formula for determining when an RIR qualified for additional IPv4 address space and how much address space the RIR could receive. To qualify for additional space, the RIR had to meet one of the following qualifications: it must have had less than 8 million addresses, which is less than half of a /8, left in its stock of addresses that it could distribute, or it must have lacked sufficient space to meet its members' needs for the coming nine months.

Defining the variables

The variables in the policy's formula were available space and necessary space. All an RIR's IPv4 address space was considered available for allocation unless the space was a reservation that would expire within the coming three months, or was fragmented.

A reservation is a block of address space set aside for a particular network operator at a future date. RIRs sometimes reserve particular blocks for network operators that frequently request more address space. By doing so, the RIR can ensure a sequential allocation in a single, contiguous block, and the network operator can announce these reserved spaces as a single route, reducing the burden on the routing system.

Fragmented spaces are blocks of address space that are smaller than the minimum allocation size set by the RIRs' policy-making community.

A /8 is a block of 16,777,216 contiguous IPv4 addresses. There are 256 /8s in the whole IPv4 address space. A list of all the IPv4 /8s and their purpose can be found on the IANA web site, on the ***IANA IPv4 Address Space Registry page***. One example is 10/8, which was reserved for use on private networks, such as those used in homes connected by DSL or cable connections, as well as many offices and WiFi hotspots.

The policy's formula considered recent history and then projected forward to determine how much address space an RIR might need in the future. The formula worked this way: First, it used simple averaging to determine the number of addresses allocated per month during the past six months. This average helped determine how much space an RIR was expected to need in the near term. If the RIR's available space was not enough for the next nine months of allocations, the RIR qualified for additional address space.

Special facts

The policy also allowed special facts to be taken into account when calculating how much additional IPv4 address space an RIR qualified to receive. These special facts might have applied if there was a new regional policy or external factors, such as new infrastructure, new services within the region, technological advances or legal issues. In all cases, the RIR was required to explain the change in consumption rate or the impact of the new policy, or it had to provide an analysis of the external factors. If the RIR's data was not sufficiently clear, IANA could question it.

Special facts were almost never used to support requests for additional address space. In fact, RIRs tended to request less address space than they could justify.

The calculation

Once this data was collected, the calculation could go forward.

> **Necessary Space = Average Number of Addresses Allocated Monthly during the Past 6 Months x Length of Period in Months**

Although each RIR provided all this data to ICANN's IANA Department with its request, most of the data was published every day in a standard format log file, and was mirrored on the IANA FTP site. But whether the calculation was done by ICANN staff or by an observer, using the data published by the RIRs made calculating the results simple. The numbers could be entered in a spreadsheet that calculated how much space an RIR could receive.
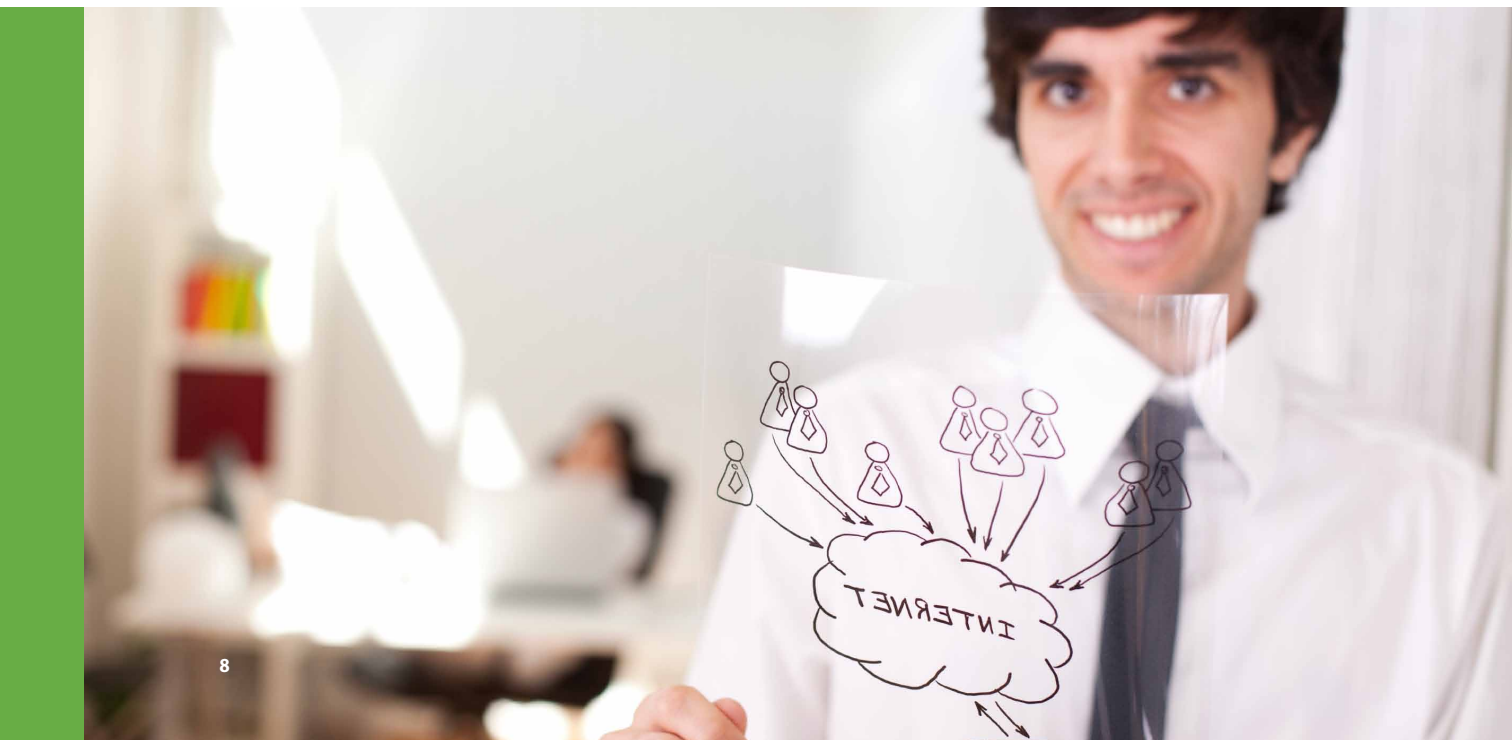
HOW ARE IPv6 ADDRESSES DISTRIBUTED?

ICANN's Board of Directors ratified the policy governing the allocation of IPv6 address space to RIRs in September 2006. The key policy elements are:

- RIRs receive IPv6 blocks in /12 units.

- RIRs can receive an additional block when they have just one half of a block left.

- The number of /12 units RIRs receive is based on a formula established by IANA.

The policy details

Similar to the IPv4 policy, the IPv6 policy contains a formula for determining when an RIR qualifies for additional IPv6 address space and how much it can receive. To qualify for additional IPv6 address space, the RIR must have less than 50 percent of a /12 left, or it must not have enough space to meet its members' needs for the coming nine months.

Defining the variables

The variables in the policy's formula are available space and necessary space. All an RIR's IPv6 address space is considered available for allocation unless the space is a reservation that will expire within the next three months, or is fragmented.

The policy's formula considers recent history and then projects forward to determine how much address space an RIR might need in the future. The formula works this way: First, simple averaging is used to determine the number of addresses allocated per month during the past six months. This average helps determine how much space an RIR is expected to need in the near future. If the RIR's available space is not enough for the next nine months of allocations, the RIR qualifies for additional address space.

Special needs and the calculation

Special needs and the calculation determining how much IPv6 space an RIR needs are handled the same in IPv6 as they were for IPv4.

WHO SETS THESE POLICIES?

These distribution policies are developed in the RIRs' regional public policy forums. The process is very similar to the consensus-based, bottom-up approach used to develop other ICANN policies. The RIRs allocate addresses to ISPs and other network operators according to the policies developed in these public policy forums, in which representatives from industry, governments, and civil societies participate.

These forums are open to participation by anyone with access to email. Discussions happen via open, archived mailing lists and at open meetings. RIR membership is not required to fully participate in the policy development process. This means everyday Internet users—including you—can participate.

Anyone can submit a global policy proposal. The proposal can be submitted to an individual RIR's policy-making process, like any other regional policy proposal, or they can be submitted directly to the Address Supporting Organization Address Council (ASO AC). The ASO AC is the body that makes sure a global policy proposal has reached consensus properly in all five RIR regions before the proposal is sent to the ICANN Board of Directors to be ratified.

The ASO AC can be contacted through the addresses listed on its web site at *http://aso.icann.org/contact/*.

A /12 is a block more than a million times the size of the minimum allocation made by RIRs to ISPs and other network operators. Some ISPs run very large networks and receive blocks thousands of times larger than the minimum, but a /12 allows for at least tens of thousands of allocations to organizations running networks before the block is fully allocated.

To give you a sense of how many IP addresses are in a /12 block, think about this: All five RIRs were allocated a /12 of IPv6 address space in 2006. As of the end of 2010, none of them had requested additional address space.

WHY DOES EVERY DEVICE NEED AN IP ADDRESS?

IP addresses are the numbers that identify devices connected to a network. If your device only needs access to a local network, it can be identified with an address that has only a local context. These are called private addresses. But when your device needs to access services on other networks, it needs to use a unique address. In some cases, this is done by translating a private address into a unique address at the border between your network and your ISP's network. This technology is called Network Address Translation, or NAT.

NAT has the advantage of allowing multiple devices to share a single, unique address, but it also has disadvantages. One of these is that the device doing the NAT must understand the protocol being used by the devices communicating through it. If the protocol you want to use is not supported by the NAT, you cannot use it.

This can cause frustration when, for instance, you are unable to use your Voice over IP (VoIP) service from a hotel or airport lounge while travelling. But there is also a second problem. If a new NAT device does not support a protocol, it will stop the people using the network it serves from also using that protocol, unless it is replaced. This stifles innovation in the services that can be provided over the Internet.

Losing innovation means losing access to new services that could enrich our lives. But the variability in the protocols supported by NATs means that services often either work or break depending on the equipment used by the network operator, not by the setup on the individual user's computer.

ARE THE INTERNET AND ITS TECHNOLOGY READY FOR THE TRANSITION TO IPv6?

Most of the existing systems that we use today already support IPv6. If you're using a laptop, odds are, it supports IPv6 and has done so for quite some time. IPv6 is not dramatically different on the network from IPv4, and the machines we used 30 years ago were capable of running IPv6. This means that if the kind of computers operating thirty years ago could run IPv6, then pretty much any cell phone (or even pocket calculator) could run IPv6 today, if you really wanted it to.

WILL I BE ABLE TO ACCESS THE WHOLE INTERNET AS IPv6 USE BECOMES MORE COMMON?

Don't worry—we're not doomed. While an IPv4-only machine cannot communicate directly with an IPv6-only machine, there are a number of ways to get them to communicate when using protocol translators. Also, ISPs are developing and deploying new access mechanisms that will allow new Internet users some IPv4 connectivity through multiple layers of private addressing.

HOW CAN I GET IPv6 CONNECTIVITY?

If you're an average home user, your ISP will initiate the transition from IPv4 to IPv6 on your network. In most cases, you won't have to do anything. If you are required to change something, such as your Internet router, your ISP will let you know.

ADDITIONAL INFORMATION

How can I find out more?

Q Does my ISP provide me IPv6 connectivity now? Do they plan to provide it?

A Your ISP can tell you what they currently offer and when they plan to provide it.

Q Which RIR runs the open policy forum for my region?

A RIRs serve regions of roughly continental scope, with one RIR per continent. A list of regions and places served can be found on the NRO web site at *www.nro.net/about/get_resources.html*.

Q Where can I find out more about IP address management?

A Go to *http://audio.icann.org/icann-start-05-ipv6-20100429-en.mp3* to listen to an e-learning podcast about IPv6. You can read its transcript at *http://icann.org/en/learning/transcript-icann-start-05-29apr10-en.pdf*.

More information about IP address management can be obtained from ICANN, the RIRs and the Address Supporting Organization's Address Council:

- *www.icann.org*
- *www.nro.net*
- *aso.icann.org*
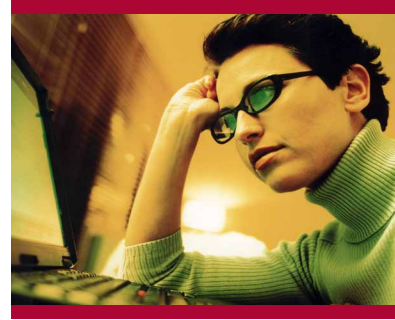
GLOSSARY

ASO	Address Supporting Organization
ASO AC	Address Supporting Organization Address Council
ccNSO	Country Code Names Supporting Organization
DSL	Digital Subscriber Line
GNSO	Generic Names Supporting Organization
IANA	Internet Assigned Numbers Authority
ICANN	Internet Corporation for Assigned Names and Numbers
ISP	Internet Service Provider
LAN	Local Area Network
NAT	Network Address Translation
NRO	Number Resource Organization
PAN	Personal Area Network
RIR	Regional Internet Registry
VoIP	Voice over Internet Protocol

ONE WORLD. ONE INTERNET.

About ICANN

ICANN's mission is to ensure a stable and unified global Internet.

To reach another person on the Internet you have to type an address into your computer—a name or a number. That address has to be unique so computers know where to find each other. ICANN coordinates these unique identifiers across the world. Without that coordination we wouldn't have one global Internet.

ICANN was formed in 1998. It is a not-for-profit public-benefit corporation with participants from around the world dedicated to keeping the Internet secure, stable and interoperable. It promotes competition and develops policy on the Internet's unique identifiers.

ICANN doesn't control content on the Internet. It cannot stop spam and it doesn't deal with access to the Internet. But through its coordination role of the Internet's naming system, it does have an important impact on the expansion and evolution of the Internet. For more information please visit *www.icann.org.*

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