

## IPv6 White Paper

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### Executive Summary

Internet Protocol version 6 or IPv6 is an improved version of the current and most widely used Internet Protocol, IPv4. IP enables data to be sent via the Internet and ensures that it arrives at its correct destination. In addition to creating more addresses so that more people and devices can connect to the Internet, IPv6 provides some exciting enhancements over IPv4.

This white paper includes the following sections:

#### **A. What is IPV6?**

Introduces IPv6, examining its evolution and the drivers behind the transition to IPv6.

#### **B. How does IPV6 work?**

Provides a technical overview of IPv6 and the integration requirements for IPv4 and IPv6.

#### **C. How does AT support IPV6?**

Demonstrates the readiness of Allied Telesis' products for the transition to IPv6.

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## A. What is IPv6?

### Introduction

The popularity of the Internet today and its complex spaghetti junction of wires, connections, delivery mechanisms and addresses could not have possibly reached the outer limits of the imaginations of the Internet's forefathers. Nor could they have imagined the associated commercial and social phenomena they were unleashing.

Between 1973 and 1983, Vinton Cerf, Robert Kahn and others devised a networking system that enabled them to communicate with each other and utilise each other's computers. Their work led to the introduction of the TCP/IP protocol (Transmission Control Protocol/Internet Protocol), which enables data to be broken up into packets and sent from one computer to another in a network. Their invention now gives us the ability to link together 4 billion machines, a number that would have seemed enormous in the 1970s, but is now barely enough.

The Internet has fundamentally changed the way that both individuals and businesses operate and communicate, especially in the developed world. Almost every individual in the developed world has an Internet connection, and soon the homes of these people will also contain numerous Internet enabled appliances. A recent report has indicated that 553 million people are now connected to the Internet from their homes<sup>1</sup>.

This huge growth in Internet use has not only led to increased demand for better, faster technology, but has also increased the demand for addresses from which to send and receive information. This is especially true for developing countries where people are only really starting to use the Internet.

### What is IPv6?

Internet Protocol version 6 or IPv6<sup>2</sup> is an improved version of the current and most widely used Internet Protocol, IPv4. IP enables data to be sent from one computer to another in a network and is known as a connectionless protocol because there is no continuous connection between the two communicating devices. So, when a message is sent via IP it is broken up into packets, which may travel via a number of different routes to their final destination, and on arrival at their destination they are reassembled in their original form. Each device in a network has an IP address, which is used by the IP protocol to ensure that the packets of information reach their correct destination.

IPv4 was the first commercial version of IP and is now being replaced with IPv6 (also known as IPng, IP next generation). The key feature of IPv6 is its extra address space from the IPv4's 32 bits to 128 bits, which increases the number of available IP addresses from 4 billion to over 340 trillion trillion trillion.

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<sup>1</sup> Nielsen- NetRatings

<sup>2</sup> Defined in RFC 2460 – Internet Protocol version 6 (IPv6)

## What is driving the use of and transition to IPv6?

Address depletion has been the primary driver behind the need for IPv6, but it is also driven by the demand for wireless devices, which, because they access the Internet, require their own IP addresses. The explosion in the use of handheld wireless devices is evidenced by their predicted shipment numbers, which is expected to grow from 430m in 2002 to 760m in 2006, and mobile Internet users are expected to exceed 1.2 billion before the end of the decade<sup>3</sup>. The increasing number of Internet users, systems, and the convergence of services into common infrastructure will drive the demand for IPv6.

The commercial opportunities that IPv6 can provide for wireless devices, peer-to-peer networking and the "smart home" are also driving the move to the new technology. The wireless market requires a low latency, always on, auto-roaming always-reachable IP service. Peer-to-peer networking enables a group of computers to communicate directly with each other, rather than through a central server, in order to avoid the expense and delay of handling all the traffic on a server. Peer-to-peer networking<sup>4</sup> is used for multiplayer online games, IP-telephony, video-conferencing and new business models similar to Napster. In addition, other commercial opportunities for "smart home" products, such as Internet enabled automobiles, security systems and kitchen appliances are also pushing the transition to IPv6.

In some countries, the pressures associated with address depletion, combined with these commercial opportunities, have resulted in governments mandating the move to IPv6. The European Commission as well as the Japanese, Taiwanese and Korean governments have mandated the move and other Asian countries are working towards it. The United States has been somewhat slower to take up IPv6, although the US Department of Defence has indicated it aims to complete its by 2008.

## How is IPv6 better than IPv4?

IPv6 has a number of features that overcome the limitations of IPv4. A significant improvement is that the additional addresses remove the need for Network Address Translation (NAT). NAT has extended the life of IPv4 by allowing multiple devices to sit behind a router and share the same globally unique IP address. However, NAT has introduced a number of undesirable side effects, which include difficulty in network troubleshooting, network administration, and implementing security protocols such as IPsec. IPv6 removes the need for NAT, allowing flawless transparent end-to-end security.

IPv6 will result in faster and more efficient routing because of its well-regulated address allocation. Faster routing is possible thanks to the efficient routing table created with hierarchical addressing. Also, address scoping means the data will travel only as far as it must go, reducing unnecessary network traffic.

IPv6 will make separate IPsec clients obsolete as IPv6 machines will be able to tunnel directly to each other. This is not currently possible with IPv4 because of the use of NATs. IPv6 also enables the automatic allocation and changing of IP addresses, or address auto-configuration, which eases network management and some of the issues associated with mobile computing.

IPv6 provides inbuilt Quality of Service (QoS)<sup>5</sup>, providing for the prioritisation of time sensitive streams and efficient packet handling. It also has an improved ability to carry voice and video packets alongside data.

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<sup>3</sup> Wireless System Design, June 2002, [www.isc.org](http://www.isc.org), Internet Software Consortium

<sup>4</sup> An initial intent of those designing the Internet

## How and when will we transition from IPv4 to IPv6?

The transition from IPv4 to IPv6 is one of evolution rather than revolution, so for an extended period of time both IPv4 and IPv6 will coexist. The transition will be gradual because many users have large installed equipment bases and replacing these at one time would be costly even when considering the significant benefits of IPv6. Furthermore, there are a number of “band-aids”, such as NAT, that have been designed to extend the life of IPv4, but they will only temporarily slow the drive to IPv6 and will certainly not prevent IPv6 becoming the IP of choice.

The remainder of this paper provides a technical overview of IPv6 and describes Allied Telesis’ proactive approach to the IPv6 evolution.

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<sup>5</sup> See Allied Telesis QoS white paper

## B. How does IPv6 work?

When there is a shortage of telephone numbers in a large city, additional digits are added to the front of telephone numbers to increase the amount of available numbers. Similarly, the shortage of IP addresses has been solved in IPv6 by adding additional bytes to the IP address. However, unlike the situation when there is a shortage of telephone numbers, it is not possible to make the change over night, so both IPv4 and IPv6 will coexist over a transition period. The transition mechanisms are described after the following overview of the IPv6 addressing and its other enhancements over IPv4.

### IPv6 Addressing

The architecture, hierarchical addressing, auto configuration and packet headers distinguish IPv6 addresses from IPv4 addresses.

#### Architecture<sup>6</sup>

IPv6 increases the IP address space from 32 bits to 128 bits. The new 128-bit IPv6 addresses are represented in the form of eight 16 bit components divided by colons, i.e., x:x:x:x:x:x:x:x. Hexadecimal notation, rather than familiar dotted decimal notation, is usually used to write IPv6 addresses, as shown in the following example:

**FE80:0000:0000:0000:0260:97FF:FE8F:64AA**

#### Hierarchical Addressing

Like in a telephone network, IPv6 addresses are organised in a hierarchical manner, to facilitate scaling, aggregation and routing. In a telephone network this hierarchical addressing is achieved through the use of country and area codes, permitting aggregation by using shorter telephone numbers closer to home and adding codes to achieve a wider reach.

The IPv6 hierarchical address architecture was designed to support hierarchical routing, which allows smaller routing tables and more efficient address allocation. Smaller routing tables increase routing efficiency and provide faster routing, through faster route lookup and reduced latency. With IPv6, aggregation is achieved by providing an address prefix and the organisation of addresses into two levels—public topology and interface identifier. Public topology relates to providers of public Internet services and the interface identifier relates to specific interfaces on a link. In IPv4, blocks of addresses are preassigned in a non-hierarchical manner. As a consequence, many addresses still remain unused although classless inter-domain routing has, to some extent, lessened this issue. The IPv6 solution is more effective because the higher order levels sub-divide their addresses, as required, to efficiently provide the lower levels with their addresses. Figure 1 shows the general format for IPv6 global unicast addresses, and Figure 2 is an example of the global unicast address format in use today.

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<sup>6</sup> The complete IPv6 address model is specified in RFC3513 – IPv6AddressingArchitecture

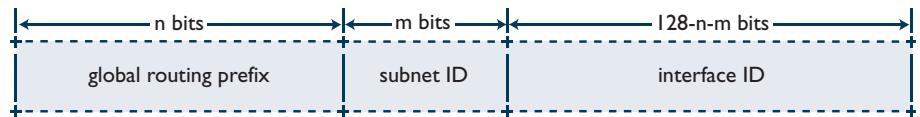


Figure 1: The general format for IPv6 addresses

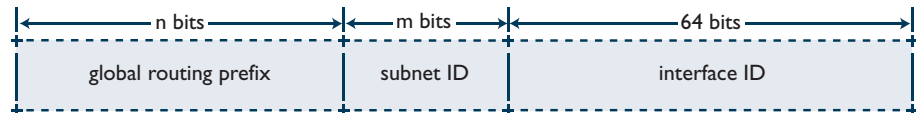


Figure 2: The IPv6 address format that is in use today

A number of other predefined address prefixes enable a variety of other functions, such as multicasting. Table 1 shows these predefined addresses and some example addresses.

Address type	Example addresses
Multicast address	ff02::1 or ff0e::101
Unicast address	3ffe:2::280:c8ff:fe02:7f41
Link-local address	fe80::2c0:dfff:fe07:6d62

Table 1: Predefined addresses and some example addresses

IPv6 uses multicast addresses instead of broadcast addresses. A multicast address enables any number of specific senders to communicate with any number of specific multiple receivers, whereas a broadcast address communicates from one point in a network to all other points in a network. A link-local address is only valid for the link that it is on and is used for auto-address configuration, neighbour discovery, and when no routers are present.

IPv6 also defines a new type of address, an anycast address, which is a communication between a single sender and the nearest of several receivers in a group. All packets are sent to one member of the anycast group. This receiver may be a host or a service, and is selected by its proximity to the sender based on its topology, the transmission protocol, or its administration policy. An anycast address can be used to identify a set of interfaces that can be on multiple devices, so that a packet sent to an anycast address is delivered to one of those interfaces. One of the key uses of anycasting is to efficiently update routing tables.

### Auto-configuration

Unlike IPv4, IPv6 does not require the IP address of a host, network mask and default gateway to be configured manually by an administrator. IPv6 enables address auto-configuration of hosts, not only providing network configuration efficiencies but also enabling mobile devices to automatically connect to the Internet.

In IPv6, auto-configuration can be performed either through a stateless or a stateful address auto-configuration. If the network does not require the use of any specific addresses, only that

the addresses be unique and routable, stateless address auto-configuration is suitable. Stateless address auto-configuration is done through router advertisements. IPv6 hosts generate their own addresses by combining their *interface identifiers*<sup>7</sup> with the IPv6 prefix(es) advertised by routers. This enables an administrator to simply configure the router to advertise IPv6 prefixes and all devices connected to the router will automatically have their addresses configured. Even without a router, IPv6 devices on the same link can communicate with each other because they have automatically generated link-local addresses, which are derived from their Media Access Control (MAC) addresses.

Stateful auto-configuration involves obtaining all required addresses and configuration information from a server and is usually used when stateless configuration fails or is inadequate. Stateful address configuration is achieved through the use of Dynamic Host Configuration Protocol version 6 (DHCPv6). DHCPv6 enables the management and dynamic configuration of addresses from a server and prefix delegation. Prefix delegation allows a router at a customer's premises to request an IPv6 prefix to be used on their site. Prefix delegation combined with router advertisements enable addresses to be automatically configured on all devices in a network.

## IPv6 Packet Header

IPv6 simplifies the address header information so the processing of IP packets is less complicated than in IPv4. IPv6 allows for header compression and optional header extensions as well as providing Quality of Service (QoS) or content prioritisation features that improve performance over IPv4.

The IPv6 header:

- No longer contains the header length, identification, flags, fragment offset and checksum in the base header; some of which now occur elsewhere, like in the extension headers.
- Is a fixed length of 40 bytes and extension headers can be concatenated after the IPv6 header.
- Uses a hop limit instead of a time to live field.
- Provides integrated QoS support through the traffic class field, which replaces the type of service field, and the flow label field.

Figure 3 on the following page demonstrates the format of IPv4 and IPv6 headers.

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<sup>7</sup> The interface identifier is a 64-bit value which is usually derived from the MAC address of the network interface



## IPv6/ IPv4 Integration

Commercially attractive applications requiring IPv6 may demand a rapid transition to IPv6, but the process of moving from IPv4 to IPv6 is one of evolution rather than revolution. The key to a successful IPv4 to IPv6 transition is to maintain compatibility with the large installed base of IPv4 hosts and routers. That is, IPv6 hosts and routers must inter-operate with the current IPv4 infrastructure and use some form of translation mechanism. A number of potential technical solutions have been developed to allow this coexistence and can be categorised into two types:

### Dual IPv4/IPv6 stack implementations:

- Dual IP Stack
- Tunnelling
- Tunnel Broker
- 6-over-4
- 6-to-4

### Network Address & Protocol Translators:

- Stateless IP/ICMP Translator, SIIT
- Network Address Translation-Protocol Translation, NAT-PT
- Transport Relay Translator

Table 2 on the following page presents a more detailed overview of the key translation mechanisms.

<b>Dual IP Stack</b>
The dual stack provides support for both IPv4 and IPv6 protocol versions. It interoperates directly with both IPv4 and IPv6. However, even though the IPv4 and IPv6 networks are on the same link, the dual stack router has to maintain two routing tables. The IPv4 and IPv6 nodes are not able to communicate directly with each other.
<b>Tunnelling</b>
Tunnelling allows IPv6 nodes that are separated by IPv4 networks to build a "virtual" link. IPv6 packets travelling over an IPv4 network are encapsulated within IPv4 packets. There are 2 types of tunnelling: <ul style="list-style-type: none"><li>• Static tunnels are manually configured. The IPv6 tunnel address and both IPv4 endpoints are specified.</li><li>• Automatic tunnels require no configuration. However, both nodes must have globally routable IPv4 addresses.</li></ul>
<b>Tunnel Broker</b>
The tunnel broker provides IPv6 connectivity by creating IPv6 over IPv4 tunnels requested by IPv6 nodes. It allows isolated IPv6 nodes to communicate with the IPv6 network.
<b>6-over-4</b>
This method uses IPv4 multicast groups to create virtual links. IPv6 multicast addresses are mapped to IPv4 multicast addresses to be able to undertake neighbour discovery.
<b>6-to-4</b>
6-to-4 allows for interconnection of isolated IPv6 domains in an IPv4 world. It is similar to automatic tunnelling but uses an IPv6 prefix that is derived from the node's IPv4 address.
<b>Stateless IP/ICMP Translator, SIIT</b>
SIIT provides a method to translate between IPv6 and IPv4 headers. Translation is done in a stateless mode. This provides a near perfect mapping between IPv6 and IPv4 headers.
<b>Network Address Translation-Protocol Translation, NAT-PT</b>
NAT-PT defines a method for communication between IPv6-only and IPv4-only hosts by maintaining the state of each connection and performing address translation for each session through the NAT-PT. It makes use of SIIT for protocol translation.
<b>Transport Relay Translator</b>
The transport relay translator allows direct communication between IPv4 and IPv6 hosts through the use of transport layer translation services. This is similar to a NAT-PT, but the translation occurs at the transport layer in the OSI model.

Table 2: Translation Mechanisms

## C. How does Allied Telesis support IPv6?

Allied Telesis has taken a proactive approach to supporting the IPv6 evolution, providing a comprehensive product range that supports IPv6 now. This enables future-conscious customers to purchase equipment that will evolve with them as they move towards IPv6.

Today, Allied Telesis' routers and Layer 3 switches provide comprehensive software support for IPv6. Some switches have full support for IPv6 in their hardware. These products support the full implementation of IPv6 networking and facilitate the transition from IPv4 to IPv6.

Allied Telesis' full implementation of IPv6 networking is provided through:

### Hardware Readiness for IPv6

Depending on your geographical location, IPv6 functionality may already be available on your Allied Telesis product. If not, IPv6 can be enabled with a feature licence on all Allied Telesis products, including the x900-24XT (previously known as AT-9924Ts). The x900-48FE (previously AT-8948) and AT-9924T/4SP switches can take the optional AT-ACC01 IPv6 accelerator card. With this card, the x900-48FE routes IPv6 traffic at wire speed, and the AT-9924T/4SP routes IPv6 traffic at 10Gbps.

### Stateless Address Auto-configuration

Allied Telesis routers and switches support stateless address auto-configuration, enabling the assignment of IPv6 addresses to interfaces. These addresses are link-local addresses and are sufficient for communication among devices on the same link.

### IPv6 Interfaces and Addresses

Allied Telesis routers and switches support the addition of IPv6 addresses directly to Point-to-Point Protocol (PPP), physical Ethernet interfaces, VLAN interfaces and IPv6 over IPv4 tunnels. The router and switch interfaces allow for multiple IPv6 addresses, as well as various types of addresses, such as global unicast addresses, anycast addresses and link-local addresses. The Allied Telesis implementation is compliant with RFC 2373 – IP version 6 Addressing Architecture.

### Name to IPv6 Address Mapping

Allied Telesis routers and switches allow IPv6 hosts to be given user-defined names in the router's host name table. This allows users to enter a short, easy-to-remember name for the host rather than the host's full IPv6 address.

### IPv6 Routing and RIPv6

Allied Telesis routers and switches maintain and process the routing tables containing IPv6 addresses and support the routing protocol RIPv6 (also known as RIPng). RIPv6 allows the router to share routing information with other RIPv6 enabled devices. The Allied Telesis implementation is compliant with RFC 2080 - RIPng for IPv6. If the route determined using RIPv6 is not the most desirable one, the Allied Telesis implementation allows the route to be added manually.

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<sup>10</sup> IPv6 cannot be enabled on the AR100 and AR300

## Neighbour Discovery

Allied Telesis routers and switches support the IPv6 neighbour discovery processes and are compliant with RFC 2461 - Neighbor Discovery for IP version 6 (IPv6). In this process, routers issue router advertisement messages in response to a router solicitation message from a host, to enable the host to determine the router's identity and availability. The routers also carry out Duplicate Address Detection (to detect whether configured addresses on the router are already in use by other nodes on the same network) and respond to neighbour solicitation messages with neighbour advertisement messages.

## IPsec

For mandatory security, IPsec is built into IPv6. IPsec operates at the IP layer so is transparent to applications, but still protects all upper layer protocols. The security offered by IPsec protects both end-to-end and router-to-router (also known as 'secure gateway') applications.

## IPv6 Filtering

Allied Telesis routers and switches can filter IPv6 packets when they arrive at the router or switch with a traffic filter, or when they are transmitted from the router or switch with a priority filter. Traffic filters are used to determine whether an incoming packet is accepted or rejected. Priority filters give the packets a particular priority from 0 to 7, with 0 having the highest priority.

## Telnet, Ping and Trace Functionality

Allied Telesis routers and switches support the operation of Telnet, Ping and Trace Route in IPv6. The Telnet command allows remote access to a device's command-line interface. The Ping command is used to test the connectivity between two network devices to determine whether the network devices can "see" each other. The Trace Route command reveals the route used to pass packets between two systems.

## IPv6 Multicasting

Allied Telesis routers and switches support the use of Multicast Listener Discovery (MLDv1 and v2) for multicast group management. Allied Telesis routers also support multicast routing using Protocol Independent Multicast Sparse Mode (PIM-SM) and Protocol Independent Multicast Dense Mode (PIM-DM).

## DHCPv6

Allied Telesis routers and switches support the implementation of DHCPv6 for stateful address auto-configuration. The DHCP server can allocate prefixes to IPv6 subnets, assign normal IPv6 addresses and assign temporary IPv6 addresses for the purpose of privacy extensions. As a DHCPv6 client, each IPv6 interface can obtain address information from a DHCPv6 server. Each IPv6 interface can serve various types of addresses. The Allied Telesis implementation is compliant with the unreleased RFC 3633, IPv6 Prefix Options for Dynamic Host Configuration Protocol (DHCP) version 6.

## IPv4/IPv6 Transition

To allow customers to transition from IPv4 to IPv6 in a seamless manner, Allied Telesis has implemented two of the most widely used methods for providing compatibility—the use of dual IP stacks and IPv6 tunnelling. Dual IP stack operation allows an interface to be configured with both an IPv6 address and an IPv4 address. The routers and switches then have the ability to send and receive both IPv6 and IPv4 packets, enabling communication with both IPv4 and IPv6 networks.

Allied Telesis routers and switches also support the tunnelling of IPv6 packets across an IPv4 network. Tunnelling is achieved by encapsulating the IPv6 packet within an IPv4 datagram. Allied Telesis routers and switches support 6-to-4 tunnelling<sup>11</sup>, automatic tunnelling and manually configured static tunnels.<sup>12</sup>

## Conformance and Interoperability Testing

In order to ensure that our products conform to IPv6 standards and interoperate with other networking products, Allied Telesis regularly participates in conformance and interoperability tests.

Allied Telesis products have been shown to successfully interoperate with IPv6 implementations of other vendors at NetWorld+InterOp, which is an annual event designed to showcase the latest networking technologies<sup>13</sup>. This event enables Allied Telesis to demonstrate their advanced IPv6 products in real network situations.

Allied Telesis also regularly participates in other conformance and interoperability events run by organisations like the non-profit group TAHI<sup>14</sup> and Japanese Gigabit Network II (JGN 2)<sup>15</sup>. These organisations also give networking vendors the opportunity to test and demonstrate their IPv6 ready products in real life and test networks.

**Every year since 2003, Allied Telesis' IPv6 ready products have been utilised in the JGN2 backbone network to multicast video footage of the Sapporo Snow Festival throughout Japan.**

## IPv6 Certification

A worldwide consortium of leading Internet vendors and network providers has established the IPv6 Forum with the aim of providing equitable access to knowledge and technology on a global scale. The IPv6 Forum sets industry standards for IPv6 conformance and interoperability.

The IPv6 Forum organises and supports a range of industry events, including an IPv6 Ready program, which certifies networking products that meet their standards. Products that carry the 'IPv6 Ready' logo have been independently tested to verify that they conform with IPv6 standards, and will operate successfully with other IPv6 enabled devices. The IPv6 Ready program reassures customers that IPv6 is currently operational and that the technology will be used in the future.

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<sup>11</sup> Allied Telesis' 6 to 4 tunnelling is compliant with RFC 3056 Connection of IPv6 Domains via IPv4 Clouds

<sup>12</sup> Allied Telesis' automatic tunnelling and configured static tunnels are compliant with RFC 1933 Transition Mechanisms for IPv6 Hosts and Routers

<sup>13</sup> For more information about NetWorld+InterOp, visit: <http://www.interop.jp/english/>

<sup>14</sup> For more information about TAHI, visit their website: <http://www.tahi.org>

<sup>15</sup> For more information about JGN2, visit their website: <http://www.jgn.nict.go.jp/e/index.html>

The following Allied Telesis products have IPv6 Ready certification:

Switches:

- Rapier Series – Managed Layer 3 Switches
- AT-9800 Series – Managed Layer 3 Gigabit Switches
- AT-8948 – Multilayer IPv4 and IPv6 Switch
- AT-9924T, 9924SP, 9924T/4SP – Enhanced Layer 3+ Gigabit Switches

Routers:

- AR410/AR410S – Secure Modular Branch Office Router
- AR440S/AR441S – Secure ADSL Routers, Annex A/B
- AR450S – Secure Ethernet Router
- AR725 – Modular Enterprise Router
- AR745 – Modular Enterprise Router with NSM Bay



The testing and certification of IPv6-capable products now, before the new technology has been widely adopted, will ensure a smooth transition to IPv6. In conjunction with Allied Telesis, IPv6 enables companies to reap the benefits of the Internet revolution, now and in the future.

## IPv6 Implementations Today

IPv6 is already widely deployed in Japan. IPv6 was trialed as a way of monitoring traffic by installing detectors in cars. Quickly seeing the potential of this technology, one Tokyo taxi company uses IPv6 technology to keep its customers dry. When it rains on one of their taxis and the windscreen wipers are turned on, detectors on the wipers send a message to the company's headquarters. From this message, the company can locate the taxi and dispatch more taxis to that area in anticipation of more people also wanting to stay dry.

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