

Network Working Group
Request for Comments: 5214
Obsoletes: 4214
Category: Informational

F. Templin
Boeing Phantom Works
T. Gleeson
Cisco Systems K.K.
D. Thaler
Microsoft Corporation
March 2008

Intra-Site Automatic Tunnel Addressing Protocol (ISATAP)

Status of This Memo

This memo provides information for the Internet community. It does not specify an Internet standard of any kind. Distribution of this memo is unlimited.

IESG Note

The IESG thinks that this work is related to IETF work done in WG softwires, but this does not prevent publishing.

Abstract

The Intra-Site Automatic Tunnel Addressing Protocol (ISATAP) connects dual-stack (IPv6/IPv4) nodes over IPv4 networks. ISATAP views the IPv4 network as a link layer for IPv6 and supports an automatic tunneling abstraction similar to the Non-Broadcast Multiple Access (NBMA) model.

Table of Contents

1. Introduction	2
2. Requirements	3
3. Terminology	3
4. Domain of Applicability	4
5. Node Requirements	4
6. Addressing Requirements	4
6.1. ISATAP Interface Identifiers	4
6.2. ISATAP Interface Address Configuration	5
6.3. Multicast/Anycast	5
7. Automatic Tunneling	5
7.1. Encapsulation	5
7.2. Handling ICMPv4 Errors	5
7.3. Decapsulation	6
7.4. Link-Local Addresses	6
7.5. Neighbor Discovery over Tunnels	6
8. Neighbor Discovery for ISATAP Interfaces	6
8.1. Conceptual Model of a Host	7
8.2. Router and Prefix Discovery - Router Specification	7
8.3. Router and Prefix Discovery - Host Specification	7
8.3.1. Host Variables	7
8.3.2. Potential Router List Initialization	7
8.3.3. Processing Received Router Advertisements	8
8.3.4. Sending Router Solicitations	8
8.4. Neighbor Unreachability Detection	9
9. Site Administration Considerations	9
10. Security Considerations	9
11. IANA Considerations	10
12. Acknowledgments	10
13. References	11
13.1. Normative References	11
13.2. Informative References	12
Appendix A. Modified EUI-64 Addresses in the IANA Ethernet Address Block	13

1. Introduction

This document specifies a simple mechanism called the Intra-Site Automatic Tunnel Addressing Protocol (ISATAP) that connects dual-stack (IPv6/IPv4) nodes over IPv4 networks. Dual-stack nodes use ISATAP to automatically tunnel IPv6 packets in IPv4, i.e., ISATAP views the IPv4 network as a link layer for IPv6.

ISATAP enables automatic tunneling whether global or private IPv4 addresses are used, and it presents a Non-Broadcast Multiple Access (NBMA) abstraction similar to [RFC2491],[RFC2492],[RFC2529], and [RFC3056].

The main objectives of this document are to: 1) describe the domain of applicability, 2) specify addressing requirements, 3) specify automatic tunneling using ISATAP, 4) specify the operation of IPv6 Neighbor Discovery over ISATAP interfaces, and 5) discuss Site Administration, Security, and IANA considerations.

2. Requirements

The keywords MUST, MUST NOT, REQUIRED, SHALL, SHALL NOT, SHOULD, SHOULD NOT, RECOMMENDED, MAY, and OPTIONAL, when they appear in this document, are to be interpreted as described in [RFC2119].

This document also uses internal conceptual variables to describe protocol behavior and external variables that an implementation must allow system administrators to change. The specific variable names, how their values change, and how their settings influence protocol behavior are provided in order to demonstrate protocol behavior. An implementation is not required to have them in the exact form described here, as long as its external behavior is consistent with that described in this document.

3. Terminology

The terminology of [RFC2460] and [RFC4861] applies to this document. The following additional terms are defined:

ISATAP node/host/router:

A dual-stack (IPv6/IPv4) node/host/router that implements the specifications in this document.

ISATAP interface:

An ISATAP node's Non-Broadcast Multi-Access (NBMA) IPv6 interface, used for automatic tunneling of IPv6 packets in IPv4.

ISATAP interface identifier:

An IPv6 interface identifier with an embedded IPv4 address constructed as specified in Section 6.1.

ISATAP address:

An IPv6 unicast address that matches an on-link prefix on an ISATAP interface of the node, and that includes an ISATAP interface identifier.

locator:

An IPv4 address-to-interface mapping; i.e., a node's IPv4 address and its associated interface.

Per Section 2.5.1 of [RFC4291], ISATAP nodes are not required to validate that interface identifiers created with modified EUI-64 tokens with the "u" bit set to universal are unique.

6.2. ISATAP Interface Address Configuration

Each ISATAP interface configures a set of locators consisting of IPv4 address-to-interface mappings from a single site; i.e., an ISATAP interface's locator set **MUST NOT** span multiple sites.

When an IPv4 address is removed from an interface, the corresponding locator **SHOULD** be removed from its associated locator set(s). When a new IPv4 address is assigned to an interface, the corresponding locator **MAY** be added to the appropriate locator set(s).

ISATAP interfaces form ISATAP interface identifiers from IPv4 addresses in their locator set and use them to create link-local ISATAP addresses (Section 5.3 of [RFC4862]).

6.3. Multicast/Anycast

It is not possible to assume the general availability of wide-area IPv4 multicast, so (unlike 6over4 [RFC2529]) ISATAP must assume that its underlying IPv4 carrier network only has unicast capability. Support for IPv6 multicast over ISATAP interfaces is not described in this document.

Similarly, support for Reserved IPv6 Subnet Anycast Addresses is not described in this document.

7. Automatic Tunneling

ISATAP interfaces use the basic tunneling mechanisms specified in Section 3 of [RFC4213]. The following sub-sections describe additional specifications.

7.1. Encapsulation

ISATAP addresses are mapped to a link-layer address by a static computation; i.e., the last four octets are treated as an IPv4 address.

7.2. Handling ICMPv4 Errors

ISATAP interfaces **SHOULD** process Address Resolution Protocol (ARP) failures and persistent ICMPv4 errors as link-specific information indicating that a path to a neighbor may have failed (Section 7.3.3 of [RFC4861]).

7.3. Decapsulation

The specification in Section 3.6 of [RFC4213] is used. Additionally, when an ISATAP node receives an IPv4 protocol 41 datagram that does not belong to a configured tunnel interface, it determines whether the packet's IPv4 destination address and arrival interface match a locator configured in an ISATAP interface's locator set.

If an ISATAP interface that configures a matching locator is found, the decapsulator **MUST** verify that the packet's IPv4 source address is correct for the encapsulated IPv6 source address. The IPv4 source address is correct if:

- o the IPv6 source address is an ISATAP address that embeds the IPv4 source address in its interface identifier, or
- o the IPv4 source address is a member of the Potential Router List (see Section 8.1).

Packets for which the IPv4 source address is incorrect for this ISATAP interface are checked to determine whether they belong to another tunnel interface.

7.4. Link-Local Addresses

ISATAP interfaces use link-local addresses constructed as specified in Section 6 of this document.

7.5. Neighbor Discovery over Tunnels

ISATAP interfaces use the specifications for neighbor discovery found in the following section of this document.

8. Neighbor Discovery for ISATAP Interfaces

ISATAP interfaces use the neighbor discovery mechanisms specified in [RFC4861]. The following sub-sections describe specifications that are also implemented.

8.1. Conceptual Model of a Host

To the list of Conceptual Data Structures (Section 5.1 of [RFC4861]), ISATAP interfaces add the following:

Potential Router List (PRL)

A set of entries about potential routers; used to support router and prefix discovery. Each entry ("PRL(i)") has an associated timer ("TIMER(i)"), and an IPv4 address ("V4ADDR(i)") that represents a router's advertising ISATAP interface.

8.2. Router and Prefix Discovery - Router Specification

Advertising ISATAP interfaces send Solicited Router Advertisement messages as specified in Section 6.2.6 of [RFC4861] except that the messages are sent directly to the soliciting node; i.e., they might not be received by other nodes on the link.

8.3. Router and Prefix Discovery - Host Specification

The Host Specification in Section 6.3 of [RFC4861] is used. The following sub-sections describe specifications added by ISATAP interfaces.

8.3.1. Host Variables

To the list of host variables (Section 6.3.2 of [RFC4861]), ISATAP interfaces add the following:

PrlRefreshInterval

Time in seconds between successive refreshments of the PRL after initialization. The designated value of all ones (0xffffffff) represents infinity.

Default: 3600 seconds

MinRouterSolicitInterval

Minimum time in seconds between successive solicitations of the same advertising ISATAP interface. The designated value of all ones (0xffffffff) represents infinity.

8.3.2. Potential Router List Initialization

ISATAP nodes initialize an ISATAP interface's PRL with IPv4 addresses acquired via manual configuration, a DNS Fully Qualified Domain Name (FQDN) [RFC1035], a DHCPv4 [RFC2131] vendor-specific option, or an unspecified alternate method. Domain names are acquired via manual

configuration, receipt of a DHCPv4 Domain Name option [RFC2132], or an unspecified alternate method. FQDNs are resolved into IPv4 addresses through a static host file lookup, querying the DNS service, querying a site-specific name service, or with an unspecified alternate method.

After initializing an ISATAP interface's PRL, the node sets a timer for the interface to PrlRefreshInterval seconds and re-initializes the interface's PRL as specified above when the timer expires. When an FQDN is used, and when it is resolved via a service that includes Times to Live (TTLs) with the IPv4 addresses returned (e.g., DNS 'A' resource records [RFC1035]), the timer SHOULD be set to the minimum of PrlRefreshInterval and the minimum TTL returned. (Zero-valued TTLs are interpreted to mean that the PRL is re-initialized before each Router Solicitation event; see Section 8.3.4.)

8.3.3. Processing Received Router Advertisements

To the list of checks for validating Router Advertisement messages (Section 6.1.2 of [RFC4861]), ISATAP interfaces add the following:

- o IP Source Address is a link-local ISATAP address that embeds V4ADDR(i) for some PRL(i).

Valid Router Advertisements received on an ISATAP interface are processed as specified in Section 6.3.4 of [RFC4861].

8.3.4. Sending Router Solicitations

To the list of events after which Router Solicitation messages may be sent (Section 6.3.7 of [RFC4861]), ISATAP interfaces add the following:

- o TIMER(i) for some PRL(i) expires.

Since unsolicited Router Advertisements may be incomplete and/or absent, ISATAP nodes MAY schedule periodic Router Solicitation events for certain PRL(i)s by setting the corresponding TIMER(i).

When periodic Router Solicitation events are scheduled, the node SHOULD set TIMER(i) so that the next event will refresh remaining lifetimes stored for PRL(i) before they expire, including the Router Lifetime, Valid Lifetimes received in Prefix Information Options, and Route Lifetimes received in Route Information Options [RFC4191]. TIMER(i) MUST be set to no less than MinRouterSolicitInterval seconds where MinRouterSolicitInterval is configurable for the node, or for a specific PRL(i), with a conservative default value (e.g., 2 minutes).

When `TIMER(i)` expires, the node sends Router Solicitation messages as specified in Section 6.3.7 of [RFC4861] except that the messages are sent directly to `PRL(i)`; i.e., they might not be received by other routers. While the node continues to require periodic Router Solicitation events for `PRL(i)`, and while `PRL(i)` continues to act as a router, the node resets `TIMER(i)` after each expiration event as described above.

8.4. Neighbor Unreachability Detection

ISATAP hosts **SHOULD** perform Neighbor Unreachability Detection (Section 7.3 of [RFC4861]). ISATAP routers **MAY** perform Neighbor Unreachability Detection, but this might not scale in all environments.

After address resolution, ISATAP hosts **SHOULD** perform an initial reachability confirmation by sending Neighbor Solicitation messages and receiving a Neighbor Advertisement message. ISATAP routers **MAY** perform this initial reachability confirmation, but this might not scale in all environments.

9. Site Administration Considerations

Site administrators maintain a Potential Router List (PRL) of IPv4 addresses representing advertising ISATAP interfaces of routers.

The PRL is commonly maintained as an FQDN for the ISATAP service in the site's name service (see Section 8.3.2). There are no mandatory rules for the selection of the FQDN, but site administrators are encouraged to use the convention "isatap.domainname" (e.g., isatap.example.com).

When the site's name service includes TTLs with the IPv4 addresses returned, site administrators **SHOULD** configure the TTLs with conservative values to minimize control traffic.

10. Security Considerations

Implementers should be aware that, in addition to possible attacks against IPv6, security attacks against IPv4 must also be considered. Use of IP security at both IPv4 and IPv6 levels should nevertheless be avoided, for efficiency reasons. For example, if IPv6 is running encrypted, encryption of IPv4 would be redundant unless traffic analysis is felt to be a threat. If IPv6 is running authenticated, then authentication of IPv4 will add little. Conversely, IPv4 security will not protect IPv6 traffic once it leaves the ISATAP domain. Therefore, implementing IPv6 security is required even if IPv4 security is available.

The threats associated with IPv6 Neighbor Discovery are described in [RFC3756].

There is a possible spoofing attack in which spurious ip-protocol-41 packets are injected into an ISATAP link from outside. Since an ISATAP link spans an entire IPv4 site, restricting access to the link can be achieved by restricting access to the site; i.e., by having site border routers implement IPv4 ingress filtering and ip-protocol-41 filtering.

Another possible spoofing attack involves spurious ip-protocol-41 packets injected from within an ISATAP link by a node pretending to be a router. The Potential Router List (PRL) provides a list of IPv4 addresses representing advertising ISATAP interfaces of routers that hosts use in filtering decisions. Site administrators should ensure that the PRL is kept up to date, and that the resolution mechanism (see Section 9) cannot be subverted.

The use of temporary addresses [RFC4941] and Cryptographically Generated Addresses [RFC3972] on ISATAP interfaces is outside the scope of this specification.

11. IANA Considerations

The IANA has specified the format for Modified EUI-64 address construction (Appendix A of [RFC4291]) in the IANA Ethernet Address Block. The text in the Appendix of this document has been offered as an example specification. The current version of the IANA registry for Ether Types can be accessed at:

<http://www.iana.org/assignments/ethernet-numbers>

12. Acknowledgments

The ideas in this document are not original, and the authors acknowledge the original architects. Portions of this work were sponsored through SRI International and Nokia and Boeing internal projects and government contracts. Government sponsors include Monica Farah Stapleton and Russell Langan (U.S. Army CECOM ASEO) and Dr. Allen Moshfegh (U.S. Office of Naval Research). SRI International sponsors include Dr. Mike Frankel, J. Peter Marcotullio, Lou Rodriguez, and Dr. Ambatipudi Sastry.

The following are acknowledged for providing peer review input: Jim Bound, Rich Draves, Cyndi Jung, Ambatipudi Sastry, Aaron Schrader, Ole Troan, and Vlad Yasevich.

The following are acknowledged for their significant contributions: Marcelo Albuquerque, Brian Carpenter, Alain Durand, Hannu Flinck, Jason Goldschmidt, Christian Huitema, Nathan Lutchansky, Karen Nielsen, Mohan Parthasarathy, Chirayu Patel, Art Shelest, Markku Savela, Pekka Savola, Margaret Wasserman, Brian Zill, and members of the IETF IPv6 and V6OPS working groups. Mohit Talwar contributed to earlier versions of this document.

The authors acknowledge the work done by Brian Carpenter and Cyndi Jung in RFC 2529 that introduced the concept of intra-site automatic tunneling. This concept was later called: "Virtual Ethernet" and researched by Quang Nguyen under the guidance of Dr. Lixia Zhang.

13. References

13.1. Normative References

- [RFC1035] Mockapetris, P., "Domain names - implementation and specification", STD 13, RFC 1035, November 1987.
- [RFC2119] Bradner, S., "Key words for use in RFCs to Indicate Requirement Levels", BCP 14, RFC 2119, March 1997.
- [RFC2131] Droms, R., "Dynamic Host Configuration Protocol", RFC 2131, March 1997.
- [RFC2132] Alexander, S. and R. Droms, "DHCP Options and BOOTP Vendor Extensions", RFC 2132, March 1997.
- [RFC2460] Deering, S. and R. Hinden, "Internet Protocol, Version 6 (IPv6) Specification", RFC 2460, December 1998.
- [RFC4861] Narten, T., Nordmark, E., Simpson, W., and H. Soliman, "Neighbor Discovery for IP version 6 (IPv6)", RFC 4861, September 2007.
- [RFC4213] Nordmark, E. and R. Gilligan, "Basic Transition Mechanisms for IPv6 Hosts and Routers", RFC 4213, October 2005.
- [RFC4291] Hinden, R. and S. Deering, "IP Version 6 Addressing Architecture", RFC 4291, February 2006.
- [RFC4862] Thomson, S., Narten, T., and T. Jinmei, "IPv6 Stateless Address Autoconfiguration", RFC 4862, September 2007.

13.2. Informative References

- [RFC2491] Armitage, G., Schulter, P., Jork, M., and G. Harter, "IPv6 over Non-Broadcast Multiple Access (NBMA) networks", RFC 2491, January 1999.
- [RFC2492] Armitage, G., Schulter, P., and M. Jork, "IPv6 over ATM Networks", RFC 2492, January 1999.
- [RFC2529] Carpenter, B. and C. Jung, "Transmission of IPv6 over IPv4 Domains without Explicit Tunnels", RFC 2529, March 1999.
- [RFC3056] Carpenter, B. and K. Moore, "Connection of IPv6 Domains via IPv4 Clouds", RFC 3056, February 2001.
- [RFC3756] Nikander, P., Ed., Kempf, J., and E. Nordmark, "IPv6 Neighbor Discovery (ND) Trust Models and Threats", RFC 3756, May 2004.
- [RFC3972] Aura, T., "Cryptographically Generated Addresses (CGA)", RFC 3972, March 2005.
- [RFC4191] Draves, R. and D. Thaler, "Default Router Preferences and More-Specific Routes", RFC 4191, November 2005.
- [RFC4294] Loughney, J., Ed., "IPv6 Node Requirements", RFC 4294, April 2006.
- [RFC4941] Narten, T., Draves, R., and S. Krishnan, "Privacy Extensions for Stateless Address Autoconfiguration in IPv6", RFC 4941, September 2007.

Appendix A. Modified EUI-64 Addresses in the IANA Ethernet Address Block

Modified EUI-64 addresses (Section 2.5.1 and Appendix A of [RFC4291]) in the IANA Ethernet Address Block are formed by concatenating the 24-bit IANA OUI (00-00-5E) with a 40-bit extension identifier and inverting the "u" bit; i.e., the "u" bit is set to one (1) to indicate universal scope and set to zero (0) to indicate local scope. Modified EUI-64 addresses have the following appearance in memory (bits transmitted right-to-left within octets, octets transmitted left-to-right):

0		23		63
	OUI		extension identifier	
000000	ug00000000	01011110	xxxxxxxxxxxx	xxxxxxxxxxxxxxxxxxxx

When the first two octets of the extension identifier encode the hexadecimal value 0xFFFE, the remainder of the extension identifier encodes a 24-bit vendor-supplied id as follows:

0		23		39		63
	OUI		0xFFFE		vendor-supplied id	
000000	ug00000000	01011110	11111111	11111110	xxxxxxxxxxxx	xxxxxxxxxxxxxxxxxxxx

When the first octet of the extension identifier encodes the hexadecimal value 0xFE, the remainder of the extension identifier encodes a 32-bit IPv4 address as follows:

0		23		31		63
	OUI		0xFE		IPv4 address	
000000	ug00000000	01011110	11111110	xxxxxxxxxxxx	xxxxxxxxxxxxxxxx	xxxxxxxxxxxxxxxx

Authors' Addresses

Fred L. Templin
Boeing Phantom Works
P.O. Box 3707 MC 7L-49
Seattle, WA 98124
USA

EMail: fred.l.templin@boeing.com

Tim Gleeson
Cisco Systems K.K.
Shinjuku Mitsui Building
2-1-1 Nishishinjuku, Shinjuku-ku
Tokyo 163-0409
Japan

EMail: tgleeson@cisco.com

Dave Thaler
Microsoft Corporation
One Microsoft Way
Redmond, WA 98052-6399
US

Phone: +1 425 703 8835
EMail: dthaler@microsoft.com

Full Copyright Statement

Copyright (C) The IETF Trust (2008).

This document is subject to the rights, licenses and restrictions contained in BCP 78 and at <http://www.rfc-editor.org/copyright.html>, and except as set forth therein, the authors retain all their rights.

This document and the information contained herein are provided on an "AS IS" basis and THE CONTRIBUTOR, THE ORGANIZATION HE/SHE REPRESENTS OR IS SPONSORED BY (IF ANY), THE INTERNET SOCIETY, THE IETF TRUST AND THE INTERNET ENGINEERING TASK FORCE DISCLAIM ALL WARRANTIES, EXPRESS OR IMPLIED, INCLUDING BUT NOT LIMITED TO ANY WARRANTY THAT THE USE OF THE INFORMATION HEREIN WILL NOT INFRINGE ANY RIGHTS OR ANY IMPLIED WARRANTIES OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE.

Intellectual Property

The IETF takes no position regarding the validity or scope of any Intellectual Property Rights or other rights that might be claimed to pertain to the implementation or use of the technology described in this document or the extent to which any license under such rights might or might not be available; nor does it represent that it has made any independent effort to identify any such rights. Information on the procedures with respect to rights in RFC documents can be found in BCP 78 and BCP 79.

Copies of IPR disclosures made to the IETF Secretariat and any assurances of licenses to be made available, or the result of an attempt made to obtain a general license or permission for the use of such proprietary rights by implementers or users of this specification can be obtained from the IETF on-line IPR repository at <http://www.ietf.org/ipr>.

The IETF invites any interested party to bring to its attention any copyrights, patents or patent applications, or other proprietary rights that may cover technology that may be required to implement this standard. Please address the information to the IETF at ietf-ipr@ietf.org.

