Network Working Group
Internet-Draft
Expires: July 31, 2005

F. Templin
Consultant
T. Gleeson
Cisco Systems K.K.
M. Talwar
D. Thaler
Microsoft Corporation

January 27, 2005

Intra-Site Automatic Tunnel Addressing Protocol (ISATAP)
draft-ietf-ngtrans-isatap-24.txt

Status of this Memo

Copyright Notice

Abstract

The Intra-Site Automatic Tunnel Addressing Protocol (ISATAP) connects IPv6 hosts/routers over IPv4 networks. ISATAP views the IPv4 network

as a link layer for IPv6 and views other nodes on the network as potential IPv6 hosts/routers. ISATAP supports an automatic tunneling abstraction similar to the Non-Broadcast Multiple Access (NBMA) model.

Table of Contents

1. Introduction

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

ISATAP enables automatic tunneling whether global or private IPv4 addresses are used, and presents a Non-Broadcast Multiple Access (NBMA) abstraction similar to [RFC2491][RFC2492][RFC2529][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 makes use of 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 to demonstrate protocol behavior. An implementation is not required to have them in the exact form described here, so long as its external behavior is consistent with that described in this document.

3. Terminology

The terminology of [RFC2460][RFC2461] applies to this document. The following additional terms are defined:

site:
   a connected, self-contained, single administrative domain network surrounded by zero or more border-filtering routers and containing interior routers and links with their attached interfaces.

ISATAP node:
   a node 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 includes an ISATAP interface identifier.

locator:
an IPv4 address-to-interface mapping, i.e., a node's IPv4 address and its associated interface.

locator set:
a set of locators associated with an ISATAP interface, where each locator in the set belongs to the same site.

4. Domain of Applicability

The domain of applicability for this technical specification is automatic tunneling of IPv6 packets in IPv4 for ISATAP nodes within sites that observe the Security Considerations found in this document, including host-to-router, router-to-host, and host-to-host automatic tunneling in certain enterprise networks and 3GPP/3GPP2 wireless operator networks. (Other scenarios with sufficient trust basis ensured by the mechanisms specified in this document also fall within this domain of applicability.)

Extensions to the above domain of applicability (e.g., by combining the mechanisms in this document with other technical specifications) are out of scope.

5. Node Requirements

ISATAP nodes observe the common functionality requirements for IPv6 nodes found in [NODEREQ] and the requirements for dual IP layer operation found in ([MECH], section 2). They also implement the additional features specified in this document.

6. Addressing Requirements

6.1 ISATAP Interface Identifiers

ISATAP interface identifiers are constructed in Modified EUI-64 format ([RFC3513], section 2.5.1 and appendix A) by concatenating the 24-bit IANA OUI (00-00-5E), the 8-bit hexadecimal value 0xFE, and a 32-bit IPv4 address in network byte order as follows:

```
|0              1|1              3|3                             6|
|0              5|6              1|2                             3|
+----------------+----------------+--------------------------------+
|000000ug00000000|0101111011111110|mmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmm|
+----------------+----------------+--------------------------------+
```

When the IPv4 address is known to be globally unique, the "u" bit (universal/local) is set to 1; otherwise, the "u" bit is set to 0. "g" is the individual/group bit, and "m" are the bits of the IPv4 address.

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 ([RFC2462], section 5.3).

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 only unicast capability in its underlying IPv4 carrier network. 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 ([MECH], section 3). The following additional specifications are

also used:

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 IPv4 ICMP Errors

ISATAP interfaces SHOULD process ARP failures and persistent ICMPv4 errors as link-specific information indicating that a path to a neighbor may have failed ([RFC2461], section 7.3.3).

7.3 Decapsulation

The specification in ([MECH], section 3.6) 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:

- the IPv6 source address is an ISATAP address that embeds the IPv4 source address in its interface identifier, or:

- 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 section 8 of this document.

8. Neighbor Discovery for ISATAP Interfaces

ISATAP interfaces use the neighbor discovery mechanisms specified in [RFC2461] and also implement the following specifications:

8.1 Conceptual Model Of A Host

To the list of Conceptual Data Structures ([RFC2461], section 5.1), ISATAP interfaces add:

Potential Router List
: 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 ([RFC2461], section 6.2.6) 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 ([RFC2461], section 6.3) is used. ISATAP interfaces add the following specifications:

8.3.1 Host Variables

To the list of host variables ([RFC2461], section 6.3.2), ISATAP interfaces add:

PrlRefreshInterval
: Time in seconds between successive refreshments of the PRL after initialization. The designated value of all 1's (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 1's (0xffffffff) represents infinity.

8.3.2 Potential Router List Initialization

ISATAP nodes initialize an ISATAP interface's PRL with IPv4 addresses discovered via manual configuration, a DNS fully-qualified domain name (FQDN) [RFC1035], a DHCPv4 option, a DHCPv4 vendor-specific option, or an unspecified alternate method. FQDNs are established via manual configuration 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 an unspecified alternate method.

After initializing an ISATAP interface's PRL, if the PRL is empty the node SHOULD disable the interface. Otherwise, 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 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 ([RFC2461], section 6.1.1), ISATAP interfaces add:

- 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 ([RFC2461], section 6.3.4).

8.3.4 Sending Router Solicitations

To the list of events after which Router Solicitation messages may be sent ([RFC2461], section 6.3.7), ISATAP interfaces add:

- 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) such 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 [DEFLT]. 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 ([RFC2461], section 6.3.7) 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

Hosts SHOULD perform Neighbor Unreachability Detection ([RFC2461], section 7.3). Routers MAY perform neighbor unreachability detection, but this might not scale in all environments.

After address resolution, hosts SHOULD perform an initial reachability confirmation by sending Neighbor Solicitation message(s) and receiving a Neighbor Advertisement message. 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. Summary of Impact on Routing

As stated in Section 4, this document focuses on connectivity to hosts. Router-to-router protocols which rely on the use of multicast will not work over an ISATAP link, but this is not required for ISATAP's domain of applicability. For router-to-host communication, the impact on Neighbor Discovery/Router Discovery is covered in Section 8.

Finally, there is no impact on existing routing protocols outside of the ISATAP link, as any arbitrary prefix can be used, as with most other link-layer protocols.

11. Security considerations

Implementors 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 except if 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.

There is a possible spoofing attack in which an attacker outside the IPv4 site spoofs an IPv6 source address which appears to be an on-link ISATAP address, and encapsulates it to an ISATAP node. 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. ISATAP SHOULD NOT be used when the PRL is empty (see: section 8.3.2).

ISATAP has unique characteristics that do not exist in other tunneling solutions such as 6to4 [RFC3056] and result in avoiding most security issues that exist in those protocols. Unlike such protocols, ISATAP is only to be used within a site with border routers which filter ip-protocol-41 packets, as noted above. This reduces the scope of spoofing attacks to other attackers inside the site. Also unlike such protocols, ISATAP will not accept packets from arbitrary routers, only from routers in the Potential Router List it knows, as noted above. This avoids spoofing attacks that would otherwise be possible by an attacker pretending to be a router, but relies on the security of the PRL resolution method used. Together, these characteristics mean that spoofing an IPv6 source address requires either spoofing the IPv4 address embedded in an ISATAP address, or spoofing an IPv4 address in the PRL. This is

hence no worse than IPv4 without ISATAP in this respect.

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

The use of temporary addresses [RFC3041] and Cryptographically Generated Addresses [CGA] on ISATAP interfaces is outside the scope of this specification.

12. IANA Considerations

The IANA is requested to specify the format for Modified EUI-64 address construction ([RFC3513], Appendix A) in the IANA Ethernet Address Block. The text in Appendix B of this document is 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

13. Acknowledgments

The ideas in this document are not original, and the authors acknowledge the original architects. Portions of this work were sponsored through U.S. government contracts and internal projects at SRI International and Nokia. 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, Vlad Yasevich.

The following are acknowledged for their significant contributions: Alain Durand, Hannu Flinck, Jason Goldschmidt, Nathan Lutchansky, Karen Nielsen, Mohan Parthasarathy, Chirayu Patel, Art Shelest, Markku Savela, Pekka Savola, Margaret Wasserman, Brian Zill.

The authors acknowledge the work of Quang Nguyen on "Virtual Ethernet" under the guidance of Dr. Lixia Zhang that proposed very similar ideas to those that appear in this document. This work was first brought to the authors' attention on September 20, 2002.

14. References

14.1 Normative References

[MECH] Gilligan, R. and E. Nordmark, "Basic Transition Mechanisms for IPv6 Hosts and Routers", Internet-Draft draft-ietf-v6ops-mech-v2-00, February 2003.

[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.

[RFC2434] Narten, T. and H. Alvestrand, "Guidelines for Writing an IANA Considerations Section in RFCs", BCP 26, RFC 2434, October 1998.

[RFC2460] Deering, S. and R. Hinden, "Internet Protocol, Version 6 (IPv6) Specification", RFC 2460, December 1998.

[RFC2461] Narten, T., Nordmark, E. and W. Simpson, "Neighbor Discovery for IP Version 6 (IPv6)", RFC 2461, December 1998.

[RFC2462] Thomson, S. and T. Narten, "IPv6 Stateless Address Autoconfiguration", RFC 2462, December 1998.

[RFC3513] Hinden, R. and S. Deering, "Internet Protocol Version 6 (IPv6) Addressing Architecture", RFC 3513, April 2003.

14.2 Informative References

[CGA] Aura, T., "Cryptographically Generated Addresses (CGA)", Internet-Draft draft-ietf-send-cga, April 2004.

[DEFLT] Draves, R. and D. Thaler, "Default Router Preferences and More-Specific Routes", Internet-Draft draft-ietf-ipv6-router-selection-06.txt, October 2003.

[NODEREQ] Loughney, J., "IPv6 Node Requirements", Internet-Draft draft-ietf-ipv6-node-requirements, August 2004.

[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.

[RFC3041] Narten, T. and R. Draves, "Privacy Extensions for Stateless Address Autoconfiguration in IPv6", RFC 3041, January 2001.

[RFC3056] Carpenter, B. and K. Moore, "Connection of IPv6 Domains via IPv4 Clouds", RFC 3056, February 2001.

[RFC3756] Nikander, P., Kempf, J. and E. Nordmark, "IPv6 Neighbor Discovery (ND) Trust Models and Threats", RFC 3756, May 2004.

Authors' Addresses

Fred L. Templin
Consultant

Email: fltemplin@acm.org

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

Email: tgleeson@cisco.com

Mohit Talwar
Microsoft Corporation
One Microsoft Way
Redmond, WA> 98052-6399
US

Phone: +1 425 705 3131
Email: mohitt@microsoft.com

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

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

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

Modified EUI-64 addresses ([RFC3513], section 2.5.1 and Appendix A) 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 it is 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         |
000000ug00000000 01011110xxxxxxxx xxxxxxxxxxxxxxxx xxxxxxxxxxxxxxxx
```

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   |
000000ug00000000 0101111011111111 11111110xxxxxxxx xxxxxxxxxxxxxxxx
```

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          |
000000ug00000000 0101111011111110 xxxxxxxxxxxxxxxx xxxxxxxxxxxxxxxx
```

Appendix B. Changes since -22

NOTE: This section to be removed before publication as an RFC.

- added definition for the term "site"
- added new section on summary of impact on routing
- added 6to4 comparision paragraph in Security Considerations
- clarified security considerations statement on possible spoofing attacks from a node outside the site
- added "ISATAP SHOULD NOT be used when the PRL is empty" to section 8.3.2 and security considerations
- mentioned Nokia internal project work under acknowledgements

Intellectual Property Statement

Disclaimer of Validity

Copyright Statement

Acknowledgment

Funding for the RFC Editor function is currently provided by the Internet Society.