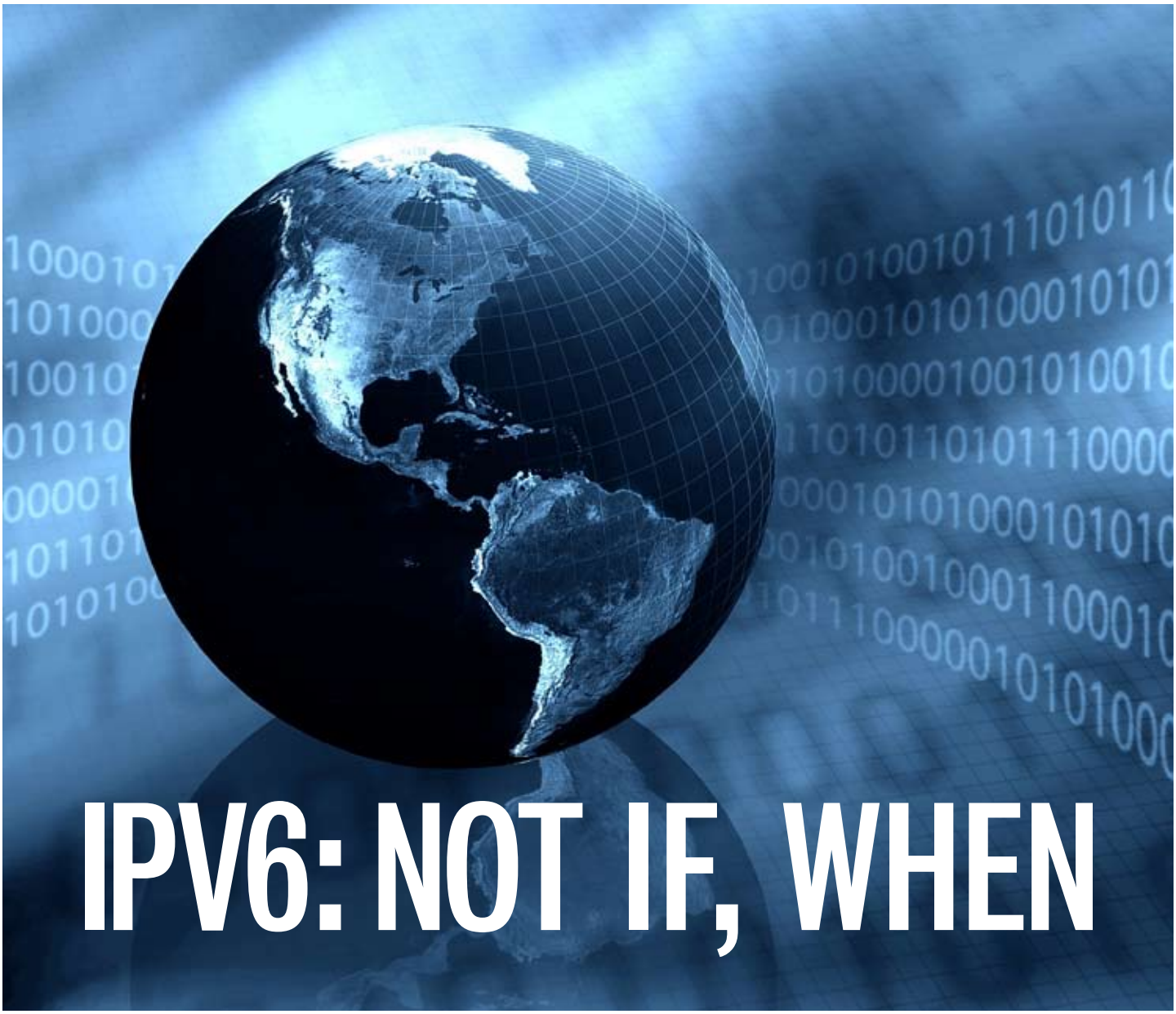
NETWORKWORLD®
EXECUTIVE GUIDE



IPV6: NOT IF, WHEN

U.S. government mandate, technological changes providing adoption momentum

Table of Contents

Profile: NTT Communications Corporation

About NTT Communications Corporation

NTT Com delivers high-quality voice, data and IP services to customers around the world. The company is renowned for its diverse information and communication services, expertise in managed networks, hosting and IP networking services, and industry leadership in IPv6 transit technology. The company's extensive global infrastructure includes Arcstar™ private networks and a Tier 1 IP backbone (connected with major ISPs worldwide), both reaching more than 150 countries, as well as secure data centers in Asia, North America and Europe. NTT Com is the wholly owned subsidiary of Nippon Telegraph and Telephone Corporation, one of the world's largest telecoms with listings on the Tokyo, London and New York stock exchanges.

About NTT America

NTT America is North America's natural gateway to the Asia-Pacific region, with strong capabilities in the U.S. market. NTT America is the U.S. subsidiary of NTT Communications Corporation, the global data and IP services arm of the Fortune Global 500 telecom leader: Nippon Telegraph & Telephone Corporation (NTT). NTT America provides world-class Enterprise Hosting, managed network, and IP networking services for enterprise customers and service providers worldwide.

U.S. product information regarding the NTT Communications Global IP Network and its award winning IPv6 transit services may be found at **http://www.us.ntt.net/**, by calling **877-8NTT-NET (868-8638)**, or by emailing **sales@us.ntt.net**.

NTT Com Operates one of the largest IP networks in the world

- The only Global Tier-1 from Asia
- The most financially stable telecom
- A global, single ASN (#2914)
- Industry leading SLAs
- Award winning customer service
- Access speeds to 10GigE
- Industry leading IPv6 and dual-stack IP transit

Introduction

IPv6: Not if, when

U.S. government mandate, technological changes providing adoption momentum

IF it seems as though IPv6 has been right around the corner for a decade now, that's because IPv6 has been around for that long: It was created by the IETF in 1998. This Network World Executive Guide to IPv6 is designed to bring IT leaders up to date on not only the adoption progress of this critical upgrade to the Internet's main communications protocol, but also its continuing technological evolution — which includes a few surprises.

Moreover, the guide features an in-depth discussion between three IPv6 experts and Network World readers who participated in an online chat session specifically about the business case for adopting IPv6.

The guide kicks off with a package of stories that examine the thinking behind a somewhat reluctant decision made by those shepherding IPv6 into the mainstream: They concluded the industry needed special Network Address Translation (NAT) devices to broker communications between IPv4-only and IPv6-only hosts. Eliminating NATs altogether had been a bedrock goal of IPv6 proponents.

"When the chips are down, NATs may be the only way we are going to get IPv6 added to the Internet," says Fred Baker, a Cisco Fellow who was chair of the IETF when IPv6 was designed. "If we have IPv4-only and IPv6-only networks, both of which we have now, NATs are the only way they will connect."

How exactly to usher in this era of the new NAT remains unresolved, although there are a number of proposals being floated and we address a number of them in this guide, including one from Comcast, the largest U.S. cable provider, and another from the government of China.

The latter is indicative of another IPv6 reality, namely that adoption abroad has far outpaced adoption in the United States. Network World National Correspondent Carolyn Duffy Marsan recently interviewed Kazuhiro Gomi, CTO of NTT America, who discussed the progress of IPv6 in the United States and in Japan. Asked if he thought America's economic troubles would spell yet more sluggishness for IPv6 adoption: "It's an interesting thought. Regardless of the economic situation, if you're in a country like Japan you got to do this within the next year or two. So I would say, IPv6 will come. And when it comes, it will be like an avalanche that spreads out quite quickly. It will come as a big wave."

Next up is a look at how U.S. government agencies are faring in meeting federal mandates to bring their networks into IPv6 compliance. All indications are that the preponderances of agencies are making the grade and there is every expectation that their adoption will spur faster IPv6 adoption in the private sector.

The balance of this Executive Guide is devoted to that online discussion between our readers and a panel of IPv6 experts. Sharing their insights were Fred Wettling, who manages architecture and strategic planning for Bechtel and is a member of the IEEE North American IPv6 Task Force; Patrick Grossetete, technical director of product management at ArchRock, makers of IP-based wireless sensor network technology; and, Ciprian Popoviciu, PhD, CCIE No. 4499, who is a technical leader at Cisco.

"From the perspective of the person that has led enterprise IPv6 implementation in a major international company, the strategic benefits are becoming clear," Wettling says, "especially where mobility, peer discovery, infrastructure management and end-to-end communications are important."

The session addresses a wide range of specific IPv6 questions and answers, some of which truly get down into the nitty-gritty. Taken in combination with the general overviews and analysis that precede it, this Executive Guide should be of great use to IT executives planning their corporate strategies.

IPv6

Section 1

Trends and analysis

Much-maligned feature being added to IPv6

Standards body weighs network address translators for next-gen Internet

■ *By Carolyn Duffy Marsan*

In a high-tech twist of irony, the Internet engineering community is adding a feature to IPv6 that the upgrade to the Internet's main communications protocol was supposed to eliminate.

One of the design goals for IPv6 was that it would rid the Internet of network address translation (NAT), gateways that match increasingly scarce public IPv4 addresses with private IPv4 addresses used inside corporations, government agencies and other organizations.

NAT is deployed in routers, servers and firewalls, and it adds complexity and cost to enterprise networks. Internet purists hate NATs because they break the end-to-end nature of the Internet; this is the idea that any end user can communicate directly to another end user over the Internet without middle boxes altering their packets.

But because it has taken so long to migrate the Internet from IPv4 to IPv6 – IPv6 is 10 years old and not yet widely deployed – and because IPv4 addresses are running out faster than Internet users are able to roll out the preferred method of IPv4-to-IPv6 transition known as dual-stack operation, the Internet engineering community has come to the conclusion that it must create special NAT devices to translate between IPv4-only and IPv6-only hosts.

"When the chips are down, NATs may be the only way we are going to get IPv6 added to the Internet," says Fred Baker, a Cisco Fellow who was chair of the IETF when IPv6 was designed. "If we have IPv4-only and IPv6-only networks, both of which we have now, NATs are the only way they will connect."

The Internet's leading standards body, the Internet Engineering Task Force, will discuss the issue of NATs for IPv6 at a meeting in Dublin, Ireland, later this month.

IETF Chair Russ Housley says NATs are "necessary for a smooth transition from IPv4 to IPv6."

Housley says most IETF participants are resigned to the fact that NATs are required to translate between IPv4 and IPv6 until all of the Internet's hosts and routers support IPv6.

"The engineers and computer scientists that make up the IETF wish that the original plan had come to pass. But, of course, it didn't," Housley says. "Given the current situation, the IETF participants are seeking a pragmatic solution, and there is rough consensus that this is the best way forward."

Housley says the IETF needs to have a NAT-for-IPv6 specification ready for deployment in the next year or two. But he's holding out hope that someday NATs will be eliminated from the Internet.

"The desire is for these NAT devices to be needed only during the transition period," Housley says. "That transition will certainly not be quick, but when it is over, the need for NAT should go away."

Baker, who chairs the IETF's IPv6 Operations working group, which has been leading the effort to develop NATs for IPv6, says it has been an "amusing debate" within the IETF. That's because there is a group of people who hate NATs and another group of people who work for companies that make money selling NATs, and sometimes people from both groups work for the same company.

The bottom line is that "we need NATs for IPv6," Baker says. The IETF leadership "says some translation approach is necessary."

Prompting the development of NATs for IPv6 is the current estimate that the Internet will run out of IPv4 addresses in 2011.

Section 1: Trends and analysis

IPv4 uses 32-bit addresses and can support 4.3 billion devices – not enough for the world's 6.5 billion people and all the Internet-connected PCs and cell phones they own.

IPv6 uses 128-bit addresses and can support a virtually limitless number of devices – 2 to the 128th power – connected directly to the Internet. IPv6 also has built-in security and network management enhancements. IPv6 backers have long touted the removal of NATs from the Internet as one of the key reasons for migrating from IPv4 to IPv6.

Despite its benefits, IPv6 has been slow to catch on outside of Asia, where IPv4 addresses are scarce. In the United States, the federal government is leading the way to IPv6 adoption.

Alain Durand, chair of the IETF's Softwires working group and a long-time IPv6 proponent, says the IETF must rethink how IPv6 will be deployed because of looming IPv4 address depletion. Durand is director of Internet governance and IPv6 architecture in the Office of the CTO at Comcast.

"The original master plan 15 years ago was that everybody was going to deploy IPv6, and all the devices would be both IPv4 and IPv6 dual stack. The whole universe would be this way long before IPv4 addresses ran out. Well, it didn't happen that way," Durand says.

The pressure for the IETF to develop NATs for IPv6 is coming from carriers and early IPv6 adopters such as the Chinese government.

When IPv4 addresses are depleted, carriers will give their new customers IPv6 addresses. But all of the PCs, printers and gaming systems owned by these customers won't be upgraded to IPv6. That's why carriers need a mechanism to translate between IPv4 and IPv6 addresses.

Both Comcast and Free, a French ISP, are considering rolling out NATs as part of their IPv6 implementations. Comcast has proposed to the IETF a NAT-and-tunneling combination called Dual-Stack Lite, while Free has proposed a mechanism that the carrier used to deploy IPv6 to 1.5 million consumers in France.

Durand's proposal includes traditional IPv4 NATs housed inside carrier networks along with IPv6-to-IPv4 tunneling at the edge of the network. Durand says this approach is the only realistic alternative to multiple layers of NATs translating between private IPv4, public IPv4 and public IPv6 addresses.

"We have found a way to combine tunnels and classic IPv4 NATs to provide IPv4 services to our customers after the exhaustion of IPv4 addresses," Durand says, declining to comment on the irony of the situation. "That's what really matters."

The Chinese government used NATs to interoperate between the Chinese Education and Research Network (CERNET), which is IPv4-only, and CERNET2, the next-generation Chinese Internet backbone that is IPv6-only.

Baker says the Chinese have been using a NAT approach dubbed IVI for about two years. "That makes it a strong contender in a world of rough consensus and running code," Baker says of IVI.

For the past year, the IETF's IPv6 Operations working group has been discussing how best to develop NATs for IPv6.

The IETF first considered network address translation with IPv6 in 2000, when it created a document entitled RFC 2766, Network Address Translation - Protocol Translation (NAT-PT). NAT-PT provided a mechanism for the dynamic allocation of public IPv4 addresses for IPv6-only nodes to allow IPv6-only nodes to communicate with IPv4-only nodes.

Last year, the IETF announced that NAT-PT causes too many deployment problems and security vulnerabilities. The rationale for avoiding NAT-PT, including the fact that it leaves networks open to denial-of-service attacks, is described in RFC 4966, Reasons to Move the Network Address Translation-Protocol Translation (NAT-PT) to Historic Status.

After much debate, the IPv6 Operations Working Group in May issued a document that outlines the requirements for NATs for IPv6. This document will be sent to the IETF leadership for approval this summer, Baker said.

Also working on NATs for IPv6 are the IETF's Behavior Engineering for Hindrance Annoyance (BEHAVE) working group, which specializes in issues related to the use of NATs over the Internet, as

well as the Softwires working group, which is developing tunneling and other mechanisms to ease the transition between IPv4 and IPv6.

"The work is important," says Dan Wing, chair of BEHAVE. Wing, a Cisco engineer, says BEHAVE will spend a significant amount of time at its face-to-face meeting in Dublin discussing NATs for IPv6.

The issue of NATs for IPv6 also is on the agenda for the Internet Area's open meeting in Dublin.

"We are going to evaluate NAT designs that avoid the problems described in RFC 4966," Wing says. "After the Dublin meeting, the [IETF leadership] will decide how to split the effort between the SOFTWIRE, INTERAREA, V6Ops and BEHAVE working groups."

The IETF is looking at five approaches for NATs for IPv6.

Choosing the best and simplest NAT approach for IPv6 is a priority for the IETF.

"A big concern of mine is that we'll make a NAT solution so good that no one moves to IPv6," Baker quips.

Geoff Huston, chief scientist at APNIC and an expert on IPv4 address depletion, says it's important for the IETF to develop high-quality NATs for IPv6 instead of ignoring the requirement as it did with NATs for IPv4.

"Frankly, it's a NAT-dense Internet these days, and I for one would rather see the world as it is than steadfastly maintain a position of high principle in the face of reality," Huston says. "The challenge to the IETF is whether it is prepared to shed its biases here and figure out what would makes NATs in IPv6 slightly less odious than what we did in IPv4."

Huston says NATs are useful for addressing, packet filtering and other functions. He says the real problem with NATs is that they lack standards, and that is an area where the IETF can make improvements in NATs for IPv6.

"The IETF's position of ignoring NATs some years back forced NAT software builders to exercise their own creativity when designing their version of NATs," Huston says. "This variation of NAT behavior is a far, far worse problem than NATs themselves."

Huston says NATs for IPv6 are "absolutely vital" for the transition from IPv4 to IPv6.

"Without NATs we might as well all go home, as we cannot drive through this transition process with a completely depleted IPv4 pool of addresses without a whole lot of additional NAT capability, both as traditional NATs and as protocol translating NATs," Huston says.

"WHEN THE CHIPS ARE DOWN, NATS MAY BE THE ONLY WAY WE ARE GOING TO GET IPV6 ADDED TO THE INTERNET. IF WE HAVE IPV4-ONLY AND IPV6-ONLY NETWORKS, BOTH OF WHICH WE HAVE NOW, NATS ARE THE ONLY WAY THEY WILL CONNECT."

FRED BAKER, a Cisco Fellow who was chair of the IETF when IPv6 was designed

IPv6 NAT proposals

The IETF is considering several NAT approaches for IPv6:

Nickname	Title	Backers	Description
Dual-Stack Lite	Dual-Stack Lite broadband deployments post IPv4 exhaustion	Comcast	This approach allows one globally unique IPv4 address to be shared among many customers, who have a tunneling mechanism in their home gateways to build IPv4 over IPv6 tunnels to reach a carrier-grade IPv4 to IPv4 NAT.
IVI	Prefix-specific and Stateless Address Mapping for IPv4/IPv6	CERNET/ CERNET2	Operational in China for two years. It embeds subsets of IPv4 addresses in prefix-specific IPv6 addresses, which allows these IPv6 addresses to communicate to both IPv6 and IPv4 networks via stateless gateways.
MNAT	Modified Network Address Translation	IMDEA Networks/ U of Auckland	Offers a modified version of the original NAT-PT concept that solves deployment problems and plugs security vulnerabilities.
NAT6	NAT for IPv6-Only Hosts	Cisco	Allows IPv6-only hosts that are inside the NAT to operate with IPv4 hosts that are outside without modifications to IPv4 hosts or apps or to the operating systems of IPv6 hosts. IPv6 applications must make changes.
NAT64	NAT64/DNS64: Network Address and Protocol Translation from IPv6 Clients to IPv4 Servers	IMDEA Networks/UC3M	This proposal includes two mechanisms: NAT64 for translating IPv6 packets to IPv4 packets and DNS64 to synchronize related DNS records. The mechanisms together enable communications between an IPv6-only client and an IPv4-only server.
SNAT-PT	Simplified Network Address Translation	Yokogawa	Seeks to resolve the problems with NAT-PT and to simplify the translation process and no longer have it depend on application layer gateways.
6rd	IPv6 Rapid Deployment on IPv4 infrastructures	Free	Uses stateless IPv6 in IPv4 encapsulation to transit IPv4-only network infrastructure. The ISP uses one of its own IP prefixes.

Section 1: Trends and analysis

NATs necessary for IPv6, says IETF chair

Housley holds out hope that NATs won't be in the Internet forever

By Carolyn Duffy Marsan

We posed a few questions to Russ Housley, chair of the Internet Engineering Task Force, about why the standards body is developing network address translations for IPv6 when IPv6 was supposed to eliminate the need for NATs on the Internet. Here's what Housley had to say.

The IETF has four working groups looking at NAT mechanisms for IPv6. How important is this work compared to other development efforts facing the IETF?

For the Internet to continue growing, the bigger address space offered by IPv6 is needed. The original designers of IPv6 expected every host and router to begin running both IPv4 and IPv6 several years ago. This strategy would have resulted in a gradual transition, with all hosts and routers being able to use IPv6 long before IPv4 address allocations became a problem. However, the economic incentives were not in place to encourage IPv6 implementation and deployment. As a result, we need the capability to translate between IPv4 and IPv6 until every host and router supports IPv6.

Isn't it ironic that the IETF is developing NAT mechanisms for IPv6 when IPv6 has been touted for years as a way of ridding the Internet of NATs?

Yes. I expect the address translation between IPv4 and IPv6 to be deployed at different places in the Internet than we have seen strictly IPv4 NAT. Further, the desire is for these NAT devices to be needed only during the transition period. That transition will certainly not be quick, but when it is over, the need for NAT should go away.

Are NATs for IPv6 a necessary evil?

They are necessary for a smooth transition from IPv4 to IPv6 so that the important properties of the Internet are preserved.

How would you characterize the debate within the IETF about NATs for IPv6?

The engineers and computer scientists that make up the IETF wish that the original plan had come to pass. But, of course, it didn't. Given the current situation, the IETF participants are seeking a pragmatic solution, and there is rough consensus that this is the best way forward.

What's the timeframe for the various IETF working groups to develop one or more new NAT mechanisms for IPv6? How fast does the Internet need this work done?

Everyone has a different crystal ball. However, my view is that the IETF needs to have a specification ready for development and deployment in the next year or two.

Section 1: Trends and analysis

Comcast pitches IPv6 strategy to standards body

Company touts simple, gradual approach to upgrade the Internet

■ *By Carolyn Duffy Marsan*

There is a coming perfect storm in which IT organizations deploy a series of initiatives, each of which is beneficial, but ends up with a situation where applications essentially cease to function. What follows are steps that IT organizations can take to minimize the impact of this perfect storm.

Comcast has developed an innovative approach for gradually migrating its customers to the next-generation Internet, and the ISP is promoting this approach to the Internet's leading standards body.

Comcast is the largest cable operator in the United States, with 24.7 million cable customers, 14.1 million broadband customers and 5.2 million voice customers.

Comcast is upgrading its networks from IPv4, the Internet's main communications protocol, to the standard known as IPv6. IPv4 uses 32-bit addresses and can support 4.3 billion devices connected directly to the Internet. IPv6 uses 128-bit addresses and supports an unlimited number of devices.

At issue is how Comcast will support new customers when IPv4 addresses run out, which is expected in 2011. Comcast can give these customers IPv6 addresses, but their home computers, printers, gaming systems and other Internet-connected devices are likely to support only IPv4.

Comcast engineers have come up with a solution to this problem, dubbed Dual-Stack Lite, which it says is backwards compatible with IPv4 and can be deployed incrementally.

Comcast outlined Dual-Stack Lite in a draft document published by the Internet Engineering Task Force on July 7. Dual-Stack Lite will be discussed at an IETF meeting in Dublin scheduled for later this month.

"This is about making IPv6 deployable incrementally," says Alain Durand, director of Internet governance and IPv6 architecture in the Office of the CTO at Comcast. Durand, a longtime IETF participant and IPv6 developer, chairs the IETF's Softwires working group, which is looking at IPv4-to-IPv6 transition issues.

"If you look at all the technologies deployed on the Internet in the last 15 years, all the successful ones have been deployed incrementally," Durand says. "You can deploy [Dual-Stack Lite] in your own network and get some benefits immediately regardless of whether your neighbors are doing it."

Durand points out that Comcast has not yet committed to using Dual-Stack Lite internally.

"This is a technology that we are looking at, but we have not committed to deploy it," Durand says. "It seems promising, but we have to make sure that it actually works and that it actually scales to the size of our network before we put it in our network."

Deploying IPv6

Comcast has been deploying IPv6 internally since 2005.

"Our backbone has been operational with IPv6 since 2006, and our original network has been progressively migrating to IPv6," Durand says. "What we are doing is moving to edge management of cable modems. This is the part that's in a trial phase."

Durand says it's critical for Comcast to be able to manage its cable modems and set top boxes after all of the IPv4 addresses are used up.

"IPv6 enables us to have global visibility of all of our networks," Durand says. "It allows us to manage tens of millions of devices in one single view."

Currently, Comcast gives one global IPv4 address to each of its customers. The customers are given home gateways that use private IPv4 addresses for each of its devices, such as PCs or gaming consoles. The global IPv4 address is matched to multiple private IPv4 addresses through a process known as network address translation (NAT), which is done by the gateway.

When IPv4 addresses are used up, Comcast will need to find a strategy for allowing a customer's IPv4-only devices to use an IPv6 address to communicate over an IPv4-driven Internet.

"We cannot force our customers to replace every single device in there homes. This is a non-starter," Durand says. "Also, if you look at the content on the Internet, the majority is reachable with IPv4. That may change in the future, but this is going to take many, many years."

The question is how Comcast can give its customers access to IPv4 content when there are no IPv4 addresses available. Unless customers upgrade their PCs to Vista, which is IPv6 enabled,

they won't be able to reach IPv4 content without a new mechanism such as NATs for IPv6.

Comcast's idea is to allow many broadband customers to share one global IPv4 address instead of giving one global IPv4 address per customer.

The exact ratio of IPv4 addresses to customers is something we are studying right now," Durand says. "We are working on some tests to see if it is 1 to 5, or 1 to 100 or 1 to 200."

This approach would be for new customers only; existing Comcast customers would keep the global IPv4 addresses they already have.

The trick with sharing public IPv4 addresses among many customers is doing it in the simplest way, Durand says.

One possibility involves two layers of NATs: one in customer gateways between private IPv4 addresses and shared public IPv4 addresses; and another inside carrier networks between shared IPv4 addresses and IPv6 addresses.

Durand says multiple layers of NATs would result in networks that are more complex and costly for carriers to operate.

"With two layers of NATs, there are two places where NATs can be tricky and create problems," Durand says. "Also your single view of the network is fragmented," which hinders debugging and repairs.

"IF YOU LOOK AT ALL THE TECHNOLOGIES DEPLOYED ON THE INTERNET IN THE LAST 15 YEARS, ALL THE SUCCESSFUL ONES HAVE BEEN DEPLOYED INCREMENTALLY, YOU CAN DEPLOY [DUAL-STACK LITE] IN YOUR OWN NETWORK AND GET SOME BENEFITS IMMEDIATELY REGARDLESS OF WHETHER YOUR NEIGHBORS ARE DOING IT."

ALAIN DURAND, director of Internet governance and IPv6 architecture in the Office of the CTO at Comcast

How Dual-Stack Lite works

Instead, the Dual-Stack Lite approach would use one layer of NAT – the carrier-grade NAT – along with IPv4 to IPv6 tunneling from the customer's gateway to the carrier's NAT.

With Dual-Stack Lite, the carrier upgrades its networks to IPv6 but uses a combination of tunneling and NAT to allow customers with IPv4-only devices and IPv6 addresses to access IPv4 and IPv6 content.

New customers with IPv6 addresses would get special home gateways that do tunneling but not NAT. These gateways would take IPv4 packets and ship them over an IPv6 tunnel to the carrier-grade NAT, which handles translation in a way that's similar to today's IPv4 NATs.

"This greatly simplifies and reduces the cost of the home gateway," Durand says. He adds that the new home gateways would be dual stack, which means they support both IPv4 and IPv6.

The carrier-grade NAT would be a dual-stack router that terminates IPv4 to IPv6 tunnels and performs traditional IPv4 NAT. Durand says the carrier-grade NAT could be implemented on a PC running Linux, or it could be implemented in software only.

"We are talking to some open source developers about creating this," Durand says.

Durand says the NAT/tunneling combination is simpler and less expensive than multiple layers of NATs for carriers to maintain during the transition from IPv4 to IPv6. This approach also allows a carrier to have visibility into home gateways through IPv6.

"The beauty of this is that there is no new technology to invent," Durand says. "This is combining pieces that already exist. We have known how to use tunnels for 15 years, and IPv4 NATs are nothing new. We'll have the same thing with the carrier-grade NAT except that it does also need the capacity to decapsulate the packets from the tunnel and remember which tunnel it was coming from."

Although Comcast's focus is on serving its residential customers, Durand says the Dual-Stack Lite approach could be used in enterprise networks.

"You can apply most of this to any large-sized network that has lots of remote branches," he says. "The remote branches would do IPv4 and IPv6 internally and then have an IPv6-only address. The IPv4 traffic would be tunneled over an IPv6 connection to a carrier-grade NAT in the corporate network. This will enable you to deploy very large IPv4 networks without worrying about running out of IPv4 addresses."

Durand says that the Dual-Stack Lite approach will accelerate the Internet's transition to IPv6, not delay it.

"The alternative is all those layers of NAT, which will be all IPv4 with not IPv6 at all," Durand says. "If we go forward with multiple layers of NATs, there is no incentive ever for deploying IPv6…This plan can accelerate the deployment of IPv6 because it makes it incrementally deployable."

Comcast points out that it is trying to propose Dual-Stack Lite as an industry-wide solution to IPv6 transition.

"This is not something that is a Comcast-only solution. This is something that we are working with the rest of the industry on," Durand says. "I have had a number of discussions with service providers around the world, especially in Japan and Europe, who are very interested in something like this."

How China is migrating to next-gen Internet

■ *By Carolyn Duffy Marsan*

Two years ago, the Chinese government adopted a controversial approach known as network address translation to bridge the gap between IPv4, the Internet's main communications protocol, and an emerging Internet standard known as IPv6.

Now, the Chinese are proposing their NAT approach - dubbed IVI - as a possible solution to other governments and carriers grappling with the looming depletion of IPv4 addresses and the long-anticipated upgrade to IPv6.

IPv4 uses 32-bit addresses and can support 4.3 billion devices connected directly to the Internet. IPv6 uses 128-bit addresses and can support a virtually limitless number of Internet-enabled devices, such as PCs, printers, gaming systems, cell phones and appliances.

IPv6 was designed a decade ago but hasn't been widely deployed outside of Asia, where IPv4 addresses are scarce. The Chinese government leads the world in IPv6 deployment, with the U.S. government working hard to catch up.

Usually, the Chinese are quiet about their Internet operations because they closely monitor and censor Web surfing by their citizens. However, details about the Chinese IPv6 network have trickled out over the years. (View a slideshow on how the Chinese Internet is different.)

Earlier this month, Chinese researchers outlined their IVI approach to the Internet's leading standards body, the Internet Engineering Task Force. In a document published July 6, engineers from the China Education and Research Network (CERNET) and Tsinghua University described their approach for co-existence and transition between IPv4 and IPv6.

To bridge between its IPv4-only CERNET and IPv6-only CERNET2, the Chinese developed IVI, a mechanism that embeds subsets of IPv4 addresses in prefix-specific IPv6 addresses. IVI allows these IPv6 addresses to communicate directly with global IPv6 networks and through stateless gateways to IPv4 networks.

The IVI scheme supports end-to-end address transparency, incremental deployment of IPv6 and performance optimization in networks that use multiple carriers, according to the document.

The Chinese are pitching IVI as a better way for IPv6 hosts to communicate with IPv4 networks than the IETF's current approaches. Existing standards propose running dual-stack hosts that support both IPv4 and IPv6 and tunneling, which involves encapsulating IPv6 packets to send over IPv4 networks.

The Chinese say a mechanism such as IVI is needed to translate between the different addressing structures used in IPv4 and IPv6. IVI can handle either IPv6 to IPv4 mapping or IPv4 to IPv6 mapping, the document says. It also can be used for client-server or peer-to-peer applications.

IVI "can satisfy most of the basic and advanced requirements for the IPv4 to IPv6 transition," the document says.

In the Chinese approach, carriers deploy gateways that are connected to both IPv6 and IPv4 networks. These gateways handle the IVI mapping and translation mechanism. The gateway runs an algorithm known as SIIT (for stateless IP/ICMP translation), which handles the translation between IPv4 and IPv6 packet headers.

The Chinese say they have successfully deployed IVI.

"The IVI gateway based on the Linux implementation has been deployed between CERNET (IPv4 and partially dual-stack) and CNGI-CERNET2 (pure IPv6) since March 2006," the document says. "The pure IPv6 Web servers using IPv6 addresses behind IVI gateways can be accessed by the IPv4 hosts and also by the global IPv6 hosts."

Several IETF working groups, including IPv6 Operations and Behavior Engineering for Hindrance Avoidance, plan to discuss IVI at a meeting in Dublin scheduled for later this month.

IVI is one of several NAT approaches under consideration for standardization by the IETF.

Fred Baker, co-chair of the IPv6 Operations working group and former chair of the IETF, says the fact that the Chinese have deployed IVI gives it a leg up over alternatives that are on paper only. "That makes it a strong contender in a world of rough consensus and running code," Baker says of IVI.

IPv6 will hit like an avalanche, NTT America CTO predicts

Progress has been slow, exec admits, but he predicts big wave of adoption

■ *By Carolyn Duffy Marsan*

NTT America is hoping that the saying from the movie "Field of Dreams" is true: If you build it, they will come. As the long-time leader in IPv6 deployment in the United States, NTT America is ready for a flood of U.S. government and business customers to upgrade to the next-generation of the Internet's main communications protocol. NTT America was the first carrier to offer commercial IPv6 transit service in 2001, and it was the first to offer IPv6-enabled firewalls in 2005. Now NTT America is inking deals with hosting companies such as The Planet and working on managed security services. Network World National Correspondent Carolyn Duffy Marsan recently interviewed Kazuhiro Gomi, CTO of NTT America. Here are excerpts from their conversation:

Kazuhiro Gomi

What is the state of IPv6 deployment by the Japanese government?

I'm not a representative of the Japanese government, so what I tell you may not be very comprehensive, but I know of the major activities that the Japanese government has done. The Ministry of Internal Affairs and Communications, which is like the FCC-equivalent of the Japanese government, had one of the biggest initiatives, which started out in 2003. It was a three-year project involving all the academic, industry and government sectors trying to show the world what IPv6 can do and to develop a couple of applications. The applications developed included a gas meter telemetry application, some sensor networks through which environmental measurements were calculated and sharing of medical information connecting different clinics in the city with rural villages. The government also put out some tax incentives for hardware vendors to develop IPv6 routers and switches. They put out guidance for federal agencies that all the government network equipment should be IPv6 compliant.

Does the Japanese government have a timeframe for its agencies to adopt IPv6?

I haven't seen anything specific. The Ministry of Internal Affairs and Communications issued in April 2007 a guideline for IPv6 adoption for electronic government systems. It's very technically oriented, and it's mainly a security policy. There are some assessments about the cost benefits of implementing IPv6 as well as some cost increases with IPv6. It's a pretty comprehensive guideline for the government systems department people to consider.

Are Japanese government agencies buying IPv6 services?

I haven't heard of anything big from the government side procuring IPv6 services. It's mostly test beds or research projects.

What are you seeing in terms of IPv6 adoption in the commercial sector in Japan?

There are more private sector initiatives rather than government sector initiatives. At NTT, we have been providing IPv6 DSL services since 2004. So right now, those who subscribe to DSL or Fiber to the Home get an IPv6 address automatically. We're providing dual-stack IPv4/IPv6 service. Those who want IPv6 service get global connectivity to reach out to the world.

What's your ballpark estimate on how many Japanese consumers use your IPv6 service?

A couple thousand.

Are there any particular applications driving

interest among Japanese consumers in IPv6?

We provide different video on demand kind of systems, and we've implemented quality of service on that. That's one application that has driven IPv6 implementation in Japan. Another one is an earthquake early alert system. I wouldn't say that it has been a driver of IPv6, but it certainly has enhanced awareness of IPv6 in Japan. This is a system run by the Japanese meteorological agency, which is trying to send a warning to the people when an earthquake happens. What the system is trying to do is 10 or 20 seconds after an earthquake is detected by central servers at the ministry, to let everybody know that a big earthquake is coming so people can hide or stay away from a danger area. IPv6 plays in quite nicely with this system, which is using multicast. Any of the devices that run this application start beeping and flashing to let people know that an earthquake is coming. If you subscribe to IPv6, this is one application you can use.

How would you compare what the Japanese government is doing to encourage IPv6 deployment versus the U.S. government [which had a mandate for all agencies to enable IPv6 on their backbone networks by June 2008]?

The Japanese government is playing the role of facilitator and promoting commercial or consumer-based applications. The U.S. government is focused on how to implement IPv6 on their own systems. The approach is a little bit different.

What do you think will be the return on investments made in IPv6?

We are the first service provider and still the only one who can do commercial IPv6 services around the world. This is a very clear differentiator for [us.] In terms of return on investment, we can say that's a big return for us.

What about for your customers?

In the United States, most of the customers we have are using IPv6 for their own development and experiments. They're trying to test out the additional address space and ease the management of their networks. I don't think we have any customers who are really using it for their internal corporate systems yet.

What trends are you seeing in demand for IPv6 services?

It's still slow. People's interest on this new technology is getting higher. All the warnings from [American Registry for Internet Numbers], RIPE [the European registry] and JPNIC [Japan Network Information Center] about IPv4 address depletion really caught everybody's eye, especially in Japan. Everybody in Japan is in crunch mode on IPv4. Many of the ISPs in Japan are worrying about their future if they keep hanging on to IPv4. Next year, they will have allocated all the IPv4 address space in Japan. So the timing has pretty much come for them.

We seem to be in a recession. Do you think that will slow IPv6 adoption?

It's an interesting thought. Regardless of the economic situation, if you're in a country like Japan you got to do this within the next year or two. So I would say, IPv6 will come. And when it comes, it will be like an avalanche that spreads out quite quickly. It will come as a big wave.

We've talked about IPv6 rollouts in Japan and the United States. What are you seeing in the rest of the world?

The U.S. and Japan are the major two areas where we have customers in IPv6. We have a very small number of customers in Europe. In Australia, we have a couple academic customers. We have some ISP customers in Latin America, so we have conversations with those ISPs about IPv6. Their awareness is very, very low.

As I continue to cover IPv6 developments, what should I be looking for to be able to tell when IPv6 reaches the tipping point?

Growth in the number of subscribers in all the different networks. Also, when it comes to the U.S. market, are there any local ISPs or cable companies who are going to launch IPv6 services? The Planet has announced IPv6 hosting services. How many other hosting companies will follow that company? That will be interesting to watch.

...IPV6 WILL COME. AND WHEN IT COMES, IT WILL BE LIKE AN AVALANCHE THAT SPREADS OUT QUITE QUICKLY. IT WILL COME AS A BIG WAVE.

Feds: We are ready for IPv6 D-Day

Agencies expect to meet deadline; future of IPv6 awaits new president

■ *By Carolyn Duffy Marsan*

U.S. federal government officials expect to declare an early victory on the IPv6 front, but they admit that meeting their much-heralded June 30 deadline for IPv6 compatibility is just the opening salvo of a long-term battle to get their networks ready for the Internet of the future.

Under a White House policy issued in August 2005, all federal agencies must demonstrate the ability to pass IPv6 packets across their backbone networks by this deadline.

Federal officials and IPv6 service providers are reporting little last-minute scrambling by agency CIOs or their network operations staff. That's because the federal IPv6 requirements aren't too difficult to meet, according to industry experts who predict agencies will file the required IPv6 test results on time to the Office of Management and Budget.

"It's surprisingly quiet given all the focus and attention and money that the agencies have spent on the IPv6 initiative and planning for it," says Bill White, vice president of federal sales for Sprint, which has worked with a half-dozen federal agencies to meet the mandate. "Agencies have done their testing and they have done the minimum to be in adherence with the OMB mandate."

"I have not heard of anybody who is not going to make the IPv6 deadline," says Pete Tseronis, chair of the IPv6 working group of the Federal CIO Council and a senior technical advisor at the U.S. Department of Energy. "For the last two-and-a-half years, agencies have been reporting on their IPv6 progress through their Enterprise Architecture quarterly and annual reports. … If someone doesn't make the deadline, it will be interesting to know why."

While the federal IPv6 deadline appears to be coming and going without drama, it is still a significant milestone in the anticipated rollout of the next-generation Internet. IPv6 has been available for a decade but has yet to be widely deployed.

IPv6 is an upgrade to the Internet's main communications protocol that provides virtually unlimited address space, built-in security and simplified network management. Created by the Internet Engineering Task Force in 1998, IPv6 replaces IPv4, which supports 4.3 billion individually addressed devices on the network.

IPv4 address space is running out, and experts agree that the 27-year-old protocol will not support all the Internet-connected devices used by the world's 6.5 billion people in the future. IPv6 provides so many IP addresses - 2 to the 128th power - that it is expected to enable secure, mobile and embedded applications that are inconceivable today.

Although commercial deployment of IPv6 is furthest along in Asia, where IPv4 addresses are scarce, the United States was the first country to require its federal networks to support IPv6 by a particular date. Indeed, the U.S. government's apparently successful effort to make its backbone networks IPv6 capable has prompted action among other countries worried about falling behind in next-generation Internet technology.

The European Commission held an IPv6 Day in Brussels, Belgium, in May to discuss Europe's lagging IPv6 deployment. European Union countries have set a goal - but not a requirement - for 25% of commercial, government and residences to use IPv6 by 2010.

"Basically, what they were saying at this meeting is that [Europe is] a little bit behind the U.S. and Asia," says Cody Christman, director of product engineering at NTT America, which has offered IPv6 Internet access for five years and counts the Federal Aviation Administration among its customers. Christman attended the May 30 IPv6 Day. "This is a call to action for the EU to get on the stick."

Karen Evans, administrator of the Office of E-Government and Information Technology in OMB, says that she expects all federal agencies to meet the IPv6 deadline.

"We have no reason to believe that agencies are not going to meet the deadline," Evans says. "Based on everything they have been reporting to us and how the process is supposed to work, there is no reason for the agencies not to be able to demonstrate compliance with IPv6."

Evans said 10 cabinet-level agencies have submitted the required e-mail to OMB from their CIOs stating that they have successfully transmitted IPv6 packets. Evans expects to receive similar e-mails from 14 other cabinet-level agencies in the next few days.

"They've done the work; they just need to send in the notification to OMB to validate the work that's been done," Evans says. "This doesn't mean I'm in a panic because I haven't received the form from 14 agencies. This is normal. We track [IPv6 progress] on a quarterly basis…We have no reason to believe that we won't receive the other notifications."

OMB's IPv6 mandate at a glance

- On Aug. 2, 2005, the Office of Management and Budget issued a memorandum entitled "Transition Planning for Internet Protocol Version 6" directing all federal agencies to be capable of supporting IPv6 on their backbone networks by June 30, 2008.
- On Nov. 18, 2007, the Department of Education was the first Cabinet-level agency to comply with OMB's IPv6 mandate.
- As of June 24, 2008, 10 Cabinet-level agencies had submitted the required e-mail to OMB confirming that they had met the OMB IPv6 mandate. These include the Department of Veterans' Affairs, the Department of Energy, the Department of Defense and the Internal Revenue Service.

Section 1: Trends and analysis

Evans says no federal agency has notified OMB of having failed to pass IPv6 packets successfully over the backbone network, and no federal agency has asked for an extension beyond June 30.

"It's a huge accomplishment for all of us to make the deadline," Evans says. "Agencies had to buy IPv6-compliant hardware, put the services out there and properly implement them so that they can run IPv6 across their backbones."

Even more important to the Bush Administration is the fact that the U.S. federal government met its IPv6 deadline without a huge influx of cash.

When the federal IPv6 mandate was being considered, some IPv6 marketers said the U.S. federal government needed to spend upwards of $10 billion on IPv6 transition. OMB proved them wrong. Instead, the U.S. government is migrating to IPv6 through its regular tech refresh budget with some minor additional spending in training and network engineering.

"We're going through this transition based on the life cycle of our IT investments," Evans says. "The infrastructure that agencies were buying already have IPv6 capabilities.... If we had done this as an after-thought, then it would have been a huge cost.... We're transitioning to IPv6 in a very concerted way."

Meeting the OMB's IPv6 mandate is relatively easy. Agencies have to prove they can pass IPv6 packets across their backbone networks, and that's possible because most routers support IPv6. However, there is no requirement for agencies to run IPv6 in production mode on their networks or to port their applications to IPv6.

The Bush Administration has no plans to establish additional IPv6-related deadlines. That will be up to the next person who directs OMB's e-government and IT initiatives, Evans says.

In the meantime, OMB will continue to require agencies to discuss IPv6 progress in their annual reports on enterprise architecture.

"Right now, we have agencies focused on segment network architectures that are robust... This information is going to be available so the next person in my position could take advantage of what we've done and make multiple deadlines for other IPv6-related capabilities," Evans said.

Some industry observers say OMB didn't go far enough with its IPv6 mandate, which didn't include deadlines for production-level deployment of the protocol.

"I think the real issue is that we don't have a lot of agencies running dual IPv4/IPv6 stacks. We don't have a lot of people adopting IPv6," says Diana Gowen, senior vice president and general manager of Qwest Government Services, which helped the Internal Revenue Service and the Federal Maritime Commission meet the IPv6 deadline. "The next Administration is going to have to worry about how we push IPv6 adoption because IPv4 address space is going to run out, and we do have reasons from a security perspective to do this."

For the next 18 months, the focus on IPv6 in the federal market will be at the National Institute of Standards and Technology (NIST), which is expected to issue in July Version 1.0 of its Profile for IPv6 in the U.S. Government. This document will detail how IPv6 hardware and software will be procured and deployed in operational government IT systems.

"There's definitely going to be a lot of work going on in IPv6 after June 30," Tseronis says. "We see much more of a collaborative relationship not only in the CIO Council and our IPv6 working group but with industry. We have a two-year program set up with NIST where they are going to work on an IPv6 compliance and interoperability testing program."

Tseronis describes OMB's IPv6 mandate and the June 30 deadline as Mile Marker 1 in a marathon-long transition to IPv6 for federal agencies.

"We've been having this conversation about IPv6 for two years. We've raised the awareness about IPv6," Tseronis says. "If I'm a CIO and I'm supposed to be forward-looking, I'll be looking at my IT refresh budget, I'll be looking at the age of my equipment, and I'll be anticipating IPv6 capabilities out there like security, multicasting and the ability to do more mobile communications. ... That's what I hope agencies are doing."

Tsesronis says the Federal CIO Council's IPv6 Working Group will offer guidance to federal agencies about re-architecting their networks to support IPv6 in dual-stack mode initially and eventually to migrate to native IPv6.

"We need to get some short-term goals for the federal government for the next two years out because IPv6 isn't a one-trick pony and it's done on June 30," Tseronis says. "June 30 is going to be a great day, but now it's about keeping the momentum going."

Carriers say most civilian agencies will deploy IPv6 through the Networx contract, a 10-year telecom program open to all federal

agencies. Networx carriers include AT&T, Verizon, Qwest, Sprint and Level 3 Communications.

"Anybody who buys services off the Networx contracts will have IPv6 capabilities," Evans says. "That was another big key thing with our IPv6 strategy. All the agencies are moving off [predecessor contract] FTS 2001 and transitioning to Networx… [Agencies] are going to be able to buy IPv6 as a service from those providers."

Sprint, for example, has submitted a contract modification to its Networx Enterprise contract for dual-stack IPv6 and IPv4 service.

"It's probably a matter of days or weeks for approval," White says. "IPv6 is something [the agencies] are expecting the carriers to take care of for them."

Global Crossing, which provides IPv6 services on the Networx Universal contract as a subcontractor to AT&T, says the carrier has received more inquiries from federal agencies about its IPv6 services during the last 90 days but hasn't closed any sales yet.

"The IPv6 discussions oftentimes evolve into deeper technical discussions on next-generation technologies like MPLS, VOIP and converged services," says Scott Camarotti, vice president of sales for federal markets for Global Crossing. "Those are some of the byproducts of the OMB IPv6 mandate."

Even though sales of IPv6 services remain weak, carriers say OMB's IPv6 mandate has had a significant impact in the federal market, particularly on civilian agencies. The Department of Defense and Department of Homeland Security have long-standing plans to adopt IPv6 as quickly as possible for its enhanced network security, mobility and the ability to support sensors and other embedded devices.

"IPv6 is going to keep on going" after June 30, predicts Paul Girardi, engineering team lead for AT&T Government Solutions. "Because of the mandate, agencies understand that it has to be part of every major procurement. Everything we are looking at has IPv6 requirements. Also, at the end of the day there will come a time where you won't be able to get IPv4 addresses. The whole industry has to go this way whether we like it or not."

Transition to IPv6 is complex: Current rates of adoption are not fast enough

■ *By M.E. Kabay*

In the current series of articles, I'm reviewing some of the papers presented at the 2008 Workshop on the Economics of Information Security (WEIS 2008) at Dartmouth College in June.

Hillary Elmore, L. Jean Camp and Brandon Stephens presented a paper entitled "Diffusion and Adoption of IPv6 in the ARIN Region." The authors point out that the absolute limit of unique 32-bit IPv4 addresses, is about 4 billion. The 128-bit IPv6 has an address space of approximately 10^38, which is incomprehensibly larger.

[A quick note to encourage the lost art of order-of-magnitude mental arithmetic: I teach my students to estimate powers of 2 (if they haven't memorized them) using the elementary observation that since (x^a)^b = x^(a*b) and 2 is approximately equal to 10^0.30103, then any power of 2 can be estimated as follows: 2^b is approximately equal to 10^(0.30103*b). Thus, 2^32 is approximately 10*9.6, or roughly 4 x 10^9 (because if the logarithm base 10 of 2 is 0.30103 then the log of 4 is 0.60206 and the log of 8 is 0.90309). So endeth the first lesson.]

For a detailed analysis of the security and economic benefits of IPv6, see the home page for the IPv6 Task Force Inquiry (completed 2006) funded by the National Telecommunications and Information Administration (NTIA). There are links there to the final report in HTML and in PDF and also to supporting materials.

Elmore, Camp and Stephens make the point that the adoption of IPv6 addressing has been surprisingly slow. They ask why. The authors provide a thoughtful analysis of available data sets and conclude that, at current rates of adoption, there is no way that IPv6 will replace IPv4 utilization before all IPv4 addresses are used (estimated to be around 2011).

Because of uncertainty resulting from choices of data and variability in those data, the estimates for 80% implementation of IPv4 in the North American region ("ARIN") is somewhere between 8 and 22 years (i.e., 2016 through 2030). If there is no practical way to assign new IP addresses, new Internet players will be shut out of the market. They write:

"Given the current expenditures on IPv4 in the United States and the investment cost necessary to switch from IPv4 to IPv6, this may not be the best option for the U.S. and other developed countries with existing IPv4 infrastructure…

"European authorities, even less than American regulatory authorities, are unlikely to tolerate a situation where incumbents are able to prevent interconnection through their own failure to adopt new technologies.

"Forced adoption would be a likely long term but difficult and contentious regulatory battle. The level of deployment in Europe was termed 'impercept[i]ble' in the final 2004 report of the European IPv6 Task Force. The U.S. may choose to effectively remain alone as the world converts, as with the case of the English to metric conversion."

I'll continue the summary of this interesting paper in my next column.

M. E. Kabay, PhD, CISSP-ISSMP is Program Director of the Master of Science in Information Assurance at Norwich University.

IPv6 illustrates resistance to new technologies

Transition to IPv6 is complex: Current rates of adoption are not fast enough

■ *By M.E. Kabay*

In my previous column, I started reviewing an interesting paper by Hillary Elmore, L. Jean Camp and Brandon Stephens entitled "Diffusion and Adoption of IPv6 in the ARIN Region" that they presented at the 2008 Workshop on the Economics of Information Security (WEIS 2008) at Dartmouth College in June.

I found the most interesting section of the paper to be part 6, the discussion of "Related Work in Economics of Information Security." I summarize below some of the key points made by the authors explaining resistance to adoption of new technologies, and I urge readers to download the paper themselves to read the details. In my own words, here are some highlights of their discussion:

- Small networks may experience relatively few benefits from adoption of new technology compared with the high cost of upgrading.
- Like patches, new protocols may have unexpected bugs or cause unexpected problems through their interactions with the existing technical infrastructure; therefore, many organizations will tend to delay implementation until others in the market have tried the new technology and ironed out the first bugs.
- The costs of implementing a change in the fundamental infrastructure mentioned in the point just above will include personnel education and training plus time and money involved in coping with inevitable problems resulting from inexperience. Such costs are difficult to explain and justify to nontechnical managers looking at the profit-and-loss statements of an organization.

Given the urgency of coping with exhaustion of the IPv4 address space, what are some measures that might encourage wider acceptance of IPv6? The authors discuss the following approaches, which are not mutually exclusive:

- Governments can offer subsidies to offset costs.
- Governments can legislate fines as negative incentives (but these are less effective than positive incentives).
- A free market in IPv4 addresses can develop which might eventually drive the price of acquiring someone else's old IPv4 address above the costs of installing a new IPv6 address…
- … or alternatively, a free market in IPv4 addresses might manage scarcity and indefinitely reduce pressures to move to IPv6.
- Government pressures to force implementation of IPv6 by the governments of "the US and Europe could force premature adoption causing a window of greater disruption and vulnerability."
- New policies by the Regional Internet Registries (RIR) community could limit assignment of new IPv4 addresses to organizations that do not currently have any. "If organizations which already have IPv4 blocks which can be routed are assigned only IPv6 addresses, this implies that the most rapidly expanding entities on the network will have the greatest incentive to move to IPv6." However, the authors continue, "Making these choices is made more complex by the fact that the RIR communities consist exactly of those organizations which already have IPv4 blocks. Thus the RIR will effectively be asking its membership to deny itself access to potentially valuable address space to ensure that others have this address space."

Readers will find a great deal to think about in this paper, and I thank the authors for checking my summary for correctness.

IPv6

Section 2

The business case

Experts make a solid business case for IPv6

Do you need IPv6 yet and if so, how do you get started?

■ *By Julie Bort*

The co-authors of Global IPv6 Strategies were the guests for a live Network World chat where they discussed all things IPv6. The group consisted of Fred Wettling, who manages architecture and strategic planning for Bechtel and is a member of the IEEE North American IPv6 Task Force, the IPv6 Forum, and is executive director of the IPv6 Business Council; Patrick Grossetete, who is technical director of product management at ArchRock, makers of IP-based wireless sensor network technology; and Ciprian Popoviciu, PhD, CCIE No. 4499, who is a technical leader at Cisco Systems. They discussed the business case for IPv6, killer apps, security tools and the role of vendors like Microsoft and Cisco.

FRED WETTLING

PATRICK GROSSETETE

CIPRIAN POPOVICIU

MODERATOR: While Fred, Patrick and Chip are typing their answers to your first questions, here's one that was submitted earlier. What is being done to reconcile the profile differences between DoD and NIST? Who is running the store?

Fred_Wettling: The basic issue you raise is that of unambiguous technical specifications that can be used to qualify U.S. government purchases. The process involves mapping use case (i.e. network-enabled war-fighter) to network function (routing) to the relevant IPv6 specification(s). DOD work on developing IPv6 profiles for qualifying IPv6 products was started several years ago by Defense information Systems Agency (DISA). Their use cases were specific to their missions. NIST profiles are targeted at most of the rest of the U.S. government and may also serve as reference models for other industries. DISA and NIST have been collaborating where possible. There is a lot of common ground. However, there are differences that will exist going forward that are being addressed. I understand dialogs are still going on. There seems to be some convergence toward the NIST profile, including a partnership with the IPv6 Read Logo.

Who's running the store? It's DISA for DOD, NIST for most other agencies. Out-

side of the U.S. federal space, the industry is deciding the standards applicable to IPv6 core functions. Many vendors are clearly mapping IPv6 capabilities to versions of their products. My recommendation is use the method of qualifying products that are most applicable to your environment.

QUESTION from Layer8: RFC1918 provides more than ample IP space for the largest of enterprises, outside of ISPs and service providers. What would be some compelling reasons to adopt IPv6 as an internal IP architecture?

Fred_Wettling: RFC 1918 does not address communications between organizations. The world is moving to end-to-end communications between people, organizations and objects. The number of people and things that are being connected exceeds the number of possible IPv4 addresses (about 4 billion).

Chip_Popoviciu: Yes, RFC 1918 address space was sufficiently large for most of the needs of today's enterprises but that might not be the case going forward. Enterprises have layered services (data, voice, wireless, etc) each with an addressing scheme. These layers will take significant resources. Then we have the new devices coming into the environment – sensors, readers, security devices. All these laments can make RFC 1918 insufficient for future needs.

Patrick_Grossetete: First, I would say that not everybody wants to share the same address space. Then, even net 10 is not large enough for large organizations if you consider the number of subnets created today for Wi-Fi or IP telephony deployments. If a large organization experiences a merger (very common) it will require re-numbering, which is always painful.

QUESTION from mikes: The government was originally committed to 2008 for IPv6 and now has a date of 2010. How real is this considering many government organizations have not even started? (And IPv6 has 3.4+38 verses IPv4's 4 billion.)

Patrick_Grossetete: I don't think the date by itself is important. It is more about acknowledging there is a lot to be done. Most world regions have IPv6 on their road maps. Japan and Korea having been the first to start.

Fred_Wettling: U.S. agencies have the challenge of quantifying technical specifications as part of their procurement process. The definition of IPv6 profiles has taken longer than anticipated.

Patrick Grossetete: What's really important is the planning and education phases, which as we know require times. When done, the deployment should not be different from other networking projects. By the way, that means we look at integration and co-existence, not a full transition to start with

Chip_Popoviciu: Setting target dates is very important in getting things going. The 2008 mandate stimulated various work (such as the profiles) and this will continue. Also, note that several governments around the world have aggressive plans in place for integration and migration.

Moderator-Julie: Pre-submitted QUESTION: What are your thoughts about Microsoft's implementation of IPv6 and in what ways will it be important?

Chip_Popoviciu: With its large customer base, Microsoft has a significant impact on technology adoption, especially when it comes to a fundamental technology such as IPv6. Windows Vista will drive and sustain IPv6 adoption by the consumers, while Windows Server 2008 will drive adoption in enterprises. Both of these markets will in turn influence the IPv6 adoption plans of service providers. Microsoft's implementation of IPv6 facilitates deployment. Through new, IPv6-only applications, it can also provide new drivers for IPv6 adoption.

Patrick_Grossetete: If you look at its operating systems' market penetration, you could see that Microsoft has "IPv6-enabled" more than 85% of the market. IPv6 is "default" on 18% of the market through Vista, another 69% needs to get it configured. Those are important numbers when tracking the IPv6 market penetration. http://market-share.hitslink.com/report.aspx?qprid=10

QUESTION from artking: What is the business case for IPv6? Inside my enterprise I run 10.x address space with 16 million addresses and think this is Y2K size event with NO JUSTIFICATION. At the Internet border, my ISP may give me a 4to6 gateway in the future. The only place where it may impact me in a few years is the Internet properties we run that must be regression tested and support access from v4 and v6 Internet endpoints, etc.

Fred_Wettling: Many companies will not NEED to move to IPv6 in the next few years if they are satisfied with all of the services they are using now. This is a valid tactical approach when short-term cost avoidance is important. Other companies are strategically investing in the foundation for the future, like those that started using TCP/IP and Web technology in the 1980s and 1990s… before innovations like VoIP, Google or YouTube. Incrementally testing your IT infrastructure for IPv6 compatibility is a good move, and I applaud you for this foresight. This will help you avoid problems in the long-term when implementing IPv6 becomes a higher priority for your organization

Patrick_Grossetete: Without knowing your line of business, it may not be easy to comment on potential benefits. But clearly some worldwide regions and market segments are adopting IPv6. What

would be the impact on your business if you couldn't properly get customers or partners reaching your sites? Remember that a 4to6 gateway will have the same challenges as current IPv4 NAT, so why not simplifying the architecture by considering the original TCP/IP model.

Fred_Wettling: From the perspective of the person that has led enterprise IPv6 implementation in a major international company, the strategic benefits are becoming clear, especially where mobility, peer discovery, infrastructure management and end-to-end communications (without the application headaches of NAT traversal) are important. Chapter 5 of Global IPv6 Strategies has several real-life use cases that might interest you.

QUESTION from Layer8Solutions: Are there any large enterprises that have even begun a global IPv6 deployment, other than the government?

Fred_Wettling: I started leading the IPv6 deployment at Bechtel in early 2005. Right now 93 % of all desktops and laptops are running IPv6 (dual stack). Our major data centers are running IPv6, and our WAN is running IPv6 through GRE tunnels where no native carrier IPv6 access is available to the premises. (Shameless plug …) Chapter 5 of our book, Global IPv6 Strategies, has detailed profiles on several companies that are implementing IPv6.

QUESTION from bruce.curtis: We have enabled IPv6 for all of the clients on our networks and are working on some issues with load balancers etc., for our servers. I see signs that ISPs are moving toward enabling IPv6 but other than Google, I don't see many destination sites enabling IPv6. Do you see more destination sites preparing for IPv6 than I have seen? Is there any way to get the sites like Yahoo, etc., to expedite enabling IPv6?

Chip_Popoviciu: Availability of Internet content over IPv6 is indeed a challenge and it makes offering IPv6 based IA services difficult to justify. That does not mean however that deployments are gated by the availability of Internet content. There are walled-in garden deployments which offer specific IPv6 services that can be managed within that domain. Migration of content to IPv6 will depend a lot on demand and that is a way to stimulate content providers to put content on IPv6. Also, there is work done in IETF to provide mechanisms that will encourage providers to put content directly on IPv6 but make it available to IPv4 users as well. Work in progress to be sure.

Fred_Wettling: Bechtel and others have run into a few bumps with product maturity and the versions in operation. One is the lack of IPv6 support in Microsoft ISA Server 2006. We have found work-arounds for most of the issues. But, just to note, IPv6.olympics.cn is an example of a high-profile site.

bruce.curtis: Yes ipv6.olympics.cn was a good sign of progress but at least for the little bit of looking that I did it often took you to another site that offered the content over IPv4. If I remember correctly for the few that I looked at the content came from Akamai. We have a few Akamai servers at our university and I think they and similar service providers are another important group to convince to enable IPv6.

Patrick_Grossetete: That's effectively something we discovered. Many websites use absolute URL (IPv4 addresses), redirecting traffic from v6 to v4. I agree that education is important as well for people developing Web applications, including caching and redirection. As we explained in the book, it is a long process.

Fred_Wettling: NTT is delivering broadcast TV service to many (millions) in Japan. This is not a service that you can ping with your browser, but is a clear indication of the underlying trend.

Moderator-Julie: Pre-submitted QUESTION: What kinds of interesting consumer IPv6 applications have you seen? Have you seen set top boxes, refrigerators, etc. outfitted with IPv6 and ready to hit the IPv6 Internet when it becomes more readily used?

Chip_Popoviciu: All of the above! A visit to the IPv6 showroom in Tokyo will be very enlightening in this sense. It will show how many of our current IP devices are IPv6 ready and it will show how far the Internet is expanding in terms of devices.

Patrick_Grossetete: Now working for ArchRock who develops IP wireless sensor networks, I may add that IPv6 plays a fundamental role in this new layer of Internet nodes. You need the large address space not only because you expect to connect many sensors but also because it eases the compression over radio links and helps to target "zero config" deployment for this class of devices. Applications range from environmental outdoor monitoring to wireless city services (parking metering, electricity/water/gas metering,…) green building, to data center to machine to transportation and other areas. You can now get any sensing location part of your IT environment to collect the appropriate data and take decision. A nice example is described on http://comnews.com/features/2008_april/0408_wireless.aspx.

Fred_Wettling: Have a Mac or Sony PlayStation 2 (or later)? These are a couple of examples where IPv6 is already "in play." For example, Apple uses IPv6 in Mac OS X as part of its network device discovery process…. Seamless, smooth and efficient. Apple's product promotion is focused on the "MAC Experience," not the fact they are using IPv6. Cable providers are starting to deliver

set-top boxes that comply with Data Over Cable Service Interface Specification (DOCSIS) 3.0. Motorola started selling DOCSIS 3.0 cable modems earlier this year.

QUESTION from bvalaski: I recently saw a webcast from SANS about implementing IPv6, and one of the largest setbacks seemed to be ISP implementation. Having to tunnel IPv6 over IPv4 seems to add a bit (no pun intended) of overhead. What incentives are being presented to the ISPs to 'win them over' to performing the infrastructure upgrade, and how effective are those so far?

Patrick_Grossetete: IPv6 over IPv4 tunnels was really the first step to get IPv6 packets flowing across the Internet. Today, native IPv6 (really dual-stack) being available on router's hardware, the recycling process allows ISP to turn on IPv6. Incentives such as winning a government or enterprise contract certainly helps. Several broadband ISP are running IPv6 as well, like mine (Free Telecom). They are now launching innovative services which leverage IPv6.

Moderator-Julie: Pre-submitted QUESTION: What is the scope of IPv6 applications that we will eventually find in the enterprise?

Fred_Wettling: Versions of ALL major operating systems have been shipping as IPv6 capable for years. With only minor configuration changes, IPv6 is enabled on OSes like Windows XP and Server 2003. Today, all major operating systems are shipping with IPv6 enabled by default, including Apple (10,3), MAC OS X Leopard, BSD, HP-UX 22iv2, AIX 6, Windows Vista, Windows Server 2008, Linux 2.6 Kernel and Solaris 2.10. On top of these platforms the vendors are at various stages of implementing IPv6 in their products. For example, SharePoint 2003 on an IPv6-enabled Windows Server 2003 platform supports IPv6 end-to-end communications, with a few limitations. Then again, Microsoft Exchange 2003 and ISA Server do not even know IPv6 exists. Web servers and services are straightforward to enable on most platforms. Talk with your software suppliers and ask for the IPv6 road maps on products that are important to you. Your application developers should be using development and testing platforms that will ensure IP version-agnostic operations.

Patrick_Grossetete: To add to Fred's list, I would like to add that IPv6 is also available on other operating systems such as Windows Mobile 5 and 6, Symbian-embedded Linux and TinyOS. This allows new classes of devices - smartphones, PDAs, cameras, IP phones, sensors - to be part of the game. On Windows Server 2008, clustering (or whatever they've named that feature) can be done at Layer 3 by running IPv6. Windows Vista Peer-to-Peer framework runs over IPv6 (). Those are just some examples.

QUESTION from mikes: How prepared are the support organizations for this? Will all the CCNA's be up to speed? And WHEN? Orgs will never change if the support function is not in place.

Chip_Popoviciu: This is an excellent question and touches on a topic sometimes overlooked. It is not easy or cheap to find IPv6-qualified folks, and a significant investment will be needed in preparing the staff for deploying and operating IPv6 environments. There are many courses available for IPv6 education, and the certification tracks are catching up. CCXX certifications do contain IPv6 modules now. Cisco engineers, in all organizations, including Customer Advocacy, have gone through IPv6 training.

Patrick_Grossetete: I could add that CERT Alert also covers IPv6.

QUESTION from ipv6_novice: How much of training is required for an IT force to migrate from IPv4 to IPv6 once they are convinced?

Fred_Wettling: You need to address all parts of the IP organization in your training and awareness efforts. The level of education will depend on the employee's role. App developers need to be educated and their development environments to be IP-version agnostic. QA environment needs to be IPv6-enabled. Support people need some basic awareness training. Security will be involved with IPv6, too.

Moderator-Julie: Pre-submitted QUESTION: Is the Internet community working on a way to make NAT the bridge by which people run dual IPv4 and IPv6 networks, and which vendors are behind such a thing?

Chip_Popoviciu: There are several efforts in IETF to address some of the problems we face due to the address exhaustion pressures and the fact that we don't have all the pieces in place to switch to IPv6 (for example, the IPv6 Internet content is nowhere near to the IPv4 one). There are efforts geared toward using IPv4 NAT to further re-use address space beyond what we do today. There are efforts to create Protocol Translators (remember that NAT-PT was deprecated) that would interface the v4 and v6 Worlds and then there are creative ideas that use IPv6 in order to further re-use IPv4 address space. The one important thing to remember is that these efforts, some of which will be useful, some not, do not intend to prolong IPv4's life indefinitely but rather to provide short-term relief as the migration to IPv6 takes place without an Internet growth slowed down by lack of IPv4 addresses.

This is an Internet communitywide effort. Cisco is actively participating in the standardization work related to this topic while it explores the implementation of these ideas in products. Cisco demonstrated proof

of concepts for several of these NAT options, most recently at the IETF meeting in Dublin. [NOTE: See story Much-maligned feature, NAT, being added to IPv6)

Patrick_Grossetete: It is important to understand that all of the actual IETF proposals have challenges in term of performance, scalability and security. So, they will certainly be helpful to smooth the transition to IPv6 but won't guarantee the Internet growth to cope with new Internet comers - remember that the Earth's population growth forecast is 50% in 2030-2050.

Fred_Wettling: Prudent organizations are positioning themselves to avoid global IPv6 transition problems by implementing IPv6 in a dual-stack (IPv4+IPv6) mode now. A current constraint is the slow pace of many carriers to provide native dual-stack services to their customers. Carriers like NTT and Hurricane Electric are providing services today that will eliminate the need of translation technologies for their fully dual-stack customers.

mikes: Integration and coexistence is just more work than a full transition and even this is not real.

Patrick_Grossetete: I don't think integration and coexistence are more work to start with. In fact, it allows you to pick an application and run it over IPv6 for a given geography. This represents minimum risks and doesn't require you to upgrade all IP nodes and applications you have in an organization. Long term, I am convinced we will see people moving to IPv6-only but it is still too soon. I don't see that as being different from integrating IPv4, then moving away just like we did with SNA/DECnet/Appletalk/IPX in the 1980s.

Moderator-Julie: Pre-submitted QUESTION: You hear a lot about the address shortage (which NAT has solved for a lot of companies) and about new features of IPv6. So, if it's not just about address space, what's the killer IPv6 application?

Chip_Popoviciu: Today we do not have a killer IPv6 app. Chasing a killer app is a deceiving perspective on IPv6. This is a fundamental technology which is valuable by the simple fact that it enables us to scale our networks and services. Do we have services available only over IPv6? Yes we do but they are not yet perceived to be killers.

Patrick_Grossetete: I will not call it a killer application, but IP wireless sensor networks are clearly a new layer of Internet nodes that get connected. For technical reasons, IPv6 is THE protocol selected by the IETF 6LoWPAN working group, there is no IPv4 equivalent. It just demonstrates that people start to be creative when not being zealots about IP protocol version.

Fred_Wettling: IPv4 had been around for quite a while when Google opened for business in Menlo Park, CA in 1998. Skype Beta was released in 2003. YouTube was started in 2005. Are these IPv4-based successes "killer apps"? IPv6 "killer apps" will certainly evolve as end-to-end use of IPv6 becomes more pervasive.

QUESTION from thindson: What would be good first planning steps for a large enterprise that has more than one Internet provider and extensive private addressing internally?

Fred_Wettling: Work with enterprise leadership, at least within IT, to ensure there is an understanding of the strategic global importance of IPv6. Understand that this will take time. Bechtel found it useful to embed IPv6 in already existing change processes, from development, through QA, into production. IPv6 is now just another check box on natural control points... just like security and other controls. If I may offer another plug, we cover this subject in a good level of detail in chapter 6 of our book.

Chip_Popoviciu: I would add that in order to minimize costs of integration, it is essential to tie IPv6 projects into other infrastructure projects such as bandwidth expansion, or insertion of new network elements. Adding the IPv6 component in such projects requires a small additional investment (if any) but it helps ready the environment for IPv6 at minimal costs. Even if the goal of the project is not IPv6, keeping IPv6 in mind helps reduce costs in the long run.

QUESTION from Layer8Solutions: Moving toward IPv6 is a huge undertaking in capital and human resources. How do you begin to cost justify such a move to the business unit? I would argue that even the merger of two enterprises, running IPv6 would require the same network integration effort as would two companies running IPv4.

Chip_Popoviciu: The size of the investment depends significantly on how soon one gets started preparing for IPv6. Leveraging refresh cycles early on makes a big difference in integration costs. Please refer to my reply to the previous question. As I said, it is essential to tie IPv6 projects into other infrastructure projects such as bandwidth expansion, or insertion of new network elements. I would add that in order to minimize costs of integration, integrating IPv6 in all IT projects will help reduce costs for the overall IPv6 integration project.

Patrick_Grossetete: In fact, one of the first reasons an enterprise may start considering IPv6 should be security. Knowing you have IPv6 implemented on all recent OS - (see previous Q&A on the scope of IPv6 applications) - how could you let traffic going through your network without monitoring it?

Fred_Wettling: Bechtel is a $20+ billion global enterprise with 44,000 employees. As I mentioned in my response to the earlier ques-

tion from thinsdon, Bechtel took advantage of our natural change processes, including product refreshes. For example, over the last two years, we have completed application verification for all client apps and most of our server-apps. The incremental cost of adding IPv6 to the OS when testing things like Office 2007 is insignificant. We found that approaching IPv6 as an addition to all other IT-related activities held costs to a minimum. Here's one example. Windows 2003 Server build profiles were modified one time to include required IPv6 parameters. After that, new servers include IPv6 as part of the build process. This is less effort and cost than a project to go around the enterprise and enable IPv6 as a discrete task.

Moderator-Julie: Pre-submitted QUESTION: What is Cisco's road map for IPv6 in the switching market? Today many players are offering RIPng in small switches?

Chip_Popoviciu: Cisco is developing road maps for its products based on customer demands, incrementally adding features as the market demands them. This strategy applies to the small switch products as well. Currently, Cisco small switches such as 3560/3750 go beyond supporting RIPng, they support OSPFv3 and EIGRP for IPv6. For the latest information on a specific feature support on a specific platform, it is best to contact your Cisco account team.

Moderator-Julie: Pre-submitted QUESTION: Some people say that people will sell their old IPv4 addresses and that this might drive the cost of IPv4 above IPv6 . Do you believe this is likely and have you seen any evidence of it yet?

Chip_Popoviciu: Like any finite resource, IPv4 addresses always had and will have a value even though this might have not been self evident. Now that we approach exhaustion, this value is becoming more and more relevant. Acquiring someone's IPv4 address space is not a new concept. There are organizations known to have considered buying other organizations for their IPv4 address space. A market, open or black, for trading IPv4 address space is inevitable. Work is ongoing on how such markets should be organized and managed.

Fred_Wettling: As IPv4 exhaustion nears, this has become a hot policy topic at the five regional Internet registries (RIRs). The fundamental issue is that companies don't own their allocations. They are just granted permission for exclusive use of the numbers from upstream numbering authorities. IANA (Internet Assigned Numbers Authority) allocates large blocks of IPv4 and IPv6 addresses to the RIRs. RIRs allocate smaller blocks to local (LIR) and national (NIR) registries, and the process continues to trickle down. IANA and RIR policies are used to govern allocation criteria and governance, including reclamation.

QUESTION from JoeRockHead: What is the status of good security tools for IPv6?

Fred_Wettling: We have found that several security tools (firewall, IDS, IPS) are ready for IPv6 traffic, others are at varying stages of maturity. While Microsoft should be applauded for its IPv6 deployment in its operating systems, it has not yet addressed IPv6 in its ISA Server that several organizations use for Internet traffic security logging. Current versions of Squid DO support IPv6. The "bad guys" are exploring the use of IPv6 to gain access to systems. A common approach is the use of tunnels that may be turned on in a default configuration ... like Teredo, ISATAP or 6to4. Security awareness is important when deploying IPv6. A lot of potential risks can be solved with prudent configuration, including turning host-based tunnels OFF by default. Command Information has been doing some interesting work in this area.

Moderator-Julie: Pre-submitted QUESTION: What is IPv6 multi-homing and when is it important?

Chip_Popoviciu: IPv6 multi-homing is the same thing as IPv4 multi-homing and it applies in the same scenarios as for IPv4. Let's remember that IPv4 multi-homing mechanisms are problematic. If we want to stick to them, we can implement them the same way in IPv6. The question really is: Can we do better? It actually is imperative we do better. So now we need to find that better way.

Patrick_Grossetete: At the beginning, multi-homing is an asset of policies and business rules between ISP and their customers. Technology has been enhanced to deal with those policies but issues such as routing table growth, routing protocol convergence and stability, etc., have to be faced. For those reasons, some people thought IPv6 multi-homing policies should not be allowed, but market realities make it a must. As Chip wrote, multi-homing on IPv6 can be done exactly the same way as IPv4, but the community still needs to solve the issues whatever the protocol version.

Moderator-Julie: Thanks for attending! Our time is up. We want to thank our guests for an excellent chat.

Back to TOC

NTT Communications White Paper

Sponsored by NTT Communications
http://us.ntt.net/

Tapping the Benefits of IPv6

Implementers around the globe are finding out how the next-generation Internet Protocol can help them build better, more flexible networks and new applications.

An NTT Communications White Paper **February 2008**

Contents

Introduction

Around the world, IPv6 is catching on, with companies and organizations of various types putting the next-generation Internet Protocol to use in ways that showcase how the protocol enables innovative new applications and useful additions to existing ones.

In countries including Japan, Korea and China, not to mention the U.S., government entities, enterprises and other organizations are embracing IPv6 for projects as diverse as weather monitoring and first-responder communications to setting up next-generation networks more quickly. In the U.S., federal government agencies face a mandate (U.S. Office of Management and Budget Memorandum 05-22) that their networks support IPv6 by the end of June 2008 in order to maintain U.S. leadership in Internet technologies. That deadline is having a trickle-down effect on many other organizations, including government subcontractors and others that do business with government agencies.

Rather than balk at the mandate, leading organizations are embracing it and examining the ways in which IPv6 can help them build better, more flexible and secure networks. "We see IPv6 as a real foundation for innovation and transformation in the company," says Fred Wettling, manager of IT standards and strategies and a fellow with Bechtel Corp., the giant construction, engineering and project management firm.

ROI of 10:1

Bechtel is far from alone in expecting a big return from its IPv6 investment. A study conducted by RTI International for the National Institute of Standards and Technology (NIST) and the National Telecommunications and Information Administration (NTIA) finds that IPv6 is expected to return $10 for each dollar invested. Study participants identify several major categories of IPv6 applications that, in total, they estimate would deliver benefits in excess of $10 billion per year. The cost of migrating to IPv6, meanwhile, is estimated at $25 billion over 25 years, or $1 billion per year. So, a $1 billion annual investment yields a return in excess of $10 billion per year - a hefty return on investment. Benefits of IPv6 cited in the report include cost reductions from improved security, increased efficiency and innovations that lead to new products and services.[1]

[1] "IPv6 Economic Impact Assessment," prepared by Michael P. Gallaher, Ph.D., and Brent Rowe, RTI International, October 2005.

In terms of security, IPv6 includes native support for IPSec. By itself, this is not generally considered a big advantage over IPv4 because IPSec is already widely used, given it is relatively simple to add to an IPv4 network. But when considered in combination with other capabilities, notably IPv6's self-discovery capabilities and peer-to-peer nature, IPSec plays an important role in creating networks that are both simple to set up and inherently secure.

Security also plays a role in another expected benefit of IPv6: remote access capabilities. With its larger address space, IPv6 offers the ability for any device to be globally addressable, making the protocol ideal for applications such as secure remote monitoring and support. This applies not only to monitoring IT infrastructure components, but virtually anything, from automobiles to appliances. Such a capability could allow manufacturers to increase the life expectancy and functionality of their products while decreasing service costs, the RTI report notes.

IPv6 is also expected to give rise to entirely new applications that would either be difficult or impossible to deploy with IPv4. The multicast capabilities of IPv6, allowing one-to-many communications, may give rise to everything from new forms of games to social network applications. Tom Patterson, former CEO of the IPv6-focused consultancy and service provider Command Information Inc., often cites the example of a form of dating service where people with similar interests are alerted when they happen to be near each other. Perhaps such an application could be combined with an advertisement, where if the pair meet at a nearby coffee shop they get a 2-for-1 deal.

Outlining the Need

Of course the movement to IPv6 is driven largely by a more fundamental need: The world is running out of IPv4 addresses. In October 2007, the IPv4 Address Report Web site predicted that the Internet Assigned Numbers Authority (IANA), which manages IPv4 addresses, would run out of addresses on May 12, 2010. The Regional Internet Registries (RIRs), which distribute IP addresses in their respective regions, are slated to run out a bit later: Feb. 11, 2011, according to the site.[2]

Indeed, both the American Registry for Internet Numbers (ARIN) and RIPE, which serves as the RIR for European ISPs, are both warning that depletion of IPv4 addresses is imminent. "The available IPv4 resource pool has now been reduced to the point that ARIN is compelled to advise the Internet community that migration to IPv6 is necessary for any applications that require ongoing availability from ARIN of contiguous IP number resources," ARIN says in a May 2007 statement.[3] RIPE sounds a similar alarm. "We urge those who will need significant new address resources to deploy IPv6," RIPE says in an October 2007 statement. "We urge that the widespread deployment of IPv6 be made a high priority by all stakeholders."[4]

---

[2] Source : IPv4 Address Report: http://www.potaroo.net/tools/ipv4/index.html#r4

[3] "ARIN Board Advises Internet Community on Migration to IPv6," May 21, 2007. http://www.arin.net/announcements/archives/20070521.html

[4] "RIPE Community Resolution on IPv4 Depletion and Deployment of IPv6," Oct. 26, 2007. http://www.ripe.net/news/community-statement.html

Solving the Address Quandary

Other predictions vary, but there's no denying that the 4 billion-plus unique addresses that are possible with the 32-bit IPv4 address field will be exhausted within the next few years. IPv6, on the other hand, has a 128-bit address field, "enough to assign trillions of addresses to each person now on earth or even to every square inch of the earth's surface," according to a January 2006 U.S. Department of Commerce report.[5]

> ***"A freight train is coming. Do you want to go with it or stand in front of it and get mowed down?"***
>
> **Fred Wettling**
> Manager of IT standards and strategies and a fellow with Bechtel Corp.

Such an increase in available addresses has a number of important implications. For one, it means organizations no longer have to rely on Network Address Translation (NAT) devices to conserve address space. NAT evolved largely as a way to get around the address limitations of IPv4. With NAT, an organization can advertise its assigned IP address to those outside its corporate walls, but use different addresses inside its own network, with the NAT device translating between the two. That means the organization is free to use any IP addresses inside the NAT device, even those that are technically assigned to a different organization, essentially allowing a single IPv4 address to support many more users.

But NAT can make it difficult for organizations to open up their networks to one another, as they increasingly need to do. NAT also makes it more difficult to create end-to-end applications, where two end devices can communicate freely with each other. Essentially, NAT stands in the way of the original intent of the Internet, which was peer-to-peer communications among devices — an idea that IPv6 restores. (That said, there are features of NAT that some network administrators like to employ, including certain management and security attributes. With that in mind, RFC 4864, Local Network Protection for IPv6, documents how these features can be implemented using IPv6, but without the problems that NAT introduces.)

The availability of more addresses also makes it feasible to tie many different types of devices into IP networks, beyond computers and network infrastructure. Suddenly, it becomes feasible to implement a vast network of sensors to monitor everything from weather conditions to manufacturing floor equipment and warehouse stock. Likewise, the ubiquitous cell phone could be IP-addressable, opening it up to new applications beyond those provided by whatever the owner's service provider offers. Additionally, any device that is IP-addressable can also be managed remotely, enabling simplified network management. Indeed, it's impossible to predict all the applications that may evolve from not just the expanded address field, but the various other benefits that IPv6 provides (see "IPv6 at a Glance," page 6).

[5] "Technical and Economic Assessment of Internet Protocol Version 6 (IPv6)," January 2006, U.S. Department of Commerce, National Institute of Standards and Technology, National Telecommunications and Information Administration.

A Freight Train is Coming

What is clear, however, is that IPv6 is coming, and it probably already exists on your network. Windows Vista ships with an IPv6 stack, and the protocol is supported in Windows XP SP1 and SP2. Windows Mobile 2003 and later editions also ship with IPv6. The Apple OSX operating system has included IPv6 support for about two years, as have many flavors of Unix and Linux, if not longer. Sun Solaris, IBM AIX and HP/Compaq OpenVMS likewise support the protocol. Similarly, network hardware vendors such as Cisco Systems, Inc. and Juniper Networks, Inc. have long offered support for IPv6.

Given all that support in existing products, the U.S. Office of Management and Budget (OMB) Memorandum 05-22, the 2005 edict that says all federal agencies must support IPv6 by June 2008, seems not so onerous.

"A freight train is coming," as Bechtel's Wettling puts it. "Do you want to go with it or stand in front of it and get mowed down?"

Bechtel and IPv6

Bechtel first embarked on the IPv6 trail in 2005, in part because it was starting to see the protocol mentioned in contracts with its many government customers, Wettling says. Some of those contracts included talk of financial penalties if certain things weren't done with IPv6. In short, IPv6 was required to win business and to execute on jobs that the company did win. So it was a business imperative for Bechtel to develop a level of competence with IPv6.

The company has certainly done that. As of September 2007, more than 14,800 Bechtel client computers — about 85% of the total in the company — had IPv6 turned on. Similarly, more than 60% of all Bechtel network ports are running dual IPv4/IPv6 stacks. By the end of 2008,

IPv6 at a Glance

IPv6 is the next-generation Internet Protocol, intended as the follow-on to IPv4 for networks worldwide. IPv6 is now a mature, stable protocol, first defined by the Internet Engineering Task Force RFC 2460 in December 1998.

The main attributes of IPv6 include the following:

- A dramatically increased address space of 128 bits, vs. 32 bits in IPv4. This allows for 340 x 10^{36} unique addresses - or 340 undecillion addresses.
- Mandated security, with support for the IPSec encryption protocol built in.
- Improved host and router discovery, with the ability to auto-configure both clients and servers. By obviating the need for manual intervention to configure a device upon installation, this capability can greatly simplify network deployments and makes it far easier to deploy numerous IP-addressable devices, including in remote, dangerous places.
- Enhanced mobility with Mobile IPv6, which allows for a device to have an address that is reachable on an IP network, no matter where the device is or what network it's on.
- Enhanced multicast capabilities including scope management and resolution to solve traffic congestion problems.
- QoS enhancements, which allow for premium services for critical Internet traffic, with guaranteed delivery and prioritization.
- Support for jumbo datagram packets of 4 GB (and soon 32 GB), up from 64 KB in IPv4.
- The Flow Label specification (RFC 3697), which enables network utilization to triple, from 27% efficiency to 81%.
- Reserved space within the datagram for future developments.
- Restoration of the end-to-end model of the Internet.

the company expects to be entirely IPv6-enabled, Wettling says (with the exception of systems due for imminent retirement).

IPv6 Drivers

In addition to the federal government mandate, another driver for IPv6 at Bechtel is that the company is converging all of its networks to IP — a concept known as XoIP. That includes everything from its voice networks, which are now about two-thirds voice over IP (VoIP), to video and office systems, and even building plant and process automation systems. For example, the company recently finished building a refinery in India that has 51,000 instruments that must be monitored and controlled. Putting all those instruments on a single IP network would enable the devices to work with the same routers and switches Bechtel normally uses in an office network, as opposed to a proprietary control system network. Some control system manufacturers are already migrating to IP — and IPv6 specifically — thus helping the company greatly simplify its network architectures.

Bechtel now sees IPv6 as a fundamental technology transition, akin to the advent of the Internet and the Web. "It's a general industry trend," Wettling says. "It's kind of like asking a company, 'Why did you implement Web servers?' "

A Gradual Migration

For Bechtel, the only question was how it should implement IPv6. One approach is the forklift upgrade, where you migrate everything at once, like upgrading an operating system. But IPv6 lends itself to a more gradual approach.

"It's not a big separate project where we attack everything. We just embed it into the normal work process," Wettling says. For example, when an infrastructure engineer updates documentation on how to build a Web server, IPv6 becomes part of it. As computers get upgraded, IPv6 gets turned on. Indeed, there's now an edict throughout the company. "If you want to implement a brand new something, it will have IPv6 turned on or it won't be implemented," he says.

"Things are occurring that we never thought of before," Wettling says. "We see IPv6 as a real foundation for innovation and transformation in the company."

Mining the Benefits

Much of the benefit in IPv6 lies in its peer discovery capabilities. One practical application for the technology is in assigning IP addresses to new devices. For desktops, the company has long used Dynamic Host Configuration Protocol (DHCP) to automatically assign addresses, but for servers, the process is manual. "We now use the automatic configuration capabilities of IPv6 for everything that can be configured automatically, including servers," he says. "That may not seem like a big change, but if you start nibbling at small things one after another — 'I don't have to do this and that anymore' — it ends up being quite a massive thing."

Another example of the benefits of IPv6 for Bechtel involves setting up networks at new construction sites. A typical Bechtel construction project may involve 20,000 to 50,000 workers. The company brings in numerous trailers to function as offices, tool sheds and the like. Each requires

a generator to supply power, phone lines and network connections. A few months later, it all gets dismantled and the trailers are moved to another location, perhaps on the same job site, where the process starts all over. "We want to get to the point where we can install a trailer, put in an IPv6 wireless router and have that trailer discover other trailers and create, on the fly, a self-configured mesh network that allows communications among them," Wettling says. "You're not going to go there with IPv4, I'll tell you that."

> ***"The real magic happens when those trailers are all configured with IPv6 and the networks and all the first-responders are prepared to talk IPv6. Any device with IPv6 in it can communicate."***
>
> **Geof Lambert**
> Chairman, CAv6TF and vice-chairman, NAv6TF

Brainstorming on New Apps

With the IPv6 infrastructure in place, now the challenge is coming up with ways to use it effectively. Toward that end, Wettling says he had a 90-minute brainstorming session with representatives from Cisco, Microsoft Corp. and Command Information, an IPv6-focused consulting company that has been working with Bechtel on its implementation. "I threw out a bone or two to prime the pot, and the group went wild. At the end, we had 25 new ideas on areas that we can exploit," he says.

Examples include installing sensors to measure wind speed during construction projects, such as during bridge construction. "Throw the sensors up, let them configure themselves quickly and easily, and it makes our lives safer," Wettling says. Another idea was to retrofit power plants with IPv6 so that, as workers walk through with tablet computers, they can pull drawings from a server, take pictures with a camera mounted to their helmet, talk via Bluetooth-enabled phones over a VoIP network and interactively collaborate with other peers adjacent to them. "You can do that with IPv4, but discovering other people is a lot harder than it is with IPv6," he says.

IPv6 Around the U.S.

Command Information has also developed a number of proof-of-concept applications that use IPv6. One is its Advanced Incident Response System (AIRS), which is intended to allow emergency personnel from various government agencies to communicate seamlessly with one another at the response site. The idea is to transport biometric, environmental and other data from sensors along with voice and video traffic over a wireless IP network that is formed on-site. The traffic gets aggregated at a central command station that is safely outside the incident area, enabling effective, centralized management of the response.

MetroNet6: Effective Early Responder Communications

MetroNet6, a planned ad hoc network for first-responders, is an example of the kind of network Command Information envisions with AIRS. The idea is to enable multiple local authorities—such as local and state police, fire and hospital personnel—to quickly establish communications with one another, and with the Office of Homeland Security in Washington, D.C., in the event of an emergency. Here again, the peer discovery capability of IPv6 is crucial to the effort.

A number of groups, including the California IPv6 Task Force (CAv6TF, a sub Task Force of the North American IPv6 Task Force, or NAv6TF) and the IPv6 Forum, are working to build a prototype MetroNet6 network in Sacramento, Calif., says Geof Lambert, chairman of the CAv6TF and vice-chairman of the NAv6TF. Some equipment is up and running, with a link to the University of New Hampshire Interoperability Lab supplied by NTT America supporting IPv6 for testing. Lambert expects a working prototype of the network to be deployed in 2008.

An example of how the network would work is that local police, state police, firefighters, hospital personnel and other local authorities would all have handheld devices that connect to a metropolitan network based on IPv6. The network would be capable of securely transmitting voice, video, data, images and other forms of information over wireless and broadband connections. Additional sub-networks would be added as required, such as for the National Guard or other U.S. agencies that may be needed in an emergency.

One of the crucial elements that IPv6 brings to MetroNet6 is peer discovery capabilities, which allow communications to be established on an ad hoc basis. Lambert uses the analogy of grains of sand. Imagine you have a handful of sand and each grain is a network node. With IPv6, you could throw the sand up in the air and by the time the individual grains reached the ground, they'd have established a network with one another. "If you threw it up in the air and tried to connect using IPv4, nothing would happen; you couldn't do it," he says. That's because some manual intervention would be required to assign IPv4 addresses, especially to get around NAT devices.

Peer discovery capabilities are critical in the case of emergencies, such as earthquakes, during which some network infrastructure is unavailable. "With IPv6, 5 minutes after the earthquake hits, we can make the most efficient use out of the infrastructure that is available," Lambert says. A short time after that, emergency network equipment can be deployed, including communications trailers or even wireless towers placed by helicopter in strategic locations. "The real magic happens when those trailers are all configured with IPv6 and the networks and all the first-responders are prepared to talk IPv6. Any device with IPv6 in it can communicate."

The grand vision is to establish MetroNet6 networks in multiple U.S. cities and to establish links between them, such that emergency personnel will be able to communicate with their counterparts wherever they may be. That's where the global addressing capability of IPv6 comes into play, making it possible for an IPv6-enabled device anywhere in the world to quickly establish communications with any other device. Of course, this kind of network also requires the cooperation of numerous service providers supporting IPv6. NTT America, for example, is involved in the Sacramento prototype of the MetroNet6 network (See Figure 1, page 10).

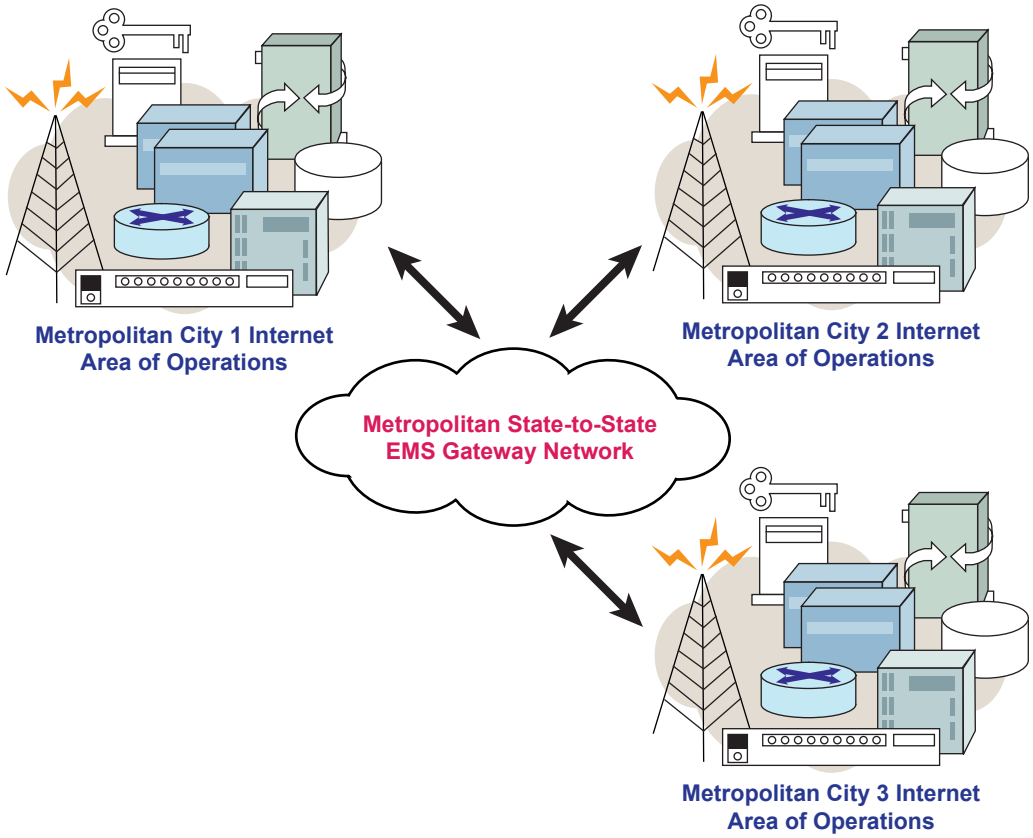
Comcast: Tackling 100M+ IP Addresses

Another service provider, the U.S. cable television and Internet service provider Comcast Corp., is adopting IPv6 to help it manage the vast network of devices installed in its customers' homes. The company previously used private IPv4 addresses to manage the cable modems installed in customer locations, according to Alain Durand, director and IPv6 architect for Comcast. But the company simply could not keep up with the number of addresses it needed. Consider that Com-

cast has some 20 million cable TV customers, with an average of 2.5 set-top boxes each, and that each box requires two IP addresses. That's 100 million addresses right there, and doesn't include additional addresses required for high-speed data and VoIP customers. Customers that get TV, voice and high-speed data service from Comcast need eight or nine IP addresses, assuming an average of 2.5 set-top boxes per household. Acquisitions and new services likewise drive up address requirements.[6]

Using IPv4 is not a viable option because it would require NAT, which would make the task far more difficult. As a result, back in 2005, Comcast began its IPv6 deployment plans. Essentially, the plan is to have multiple subnets at each customer's home or office to provide different services, such as one for video, another for Internet service, a third for maintenance on the set-top box and so on.

Figure 1:
MetroNet6 Grand Vision: City to City Command and Control



Ultimately, the MetroNet6 project is intended to create an emergency response network with communications between cities and states, all built on IPv6.

[6] Source : "IPv6 @ Comcast," a presentation by Alain Durand at the NANOG 37 meeting, June 4-7, 2006, San Jose, Calif. http://www.nanog.org/mtg-0606/durand.html

IPv6 Around the Globe

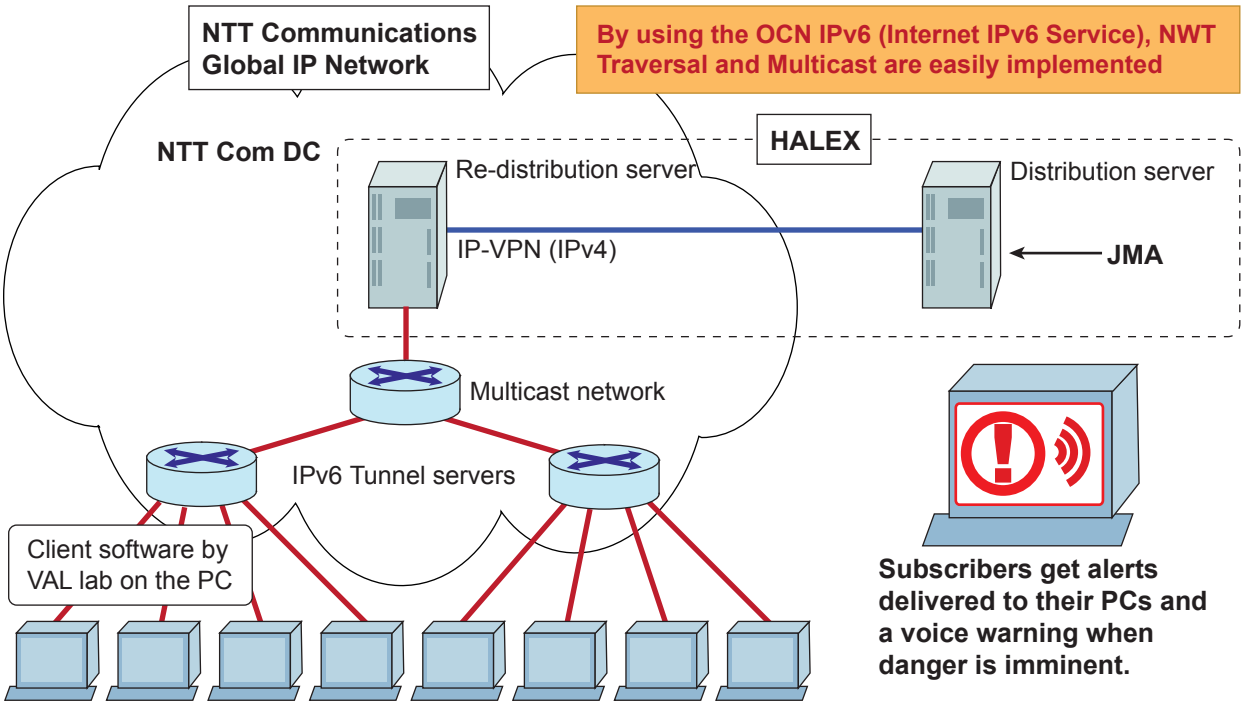
IPv6 is likewise taking hold in other countries around the world, playing a key role in a series of diverse applications, ranging from an innovative earthquake early warning system in Japan to a global communications system for embedded computers within BMW cars.

Earthquake Early Warning System

The Japan Meteorological Agency (JMA) is working with NTT Communications to use IPv6 as part of an earthquake early warning system that is intended to give advance earthquake warnings to factories, railroads and other companies. The system uses some 1,000 sensors that can detect early tremors that signal an earthquake is imminent. The sensors communicate with a JMA server, where the data is analyzed to determine the origin of the tremor, current location and direction of the seismic wave front, and where it may be headed (see Figure 2, below).

The JMA server hands off the resulting data to an NTT IPv6 multicast server, which distributes it via the NTT IPv6 multicast network to consumers and businesses that subscribe to the service. Subscribers get a warning, with an estimated intensity and a countdown in seconds, on their computer screens. The JMA, meanwhile, also issues its own warnings over TV and radio. Even a few seconds of advance warning can be crucial and that's what the system provides, given that warning data travels faster than the earthquake tremor. It could buy enough time to take important countermeasures, such as closing gas valves, alerting first responders and schools, stopping trains and elevators, extinguishing flames and taking cover.

Figure 2:
Architecture of the Japanese Earthquake Warning System



Japanese Agriculture

In another Japanese project, which began in 2002 under the auspices of Japan's Ministry of Public Management, Home Affairs, Posts and Telecommunications, IPv6 plays a role in monitoring the location and health of cattle. Each cow is outfitted with a sensor that can detect its temperature. The sensor, equipped with an IPv6 address and wireless LAN adapter, communicates to wireless LAN access points located at various points around a large ranch. The temperature sensors help monitor for disease, while the location information derived from the access point that the sensor communicates with alerts ranchers to any stray cows. The system is also intended to improve the traceability of beef throughout the growth and distribution process. Such information can help pinpoint the source of any diseases or contamination and improve overall consumer confidence in the industry.

Korea and China: Early Adopters

Since at least 2004, the Republic of Korea has been seeking to make all commercial Internet services IPv6-based by 2010. The KoreaV6 project is well on its way to meeting that goal, with the construction of the KOREAv6 backbone that interconnects domestic IPv6 networks and provides the infrastructure for pilot services aimed at businesses, schools, consumers, hospitals and government agencies. Some 35 organizations offer 11 different IPv6-based services, including a HDTV-quality video streaming service, a digital medical chart system for hospitals, a mobile education service with remote virtual storage and an ecosystem monitoring service, to name a few.[7]

China is in a similar position. In 2003, the Chinese State Department adopted the formation of the China Next Generation Internet (CNGI) as a national project. The four-phase CNGI project includes CERNET2, the Next Generation Education and Research Network in China, which will include native IPv6 support. IPv6 was a requirement in China if for no other reason than to keep up with growth in Internet users. China has an estimated 150 million to 200 million Internet users, yet only about 12% of the population is online, leaving tremendous room for growth — and tremendous demand for new IP addresses.[8]

BMW Eyes IP for Next-Gen Cars

Automaker BMW is looking at IP to network the various control systems in its automobiles. BMW today installs as many as 70 embedded computers to handle tasks ranging from engine and stability control to multimedia functions. A research group at the automaker tested IP as a way to provide real-time communications among the controllers, with promising results, according to a report in *EE Times Europe*.[9] Although the team used IPv4 for its experiments, it evaluated IPv6 as well and found "great potential for IPv6 applications," according to the *EE Times*. The impetus for the project was to keep up with the increasing number of embedded systems that BMW places in its cars

---

[7] Source: http://www.vsix.net/english/

[8] "China surpasses U.S. in Internet use," by Natalie Pace, April 3, 2006, Forbes.com. http://www.forbes.com/2006/03/31/china-internet-usage-cx_nwp_0403china.html

[9] "BMW brings Internet Protocol under the hood," by Christoph Hammerschmidt, Nov. 28, 2007, *EETimes Europe*.

and to provide connectivity from those systems to the global Internet, thus creating the potential for real-time communications and device monitoring. Given the sheer number of devices in question, IPv6 would be a natural choice due to its expanded address field.

IPv6 Futures

Looking ahead, there's almost no limit to the possibilities that IPv6 presents in terms of new applications. The peer-to-peer nature of IPv6, with its self-discovery capabilities, presents a multitude of opportunities for device-to-device communications.

For example, when used in combination with a number of other technologies, including the Session Initiation Protocol (SIP) and IP Multimedia Subsystem (IMS), IPv6 has the potential to usher in a new era of peer-to-peer services for mobile communications.

IMS is an architecture for delivering multimedia services over an IP-based mobile network. SIP is a signaling protocol used to set up and tear down telephone calls as well as multimedia sessions in an IP network. When used with the global addressing capabilities of IPv6, IMS enables rich multimedia communications between end devices over a mobile network, without the need for any intermediary servers or devices.

Such a capability could enable new forms of peer-to-peer gaming over mobile networks, with players able to easily find other players and initiate a game that involves multimedia streams. It is also the foundation technology behind the dating service cited earlier, in which two people with similar interests could be alerted when they are near each other.

IPv6 could also create some fundamental changes in the way companies currently do business. One example is home monitoring systems, says Jeffrey Young, senior analyst with the Burton Group consultancy. Think about how a security company typically operates, he says. A technician comes out to a customer's home and installs a monitoring device that costs maybe $50, but the customer is charged $200 to $300 because of the installation expense. With IPv6, the customer could install the device himself and it would be pre-configured to talk to a centralized management station, thus reducing an initial barrier to the sale. The security company still makes money on its monthly monitoring fees.

Young also cites an example of an Army warehouse, full of weapons, food and the like, that may be located somewhere in a desert. Perhaps the Army uses radio frequency identification (RFID) to keep track of inventory in the warehouse. In the IPv4 world, that requires trained technicians to network the warehouse, so that sensors can read the RFID tags on all the inventory and send signals back to the desired server. "With IPv6, you can ship the sensors out there and it's plug and play," Young says. "They come up and negotiate their globally addressable space and establish a secure association with whatever management station you set them up to deal with." The big plus is the Army doesn't have to send trained IT personnel to the desert to configure everything; it can all be done remotely.

Conclusion

As it did with Bechtel, the U.S. federal government mandate is likely to drive additional companies to explore IPv6 — and to come up with their own applications for the protocol. It's impossible to predict all the applications people might devise, but one thing is certain: We will run out of IPv4 addresses in the not-too-distant future.

While existing devices and networks connected to the Internet using IPv4 will continue to function, it will become increasingly more difficult to get contiguous IP addresses from registries such as ARIN, says John Curran, chairman of ARIN. That means organizations that are building new networks, and ISPs or mobile data providers that are adding new customers, will increasingly have no choice but to use IPv6 addresses, he says.

Already, there are organizations attempting to reach your mail and Web servers using IPv6, Curran says. In the near future, he maintains there will be an increasing number of organizations that have no choice but to use IPv6. At that point, you will need to support IPv6 in addition to IPv4 in order to be reachable by "the entire Internet," as Curran puts it.

Burton Group's Young says IPv6 represents an opportunity, at least to those who choose to seize it. His advice is simple: "Go get educated, understand IPv6 and look for ways you can implement it."

For more information:
www.us.ntt.net
877-8NTT-NET
sales@us.ntt.net

NTT Communications | NTT America

NTT Communications and IPv6

NTT Communications certainly understands IPv6. The company launched its first IPv6 transit services in 2001 and the first IPv6 managed firewall solution in 2005. Its IPv6 network now covers Asia, Australia, the U.S. and Europe. In November 2007, its subsidiary Verio, Inc. became the first North American Web hosting provider to offer IPv6 support when it announced availability of the protocol for the Verio Virtual Private Server (VPS) and Managed Private Server (MPS) hosting solutions.

No provider has a longer history in providing commercial IPv6 than NTT Communications, and the company is involved with some of the most advanced IPv6 projects worldwide.

NTT Communications' IPv6 services enable you to run dual IPv4 and IPv6 stacks for as long as you need to, allowing you to make the transition to IPv6 at your own pace. NTT America offers IPv6 commercial off the shelf (COTS) transit services on the GSA Schedule 70. The company's award winning IPv6 transit service is available in native, tunneled or dual stack modes, and may be procured using GSA Contract No. GS-35F-0322T. The U.S. Federal Aviation Administration, for example, uses IPv4 as well as IPv6 services from NTT Communications in the dual-stack mode.

The NTT Communications network also has a single global ASN worldwide, providing improved performance with no bottlenecks between network segments. As the second-largest telecommunications company by revenue in *Fortune* magazine's 2007 Global 500 survey, NTT Communications also provides the stability you require in a global carrier.

To learn more about NTT Communications and its IPv6 offerings in the U.S., please visit www.us.ntt.net .