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## IPv6 transit: what you need to know



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**PEOPLE HAVE BEEN PROCRASTINATING** about implementing IPv6 for over 10 years, but the day is coming soon [1] when this will leave your network disconnected from the only part of the Internet that is growing and innovating, the IPv6 Internet. At ARIN, we have been using IPv6 since 2003. In this article I will make some suggestions about choosing an IPv6 transit provider and offer some tips for determining if a provider's network is tunneling IPv6 over IPv4 or otherwise offering sub-optimal IPv6 services.

### The IPv6 Internet

While the names may sound similar, the protocols themselves are quite different. So different, in fact, that IPv4 and IPv6 are not layer 3 compatible. The good news is that they are layer 2 compatible in most cases, meaning that IPv4 and IPv6 can share the same wire, although even then an IPv6 host cannot connect directly to an IPv4 host; in much the same way that Appletalk and IPX are not compatible, IPv4 and IPv6 are distinct, incompatible protocols. Ultimately, this means that there are two Internets—one running IPv4 and the other IPv6. How do you connect to the IPv6 Internet? Does your current IPv4 transit provider offer IPv6 support? Is all IPv6 transit the same? Will your existing routers, firewalls, and other hardware and software support IPv6? What is different and what do you need to know to connect your network to the IPv6 Internet? I will attempt to answer these questions or provide the pointers you need to get the answers yourself.

In some ways the IPv6 Internet today is comparable to the IPv4 Internet of fifteen or twenty years ago. In 1993 there were only a handful of companies providing Internet connectivity; today there are only a few providers providing IPv6 connectivity. In 1993 there was a large disparity in the performance of transit provider networks, because many providers were not well connected or were under-provisioned. Today, many networks are not well connected to the IPv6 Internet, or their IPv6 network is not given the same level of support as their IPv4 network. In fact, only a handful of networks currently run IPv6 natively on their backbones, and many providers rely on tunnels, IPv6 carried inside of IPv4, to transit IPv6.

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## Backbones and Tunnels

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One question you must ask potential transit providers is how they transmit IPv6 over their network. Is their IPv6 network overlaid on top of their IPv4 backbone, or does it use a separate physical infrastructure? If the networks are separate, are they completely separate or do they diverge at particular points? A provider may advertise its modern 10-gigabit IPv4 backbone only to run its IPv6 network on older or more poorly provisioned equipment. Does the provider offer all of its services, from Web hosting and co-location to email and conferencing, over IPv6? A provider with broad product support over IPv6 is likely to be committed to providing good service no matter which protocol is used. Do they have a completely native IPv6 backbone, or do they tunnel portions of their IPv6 network over IPv4 in order to bypass devices that do not yet support IPv6? Tunnels can cause problems, especially if they are not well documented.

One reason tunnels can be problematic is that sudden changes in maximum transmission unit (MTU) can cause packet loss and complete failure for some protocols, such as HTTP. While IPv6 supports path MTU (PMTU) discovery, filters on routers and firewalls can cause this mechanism for detecting MTU to fail. Understanding where tunnels exist and what their MTU is can help in troubleshooting problems. If the MTU is too small, you may not be able to consider the provider at all, because your packets will never make it across their network.

There is a very easy way to detect tunnels by using the ping command. Most UNIX-like operating systems use ping6, rather than ping, to send ICMP packets over IPv6. You can use ping6 with the -s option to specify the packet size and the -Mdo (Linux) or -m (\*BSD) to disable fragmentation. The default value in most cases is 56 bytes which, when combined with the ICMP header, equals 64 bytes. You can take advantage of the ability to set the packet size with the ping6 command to find tunnels. The first thing you need to do is determine the path to test. This can be done using traceroute6 or the mtr command [2]. Both of these commands are available on most modern UNIX-like operating systems. I prefer mtr. Here's example output using mtr from my house to ARIN's Web server:

```
matt@fry:~$ mtr -6 -n www.arin.net
```

Host	Loss %	Snt	Last	Avg	Best	Wrst	StDev
1. 2001:470:e1ce:1::1	0.0	27	0.2	0.2	0.2	0.2	0.0
2. 2001:470:7:287::1	0.0	26	38.7	26.6	13.4	66.7	12.9
3. 2001:470:0:90::1	0.0	26	52.2	33.0	11.0	61.6	14.9
4. 2001:504:0:2:0:1:745:1	0.0	26	53.5	33.9	10.4	112.4	24.5
5. 2001:500:4:10::12	0.0	26	18.8	45.4	11.6	229.8	47.2
6. 2001:500:4:11::2	0.0	26	63.3	43.3	14.6	238.4	45.0
7. 2001:500:4:12::3	0.0	26	84.9	39.8	17.2	119.3	24.7
8. 2001:500:4:13::81	0.0	26	41.2	38.3	15.0	409.1	75.9

Using this output I can then use the ping6 command to ping each address listed in the path to determine if there is a tunnel along the way. Knowing that my local MTU is 1500, I'll issue pings to the address on the far side of my default gateway using ping6 -s 1480 -Mdo 2001:470:7:287::1. This produces the following output:

```
matt@fry:~$ ping6 -s 1480 -Mdo 2001:470:7:287::1
PING 2001:470:7:287::1(2001:470:7:287::1) 1480 data bytes
From 2001:470:e1ce:1:240:63ff:fef9:f6fb icmp_seq=1 Packet too big:
mtu=1480
```

I can then back down the packet size until packets get through:

```
matt@fry:~$ ping6 -s 1432 -Mdo 2001:470:7:287::1
```

```
PING 2001:470:7:287::1(2001:470:7:287::1) 1432 data bytes
1440 bytes from 2001:470:7:287::1: icmp_seq=1 ttl=63 time=12.8 ms
1440 bytes from 2001:470:7:287::1: icmp_seq=2 ttl=63 time=9.30 ms
```

I now know that the MTU for that leg of the packets' journey is just north of 1432 bytes. While this does not necessarily mean there is a tunnel, there is a very good chance that there is. At the very least there is a hop with a very odd MTU size and this is something that could cause you problems down the road.

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## Details, Details

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Understanding what type of data and which protocols you will send across the network is just as important when selecting an IPv6 provider as it was when selecting an IPv4 provider. The usual questions apply. How will their network handle your data? What is their uptime guarantee? No network has a perfect track record of uptime, but they should be able to guarantee their product with an SLA that gives credit for unplanned outages. Any provider should be able to provide uptime, latency, packet loss, and other statistics. It is important to make sure the statistics they are citing are for IPv6. It is also worth asking them if the statistics they provide are for IPv6 only or for both IPv4 and IPv6.

It can be difficult to get providers to divulge non-marketing-driven information about their network, especially details such as tunnel configurations and whether tunnels exist at all. Asking for a native IPv6 connection typically refers to your link to the ISP and does not necessarily imply that you are asking for native IPv6 from your connection to the ISP, through their network, and on to their providers and/or peers. It is important to ask if they are tunneling upstream from your connection. You may learn that they are using a tunnel to connect to their upstream providers and peers.

At least two Tier 1 providers have a native IPv6 backbone, and several other smaller providers have native IPv6 backbones that reach across the globe. There are providers that can offer tunneled service over existing IPv4 service, even when the IPv4 service is coming from another provider altogether. There are quite a few ways to get IPv6 transit right now, and in some cases it is easier and even cheaper to obtain IPv6 transit than IPv4.

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## Types of Transit Providers

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### TUNNEL BROKERS

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There are several organizations that will provide any network with free IPv6 transit using tunnels at no cost. These organizations, called tunnel brokers, are typically not-for-profit, but in some cases they are free services offered by for-profit companies. Some tunnel brokers will even allocate your network a /48 of IPv6 address space. That is 1,208,925,819,614,629,174,706,176 hosts, or 65,536 subnets, for free! In some cases BGP is allowed by providers and they will announce your IPv6 address block if you already have one, or just give you a feed of the IPv6 routing table. I mentioned above that tunnels can make troubleshooting more difficult, but the price of establishing an IPv6

tunnel cannot be beat, which makes this a good way to get your feet wet. You won't get an SLA for the price, but you will gain experience. To this day we still use tunnel broker accounts at ARIN for testing IPv6 outside of our own network. A good list of tunnel brokers is available at the IPv6Day Web site [3].

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### INTERNET EXCHANGE POINTS

Another way to participate in the IPv6 Internet is to join an exchange. At least one provider will provide free IPv6 transit if you peer with them at one of the common Internet exchange points (IXPs). In fact, if you have access to an IXP, you likely have access to several carriers willing to provide you IPv6 transit services. You will also find many smaller networks willing to peer with you over IPv6. Most IXPs now support both IPv4 and IPv6, which makes finding IPv6 peers and transit providers very easy. This approach to obtaining transit offers you great speeds, an SLA, and the opportunity to peer with other networks over IPv6, which can help reduce transit costs.

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### THE LAST MILE

So what if you want IPv6 transit with an SLA over your last-mile connection? How many providers are you likely to find that can provide you IPv6 over an OC3 or T1 to your data center or office? There are more than you might think. In 2002, when we started looking into IPv6 transit at ARIN, we had a very difficult time finding anyone that could offer us a T1 running native IPv6. We did eventually find a provider that gave us service on an experimental basis. Much of the upstream network was tunneled. The first few months involved a lot of troubleshooting, but the service worked and we did get an SLA. Today things have improved considerably. If you speak to one of the big carriers, you are likely to find IPv6 ignorance in the form of, "We don't do that," or "What is IPv6?" But if you are persistent and don't take no for an answer you may discover that IPv6 support is available. In some cases the service is tunneled over your existing IPv4 services, but you can find providers that support this configuration with an SLA.

ARIN is located in the Washington DC metro area, and something I have found over the years is that IPv6 support seems to be better among smaller ISPs. I know of several small ISPs in the DC area that offer native IPv6 transit over any last-mile connection they offer. I believe this is because smaller providers can be more agile, making it easier to implement IPv6 and have a leg up on their bigger competitors. This may be true for your area as well; you may find that the little guy is better connected to the IPv6 Internet than the big guy providing his transit! This is probably not a long-term thing, but it is worth looking at smaller providers in your area; you may be surprised at what you find.

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### INTERNET 2

There is at least one other way of getting IPv6 transit, and that is by joining the Internet2. The Internet2 is a nonprofit consortium of universities, corporations, government agencies, and laboratories. Not just anyone can join, but if your university, corporation, or agency is involved in research, you may qualify for a connection. Visit the Internet2 Web site [4] for more information about the project and to find out whether your organization is eligible to participate.

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## Selecting a Transit Provider

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It is important to apply the same criteria you used to select an IPv4 provider when selecting an IPv6 provider. Because there are so many tunnel brokers in the mix, you will probably have several providers to choose from, even if you do not have a local ISP that supports IPv6 directly. You need to make sure that the IPv6 transit being offered meets your requirements. Earlier I mentioned that the IPv6 Internet is, in some ways, less mature than the IPv4 internet. Companies are still building out their IPv6 networks and, in quite a few cases, have not started at all. Keep this in mind when speaking to providers about services. There are several important questions to ask:

- How are they connected to the IPv6 Internet?
- Do they have multiple IPv6 providers?
- How much IPv6 bandwidth do they have?
- Is that bandwidth dedicated or is it shared with IPv4 or possibly other protocols?
- Do they peer with other networks over IPv6?
- If they do peer, how many peers do they have?
- In which exchanges do they have a presence and use IPv6?

It is also very important to ask a potential provider if they offer the same SLA for IPv6 as IPv4. The answers to these questions will impact your IPv6 service provider selection decision.

Finding transit is the hardest task in your quest to establish a connection to the IPv6 Internet. Once you have a connection, things get easier. In the next part of this article I'll go over what you need to know about your routers and other equipment in order to get them to work with IPv6.

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## Connecting Your Network

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It may seem like enabling IPv6 support in your routers is going to be difficult, but generally this is the easy part. If you use Cisco or Juniper routers produced in the past six or seven years you can be fairly certain that your device supports IPv6. You may need to update the operating system on your router to a more current version, or in the case of Cisco, you may need to purchase the advanced IP services pack to enable IPv6 support. There is a good chance that you have gained IPv6 support in your routing hardware through regular software updates. If you use Linux, FreeBSD, or OpenBSD as a routing platform, you will have support out of the box, though depending on the operating system you will have some choices to make regarding firewall [5] and routing protocol daemons.

Assuming you have a router that is IPv6 capable, using it to connect to an IPv6 transit provider is no different from using it to connect to an IPv4 transit provider. In my experience, both Cisco and Juniper offer very good support for IPv6. Generally speaking, tasks like adding IPv6 addresses, ACLs, and static routes are very similar to doing the same tasks in IPv4. One thing that is critically important to understand is that IPv6 and IPv4 are treated separately in terms of access control lists. It is important that you recreate your IPv4 access control lists in IPv6. Your router will end up containing completely separate ACLs for IPv4 and IPv6. Keeping your access policies in sync between IPv4 and IPv6 can be painful, but it is very important. One thing that complicates this is the differences between the two protocols. For example, ICMP has a lot more functionality in IPv6; if you apply an IPv4 mindset to developing IPv6 ACLs, you are likely to break IPv6 features such

as path MTU discovery. I would recommend that you read up on IPv6 and understand how it uses ICMP differently from IPv4. If you understand this key difference, you will have a good start in being able to construct ACLs that do not cause breakage.

Another important thing to remember about configuring IPv6 on your router is that, much like ACLs, routing is separate from IPv4. If you keep in mind the fact that IPv6 is a separate protocol, it makes sense that routing would be separate. You must maintain a separate IPv6 routing table. You will have to explicitly configure IPv6 static routes or routing protocols for your network. You may need to establish a BGP session over IPv6 with your transit provider or with peers. Any routing policies you have must be maintained in both IPv4 and IPv6, which can make consistency a challenge. Routing in IPv6 works very much the same as in IPv4. Once you are used to the fact that IPv6 addresses just look different, you are left with something that, from a router's perspective, works very much like IPv4.

IPv6 does offer many new features, including additional security, advanced routing, and multicast capabilities, but knowledge of those features is not necessary to get your network connected to the IPv6 Internet. It is very easy to use knowledge you have gained building and maintaining IPv4 networks to enable IPv6 on your network. Once you have established transit there will still be a lot of work needed to get all of your hosts and services IPv6 enabled, but you have overcome one of the most difficult parts of the process. Taking advantage of new features in IPv6, enabling IPv6 in software, and bringing IPv6 to the desktop, laptop, and server are all subjects deserving of their own articles.

I hope this has provided you with enough useful information to establish IPv6 transit on your network. I think that you will find that implementing IPv6 is not a back-breaking, budget-busting exercise. Rather, there is a good chance your equipment and even your existing providers support IPv6 in some form, leaving you with a task that is easily manageable across networks of all sizes and complexities.

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## REFERENCES

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- [4] The Internet 2 Project: <http://www.internet2.edu/>.
- [5] David Piscitello, "Are Commercial Firewalls Ready for IP Version 6?" *login.*, vol. 33, no. 2 (April 2008): <http://www.usenix.org/publications/login/2008-04/pdfs/piscitello.pdf>.