Network Working Group
Request for Comments: 3024
Obsoletes: 2344
Category: Standards Track

G. Montenegro, Editor
Sun Microsystems, Inc.

January 2001

Reverse Tunneling for Mobile IP, revised

Status of this Memo

Copyright Notice

Abstract

Mobile Internet Protocol (IP) uses tunneling from the home agent to the mobile node's care-of address, but rarely in the reverse direction. Usually, a mobile node sends its packets through a router on the foreign network, and assumes that routing is independent of source address. When this assumption is not true, it is convenient to establish a topologically correct reverse tunnel from the care-of address to the home agent.

This document proposes backwards-compatible extensions to Mobile IP to support topologically correct reverse tunnels. This document does not attempt to solve the problems posed by firewalls located between the home agent and the mobile node's care-of address.

This document obsoletes RFC 2344.

Table of Contents

1. Introduction

Section 1.3 of the Mobile IP specification [1] lists the following assumption:

> It is assumed that IP unicast datagrams are routed based on the destination address in the datagram header (i.e., not by source address).

Because of security concerns (for example, IP spoofing attacks), and in accordance with RFC 2267 [8] and CERT [3] advisories to this effect, routers that break this assumption are increasingly more common.

In the presence of such routers, the source and destination IP address in a packet must be topologically correct. The forward tunnel complies with this, as its endpoints (home agent address and care-of address) are properly assigned addresses for their respective locations. On the other hand, the source IP address of a packet transmitted by the mobile node does not correspond to the network prefix from where it emanates.

This document discusses topologically correct reverse tunnels.

Mobile IP does dictate the use of reverse tunnels in the context of multicast datagram routing and mobile routers. However, the source IP address is set to the mobile node’s home address, so these tunnels are not topologically correct.

Notice that there are several uses for reverse tunnels regardless of their topological correctness:

- Mobile routers: reverse tunnels obviate the need for recursive tunneling [1].

- Multicast: reverse tunnels enable a mobile node away from home to (1) join multicast groups in its home network, and (2) transmit multicast packets such that they emanate from its home network [1].

- The TTL of packets sent by the mobile node (for example, when sending packets to other hosts in its home network) may be so low that they might expire before reaching their destination. A reverse tunnel solves the problem as it represents a TTL decrement of one [5].

1.1. Terminology

The discussion below uses terms defined in the Mobile IP specification. Additionally, it uses the following terms:

Forward Tunnel

A tunnel that shuttles packets towards the mobile node. It starts at the home agent, and ends at the mobile node's care-of address.

Reverse Tunnel

A tunnel that starts at the mobile node's care-of address and terminates at the home agent.

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in RFC 2119 [9].

1.2. Assumptions

Mobility is constrained to a common IP address space (that is, the routing fabric between, say, the mobile node and the home agent is not partitioned into a "private" and a "public" network).

This document does not attempt to solve the firewall traversal problem. Rather, it assumes one of the following is true:

- There are no intervening firewalls along the path of the tunneled packets.

- Any intervening firewalls share the security association necessary to process any authentication [6] or encryption [7] headers which may have been added to the tunneled packets.

The reverse tunnels considered here are symmetric, that is, they use the same configuration (encapsulation method, IP address endpoints) as the forward tunnel. IP in IP encapsulation [2] is assumed unless stated otherwise.

Route optimization [4] introduces forward tunnels initiated at a correspondent host. Since a mobile node may not know if the correspondent host can decapsulate packets, reverse tunnels in that context are not discussed here.

1.3. Justification

Why not let the mobile node itself initiate the tunnel to the home agent? This is indeed what it should do if it is already operating with a topologically correct co-located care-of address.

However, one of the primary objectives of the Mobile IP specification is not to require this mode of operation.

The mechanisms outlined in this document are primarily intended for use by mobile nodes that rely on the foreign agent for forward tunnel support. It is desirable to continue supporting these mobile nodes, even in the presence of filtering routers.

2. Overview

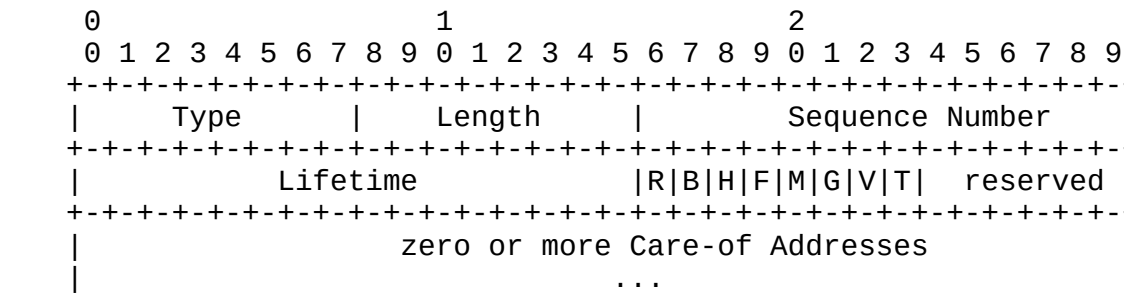
A mobile node arrives at a foreign network, listens for agent advertisements and selects a foreign agent that supports reverse tunnels. It requests this service when it registers through the selected foreign agent. At this time, and depending on how the mobile node wishes to deliver packets to the foreign agent, it also requests either the Direct or the Encapsulating Delivery Style (section 5).

In the Direct Delivery Style, the mobile node designates the foreign agent as its default router and proceeds to send packets directly to the foreign agent, that is, without encapsulation. The foreign agent intercepts them, and tunnels them to the home agent.

In the Encapsulating Delivery Style, the mobile node encapsulates all its outgoing packets to the foreign agent. The foreign agent decapsulates and re-tunnels them to the home agent, using the foreign agent’s care-of address as the entry-point of this new tunnel.

3. New Packet Formats

3.1. Mobility Agent Advertisement Extension



The only change to the Mobility Agent Advertisement Extension [1] is the additional 'T' bit:

T Agent offers reverse tunneling service.

A foreign agent that sets the 'T' bit MUST support the Direct Delivery Style. Encapsulating Delivery Style SHOULD be supported as well (section 5).

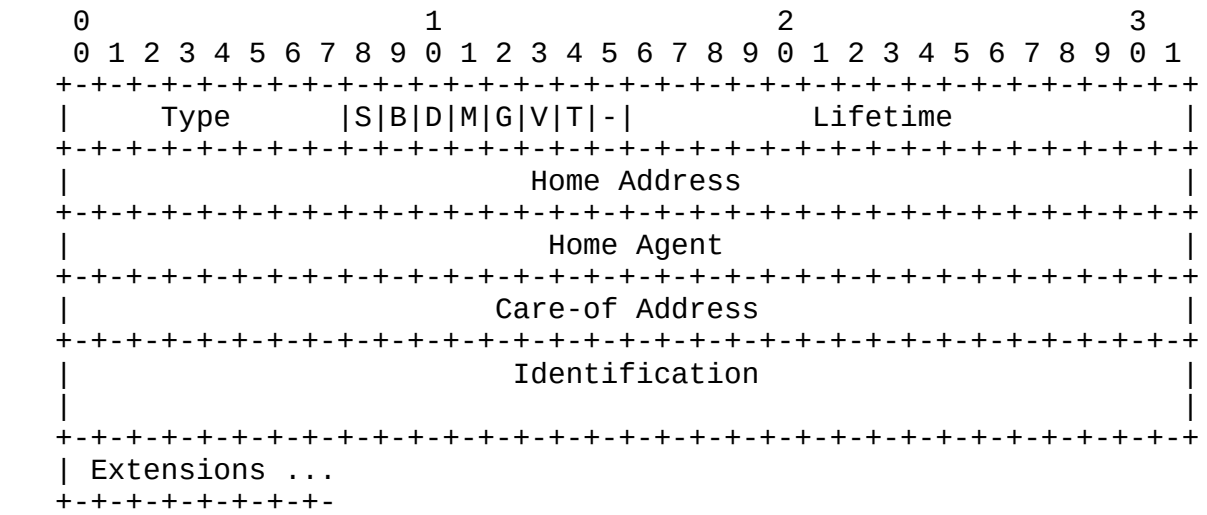
Using this information, a mobile node is able to choose a foreign agent that supports reverse tunnels. Notice that if a mobile node does not understand this bit, it simply ignores it as per [1].

3.2. Registration Request

Reverse tunneling support is added directly into the Registration Request by using one of the "rsvd" bits. If a foreign or home agent that does not support reverse tunnels receives a request with the 'T' bit set, the Registration Request fails. This results in a registration denial (failure codes are specified in section 3.4).

Home agents SHOULD NOT object to providing reverse tunnel support, because they "SHOULD be able to decapsulate and further deliver packets addressed to themselves, sent by a mobile node" [1]. In the case of topologically correct reverse tunnels, the packets are not sent by the mobile node as distinguished by its home address. Rather, the outermost (encapsulating) IP source address on such datagrams is the care-of address of the mobile node.

In Registration Requests sent by a mobile node, the Time to Live field in the IP header MUST be set to 255. This limits a denial of service attack in which malicious hosts send false Registration Requests (see Section 6).



The only change to the Registration Request packet is the additional 'T' bit:

T If the 'T' bit is set, the mobile node asks its home agent to accept a reverse tunnel from the care-of address. Mobile nodes using a foreign agent care-of address ask the foreign agent to reverse-tunnel its packets.

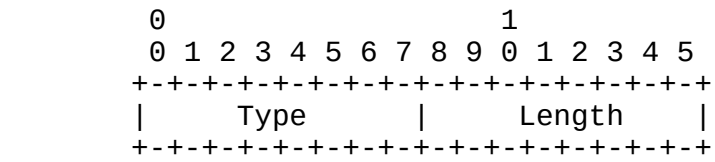
3.3. Encapsulating Delivery Style Extension

The Encapsulating Delivery Style Extension MAY be included by the mobile node in registration requests to further specify reverse tunneling behavior. It is expected to be used only by the foreign agent. Accordingly, the foreign agent MUST consume this extension (that is, it must not relay it to the home agent or include it in replies to the mobile node). As per Section 3.6.1.3 of [1], the mobile node MUST include the Encapsulating Delivery Style Extension after the Mobile-Home Authentication Extension, and before the Mobile-Foreign Authentication Extension, if present.

The Encapsulating Delivery Style Extension MUST NOT be included if the 'T' bit is not set in the Registration Request.

If this extension is absent, Direct Delivery is assumed. Encapsulation is done according to what was negotiated for the forward tunnel (that is, IP in IP is assumed unless specified otherwise). For more details on the delivery styles, please refer to section 5.

Foreign agents SHOULD support the Encapsulating Delivery Style Extension.



Type

130

Length

0

3.4. New Registration Reply Codes

Foreign and home agent registration replies MUST convey if the reverse tunnel request failed. These new reply codes are defined:

Service denied by the foreign agent:

74 requested reverse tunnel unavailable
75 reverse tunnel is mandatory and 'T' bit not set
76 mobile node too distant
79 delivery style not supported

NOTE: Code 79 has not yet been assigned by IANA.

and

Service denied by the home agent:

137 requested reverse tunnel unavailable
138 reverse tunnel is mandatory and 'T' bit not set
139 requested encapsulation unavailable

In response to a Registration Request with the 'T' bit set, mobile nodes may receive (and MUST accept) code 70 (poorly formed request) from foreign agents and code 134 (poorly formed request) from home agents. However, foreign and home agents that support reverse tunneling MUST use codes 74 and 137, respectively.

In addition to setting the 'T' bit, the mobile node also MAY request the Encapsulating Delivery Style by including the corresponding extension. If a foreign agent does not implement the Encapsulating

Delivery Style, it MUST respond to the mobile node with code 79 (delivery style not supported). This also applies if the foreign agent does not support a requested delivery style that may be defined in the future.

Absence of the 'T' bit in a Registration Request MAY elicit denials with codes 75 and 138 at the foreign agent and the home agent, respectively.

Forward and reverse tunnels are symmetric, that is, both are able to use the same tunneling options negotiated at registration. This implies that the home agent MUST deny registrations if an unsupported form of tunneling is requested (code 139). Notice that Mobile IP [1] already defines the analogous failure code 72 for use by the foreign agent.

4. Changes in Protocol Behavior

Unless otherwise specified, behavior specified by Mobile IP [1] is assumed. In particular, if any two entities share a mobility security association, they MUST use the appropriate Authentication Extension (Mobile-Foreign, Foreign-Home or Mobile-Home Authentication Extension) when exchanging registration protocol datagrams. An admissible authentication extension (for example the Mobile-Home Authentication Extension) MUST always be present to authenticate registration messages between a mobile node and its home agent.

Reverse tunneling imposes additional protocol processing requirements on mobile entities. Differences in protocol behavior with respect to Mobile IP [1] are specified in the subsequent sections.

4.1. Mobile Node Considerations

This section describes how the mobile node handles registrations that request a reverse tunnel.

4.1.1. Sending Registration Requests to the Foreign Agent

In addition to the considerations in [1], a mobile node sets the 'T' bit in its Registration Request to petition a reverse tunnel.

The mobile node MUST set the TTL field of the IP header to 255. This is meant to limit the reverse tunnel hijacking attack (Section 6).

The mobile node MAY optionally include an Encapsulating Delivery Style Extension.

4.1.2. Receiving Registration Replies from the Foreign Agent

Possible valid responses are:

- A registration denial issued by either the home agent or the foreign agent:

  a. The mobile node follows the error checking guidelines in [1], and depending on the reply code, MAY try modifying the registration request (for example, by eliminating the request for alternate forms of encapsulation or delivery style), and issuing a new registration.

  b. Depending on the reply code, the mobile node MAY try zeroing the 'T' bit, eliminating the Encapsulating Delivery Style Extension (if one was present), and issuing a new registration. Notice that after doing so the registration may succeed, but due to the lack of a reverse tunnel data transfer may not be possible.

- The home agent returns a Registration Reply indicating that the service will be provided.

In this last case, the mobile node has succeeded in establishing a reverse tunnel between its care-of address and its home agent. If the mobile node is operating with a co-located care-of address, it MAY encapsulate outgoing data such that the destination address of the outer header is the home agent. This ability to selectively reverse-tunnel packets is discussed further in section 5.4.

If the care-of address belongs to a separate foreign agent, the mobile node MUST employ whatever delivery style was requested (Direct or Encapsulating) and proceed as specified in section 5.

A successful registration reply is an assurance that both the foreign agent and the home agent support whatever alternate forms of encapsulation (other than IP in IP) were requested. Accordingly, the mobile node MAY use them at its discretion.

4.2. Foreign Agent Considerations

This section describes how the foreign agent handles registrations that request a reverse tunnel.

4.2.1. Receiving Registration Requests from the Mobile Node

A foreign agent that receives a Registration Request with the 'T' bit set processes the packet as specified in the Mobile IP specification [1], and determines whether it can accommodate the forward tunnel request. If it cannot, it returns an appropriate code. In particular, if the foreign agent is unable to support the requested form of encapsulation it MUST return code 72. If it cannot support the requested form of delivery style it MUST return code 79 (delivery style not supported).

The foreign agent MAY reject Registration Requests without the 'T' bit set by denying them with code 75 (reverse tunnel is mandatory and 'T' bit not set).

The foreign agent MUST verify that the TTL field of the IP header is set to 255. Otherwise, it MUST reject the registration with code 76 (mobile node too distant). The foreign agent MUST limit the rate at which it sends these registration replies to a maximum of one per second.

As a last check, the foreign agent verifies that it can support a reverse tunnel with the same configuration. If it cannot, it MUST return a Registration Reply denying the request with code 74 (requested reverse tunnel unavailable).

4.2.2. Relaying Registration Requests to the Home Agent

Otherwise, the foreign agent MUST relay the Registration Request to the home agent.

Upon receipt of a Registration Reply that satisfies validity checks, the foreign agent MUST update its visitor list, including indication that this mobile node has been granted a reverse tunnel and the delivery style expected (section 5).

While this visitor list entry is in effect, the foreign agent MUST process incoming traffic according to the delivery style, encapsulate it and tunnel it from the care-of address to the home agent's address.

4.3. Home Agent Considerations

This section describes how the home agent handles registrations that request a reverse tunnel.

4.3.1. Receiving Registration Requests from the Foreign Agent

A home agent that receives a Registration Request with the 'T' bit set processes the packet as specified in the Mobile IP specification [1] and determines whether it can accommodate the forward tunnel request. If it cannot, it returns an appropriate code. In particular, if the home agent is unable to support the requested form of encapsulation it MUST return code 139 (requested encapsulation unavailable).

The home agent MAY reject registration requests without the 'T' bit set by denying them with code 138 (reverse tunnel is mandatory and 'T' bit not set).

As a last check, the home agent determines whether it can support a reverse tunnel with the same configuration as the forward tunnel. If it cannot, it MUST send back a registration denial with code 137 (requested reverse tunnel unavailable).

Upon receipt of a Registration Reply that satisfies validity checks, the home agent MUST update its mobility bindings list to indicate that this mobile node has been granted a reverse tunnel and the type of encapsulation expected.

4.3.2. Sending Registration Replies to the Foreign Agent

In response to a valid Registration Request, a home agent MUST issue a Registration Reply to the mobile node.

After a successful registration, the home agent may receive encapsulated packets addressed to itself. Decapsulating such packets and blindly injecting them into the network is a potential security weakness (section 6.1). Accordingly, the home agent MUST implement, and, by default, SHOULD enable the following check for encapsulated packets addressed to itself:

> The home agent searches for a mobility binding whose care-of address is the source of the outer header, and whose mobile node address is the source of the inner header.

If no such binding is found, or if the packet uses an encapsulation mechanism that was not negotiated at registration the home agent MUST silently discard the packet and SHOULD log the event as a security exception.

Home agents that terminate tunnels unrelated to Mobile IP (for example, multicast tunnels) MAY turn off the above check, but this practice is discouraged for the aforementioned reasons.

While the registration is in effect, a home agent MUST process each valid reverse tunneled packet (as determined by checks like the above) by decapsulating it, recovering the original packet, and then forwarding it on behalf of its sender (the mobile node) to the destination address (the correspondent host).

5. Mobile Node to Foreign Agent Delivery Styles

This section specifies how the mobile node sends its data traffic via the foreign agent. In all cases, the mobile node learns the foreign agent's link-layer address from the link-layer header in the agent advertisement.

5.1. Direct Delivery Style

This delivery mechanism is very simple to implement at the mobile node, and uses small (non-encapsulated) packets on the link between the mobile node and the foreign agent (potentially a very slow link). However, it only supports reverse-tunneling of unicast packets, and does not allow selective reverse tunneling (section 5.4).

5.1.1. Packet Processing

The mobile node MUST designate the foreign agent as its default router. Not doing so will not guarantee encapsulation of all the mobile node's outgoing traffic, and defeats the purpose of the reverse tunnel. The foreign agent MUST:

- detect packets sent by the mobile node, and
- modify its forwarding function to encapsulate them before forwarding.

5.1.2. Packet Header Format and Fields

This section shows the format of the packet headers used by the Direct Delivery style. The formats shown assume IP in IP encapsulation [2].

Packet format received by the foreign agent (Direct Delivery Style):

```
IP fields:
  Source Address = mobile node's home address
  Destination Address = correspondent host's address
Upper Layer Protocol
```

Packet format forwarded by the foreign agent (Direct Delivery Style):

```
IP fields (encapsulating header):
  Source Address = foreign agent's care-of address
  Destination Address = home agent's address
  Protocol field: 4 (IP in IP)
IP fields (original header):
  Source Address = mobile node's home address
  Destination Address = correspondent host's address
Upper Layer Protocol
```

These fields of the encapsulating header MUST be chosen as follows:

IP Source Address

Copied from the Care-of Address field within the Registration Request.

IP Destination Address

Copied from the Home Agent field within the most recent successful Registration Reply.

IP Protocol Field

Default is 4 (IP in IP [2]), but other methods of encapsulation MAY be used as negotiated at registration time.

5.2. Encapsulating Delivery Style

This mechanism requires that the mobile node implement encapsulation, and explicitly directs packets at the foreign agent by designating it as the destination address in a new outermost header. Mobile nodes that wish to send either broadcast or multicast packets MUST use the Encapsulating Delivery Style.

5.2.1 Packet Processing

The foreign agent does not modify its forwarding function. Rather, it receives an encapsulated packet and after verifying that it was sent by the mobile node, it:

- decapsulates to recover the inner packet,

- re-encapsulates, and sends it to the home agent.

If a foreign agent receives an un-encapsulated packet from a mobile node which had explicitly requested the Encapsulated Delivery Style, then the foreign agent MUST NOT reverse tunnel such a packet and rather MUST forward it using standard, IP routing mechanisms.

5.2.2. Packet Header Format and Fields

This section shows the format of the packet headers used by the Encapsulating Delivery style. The formats shown assume IP in IP encapsulation [2].

Packet format received by the foreign agent (Encapsulating Delivery Style):

```
IP fields (encapsulating header):
  Source Address = mobile node's home address
  Destination Address = foreign agent's address
  Protocol field: 4 (IP in IP)
IP fields (original header):
  Source Address = mobile node's home address
  Destination Address = correspondent host's address
Upper Layer Protocol
```

The fields of the encapsulating IP header MUST be chosen as follows:

IP Source Address

The mobile node's home address.

IP Destination Address

The address of the agent as learned from the IP source address of the agent's most recent successful registration reply.

IP Protocol Field

Default is 4 (IP in IP [2]), but other methods of encapsulation MAY be used as negotiated at registration time.

Packet format forwarded by the foreign agent (Encapsulating Delivery Style):

```
IP fields (encapsulating header):
  Source Address = foreign agent's care-of address
  Destination Address = home agent's address
  Protocol field: 4 (IP in IP)
IP fields (original header):
  Source Address = mobile node's home address
  Destination Address = correspondent host's address
Upper Layer Protocol
```

These fields of the encapsulating IP header MUST be chosen as follows:

IP Source Address

Copied from the Care-of Address field within the Registration Request.

IP Destination Address

Copied from the Home Agent field within the most recent successful Registration Reply.

IP Protocol Field

Default is 4 (IP in IP [2]), but other methods of encapsulation MAY be used as negotiated at registration time.

5.3. Support for Broadcast and Multicast Datagrams

If a mobile node is operating with a co-located care-of address, broadcast and multicast datagrams are handled according to Sections 4.3 and 4.4 of the Mobile IP specification [1]. Mobile nodes using a foreign agent care-of address MAY have their broadcast and multicast datagrams reverse-tunneled by the foreign agent. However, any mobile nodes doing so MUST use the encapsulating delivery style.

This delivers the datagram only to the foreign agent. The latter decapsulates it and then processes it as any other packet from the mobile node, namely, by reverse tunneling it to the home agent.

5.4. Selective Reverse Tunneling

Packets destined to local resources (for example, a nearby printer) might be unaffected by ingress filtering. A mobile node with a co-located care-of address MAY optimize delivery of these packets by not reverse tunneling them. On the other hand, a mobile node using a foreign agent care-of address MAY use this selective reverse tunneling capability by requesting the Encapsulating Delivery Style, and following these guidelines:

Packets NOT meant to be reversed tunneled:

Sent using the Direct Delivery style. The foreign agent MUST process these packets as regular traffic: they MAY be forwarded but MUST NOT be reverse tunneled to the home agent.

Packets meant to be reverse tunneled:

Sent using the Encapsulating Delivery style. The foreign agent MUST process these packets as specified in section 5.2: they MUST be reverse tunneled to the home agent.

6. Security Considerations

The extensions outlined in this document are subject to the security considerations outlined in the Mobile IP specification [1]. Essentially, creation of both forward and reverse tunnels involves an authentication procedure, which reduces the risk for attack.

6.1. Reverse-tunnel Hijacking and Denial-of-Service Attacks

Once the tunnel is set up, a malicious node could hijack it to inject packets into the network. Reverse tunnels might exacerbate this problem, because upon reaching the tunnel exit point packets are forwarded beyond the local network. This concern is also present in the Mobile IP specification, as it already dictates the use of reverse tunnels for certain applications.

Unauthenticated exchanges involving the foreign agent allow a malicious node to pose as a valid mobile node and re-direct an existing reverse tunnel to another home agent, perhaps another malicious node. The best way to protect against these attacks is by employing the Mobile-Foreign and Foreign-Home Authentication Extensions defined in [1].

If the necessary mobility security associations are not available, this document introduces a mechanism to reduce the range and effectiveness of the attacks. The mobile node MUST set to 255 the TTL value in the IP headers of Registration Requests sent to the foreign agent. This prevents malicious nodes more than one hop away from posing as valid mobile nodes. Additional codes for use in registration denials make those attacks that do occur easier to track.

With the goal of further reducing the attacks the Mobile IP Working Group considered other mechanisms involving the use of unauthenticated state. However, these introduce the possibilities of denial-of-service attacks. The consensus was that this was too much of a trade-off for mechanisms that guarantee no more than weak (non-cryptographic) protection against attacks.

6.2. Ingress Filtering

There has been some concern regarding the long-term effectiveness of reverse-tunneling in the presence of ingress filtering. The conjecture is that network administrators will target reverse-tunneled packets (IP in IP encapsulated packets) for filtering. The ingress filtering recommendation spells out why this is not the case [8]:

> Tracking the source of an attack is simplified when the source is more likely to be "valid."

6.3. Reverse Tunneling for Disparate Address Spaces

There are security implications involved with the foreign agent's using link-layer information to select the proper reverse tunnel for mobile node packets (section A.3). Unauthenticated link-layers allow a malicious mobile node to misuse another's existing reverse tunnel, and inject packets into the network.

For this solution to be viable, the link-layer MUST securely authenticate traffic received by the foreign agent from the mobile nodes. Unauthenticated link-layer technologies (for example shared ethernet) are not recommended to implement disparate address support.

7. IANA Considerations

The Encapsulating Delivery Style extension defined in section 3.3 is a Mobile IP registration extension as defined in [1]. IANA assigned the value of 130 for this purpose at the time of the publication of RFC 2344.

The Code values defined in section 3.4 are error codes as defined in [1]. They correspond to error values associated with rejection by the home and foreign agents. At the time of the publication of RFC 2344, IANA assigned codes 74-76 for the foreign agent rejections and codes 137-139 for the home agent rejections. The code for 'delivery style not supported' has been assigned a value of 79 by the IANA for this purpose.

8. Acknowledgements

The encapsulating style of delivery was proposed by Charlie Perkins. Jim Solomon has been instrumental in shaping this document into its present form. Thanks to Samita Chakrabarti for helpful comments on disparate address space support, and for most of the text in section A.4.

References

[1] Perkins, C., "IP Mobility Support", RFC 2002, October 1996.

[2] Perkins, C., "IP Encapsulation within IP", RFC 2003, October 1996.

[3] Computer Emergency Response Team (CERT), "IP Spoofing Attacks and Hijacked Terminal Connections", CA-95:01, January 1995. Available via anonymous ftp from info.cert.org in /pub/cert_advisories.

[4] Perkins, C. and D. Johnson, "Route Optimization in Mobile IP", Work in Progress.

[5] Manuel Rodriguez, private communication, August 1995.

[6] Kent, S. and R. Atkinson, "IP Authentication Header", RFC 2402, November 1998.

[7] Kent, S. and R. Atkinson, "IP Encapsulating Payload", RFC 2406, November 1998.

[8] Ferguson, P. and D. Senie, "Network Ingress Filtering: Defeating Denial of Service Attacks which employ IP Source Address Spoofing", RFC 2267, January 1998.

[9] Bradner, S., "Key words for use in RFCs to Indicate Requirement Levels", BCP 14, RFC 2119, March 1997.

[10] Farinacci, D., Li, T., Hanks, S., Meyer, D. and P. Traina, "Generic Routing Encapsulation (GRE)", RFC 2784, March 2000.

[11] Aboba, B. and M. Beadles, "The Network Access Identifier", RFC 2486, January 1999.

[12] Rekhter, Y., Moskowitz, B., Karrenberg, D., de Groot, G.J. and E. Lear, "Address Allocation for Private Internets", BCP 5, RFC 1918, February 1996.

[13] Dommety, G., "Key and Sequence Number Extensions to GRE", RFC 2890, August 2000.

Editor and Chair Addresses

Questions about this document may be directed at:

Gabriel E. Montenegro
Sun Microsystems
Laboratories, Europe
29, chemin du Vieux Chene
38240 Meylan
FRANCE

Phone: +33 476 18 80 45
EMail: gab@sun.com

The working group can be contacted via the current chairs:

Basavaraj Patil
Nokia Networks
6000 Connection Drive
Irving, TX 75039
USA

Phone: +1 972-894-6709
Fax : +1 972-894-5349
EMail: Raj.Patil@nokia.com

Phil Roberts
Motorola
1501 West Shure Drive
Arlington Heights, IL 60004
USA

Phone: +1 847-632-3148
EMail: QA3445@email.mot.com

Appendix A: Disparate Address Space Support

Mobile IP [1] assumes that all the entities involved (mobile node, foreign agent and home agent) have addresses within the same globally routable address space. In many deployment scenarios, when a mobile node leaves its home network it may wander into a region where its home address is not routable or known by the local routing fabric. Similarly, the IP addresses of the foreign agent and the home agent may belong to disparate address spaces, which precludes their exchanging registration protocol messages directly. These issues are possible particularly if the entities involved use addresses from the ranges specified in RFC1918 [12] to support private networks.

Accurately speaking, the use of private addresses is not the only cause. It may, in fact, be the most common, but the root of the problem lies in the use of disparate address spaces. For example, corporations often have several properly allocated address ranges. They typically advertise reachability to only a subset of those ranges, leaving the others for use exclusively within the corporate network. Since these ranges are not routable in the general Internet, their use leads to the same problems encountered with "private" addresses, even though they are not taken from the ranges specified in RFC1918.

Even if the mobile node, home agent and foreign agent all reside within the same address space, problems may arise if the correspondent node does not. However, this problem is not specific to Mobile IP, and is beyond the scope of this document. The next section limits even further the scope of the issues relevant to this document. A subsequent section explains how reverse tunneling may be used to tackle them.

A.1. Scope of the Reverse Tunneling Solution

Reverse tunneling (as defined in this document) may be used to cope with disparate address spaces, within the following constraints:

- There are no provisions to solve the case in which the correspondent node and the mobile node are in disparate address spaces. This limits the scope of the problem to only those issues specific to Mobile IP.

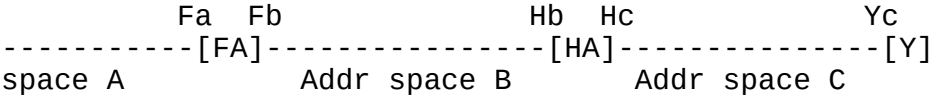
- The foreign agent and the home agent are directly reachable to each other by virtue of residing in the same address space. This limits the scope of the problem to only the simplest of cases. This also implies that the registration

protocol itself has a direct path between the foreign agent and the home agent, and, in this respect, is not affected by disparate address spaces. This restriction also applies to mobile nodes operating with a co-located care-of address. In this case, reverse tunneling is a complete and elegant solution.

- There are no additional protocol elements beyond those defined by Mobile IP [1] and reverse tunneling. In particular, additional extensions to the registration requests or replies, or additional bits in the header--although potentially useful--are outside the scope of this document.

In spite of the limitations, reverse tunneling may be used to solve the most common issues. The range of problems that can be solved are best understood by looking at some simple diagrams:

Figure A1: NON-ROUTABLE PACKETS IN DISPARATE ADDRESS SPACES



In this diagram, there are three disparate address spaces: A, B and C. The home agent (HA) has one address each on address spaces B and C, and the foreign agent (FA), on address spaces A and B. The mobile node’s (MN) has a permanent address, Mc, within address space C.

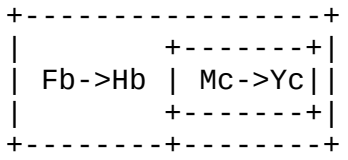
In the most common scenario both A and C are "private" address spaces, and B is the public Internet.

Suppose MN sends a packet to correspondent node (Y) in its home network. Presumably, MN has no difficulties delivering this packet to the FA, because it does so using layer 2 mechanisms. Somehow, the FA must realize that this packet must be reverse tunneled, and it must fetch the proper binding to do so. Possible mechanisms are outlined in section A.3.

However, once the packet is in address space B it becomes non-routable. Note that ingress filtering only exacerbates the problem, because it adds a requirement of topological significance to the source IP address in addition to the that of the destination address. As Mobile IP matures, others entities may be defined (for example, AAA servers). Their addition places even more requirements on the address spaces in use.

Reverse tunneling adds a topologically significant IP header to the packet (source IP address of Fb, destination of Hb) during its transit within address space B. Assuming IP in IP encapsulation (although others, like GRE are also possible), this is what the packet looks like:

Figure A2: IP IN IP REVERSE TUNNELED PACKET FROM FA TO HA



HA receives this packet, recovers the original packet, and since it is cognizant of address space C, delivers it to the appropriate interface.

Of course, for this to happen, the care-of address registered by the MN is not the usual Fa, but Fb. How this happens is outside the scope of this document. Some possible mechanisms are:

- FA recognizes mobile nodes whose addresses fall within the private address ranges specified by RFC1918. In this case, the foreign agent could force the use of Fb as the care-of address, perhaps by rejecting the initial registration request with an appropriate error message and supplemental information.

- FA could be configured to always advertise Fb as long as H->Fb and Fb->H are guaranteed to be valid forward and reverse tunnels, respectively, for all values of H. Here, H is the address of any home agent whose mobile nodes may register via FA.

- FA could indicate that it supports disparate address spaces via a currently undefined 'P' bit in its advertisements, and an indication of the relevant address space for any or all of its care-of addressed by including an NAI [11] or a realm indicator (perhaps a variant of the NAI). Alternatively, mobile nodes so configured could solicit the NAI or realm indicator information in response to advertisements with the 'P' bit set.

Additionally, the mobile node needs to supply the appropriate address for its home agent: Hb instead of the usual Hc. How this happens is outside the scope of this document. Some possible mechanisms are:

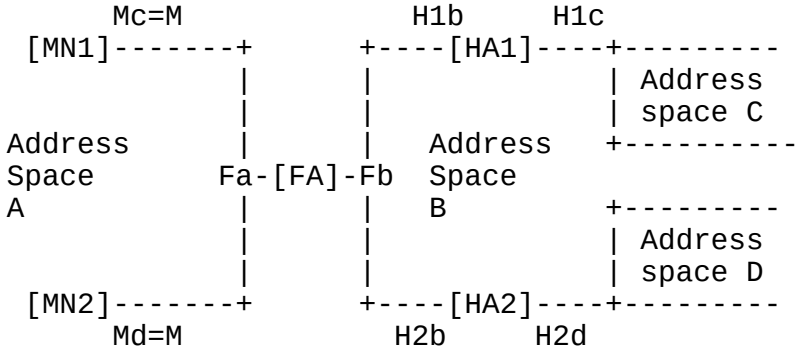
- This determination could be triggered in response to using the foreign agent's Fb as the care-of address.

- The mobile node could always use Hb as its home agent address, specially (1) if Hb is routable within address space C, or (2) if MN is certain never to be at home (in some configurations, the mobile nodes are always roaming).

- The mobile node could be configured with different home agent addresses and their corresponding address space (perhaps indicated via an NAI [11] or a variant of it).

Another major issue introduced by private addresses is that of two or more mobile nodes with the same numeric IP address:

Figure A3: MOBILE NODES WITH CONFLICTING ADDRESSES



Suppose there are two address spaces A and B, and a foreign agent (FA) with interfaces on both. There are two home agents (HA1 and HA2) in address space B, with addresses H1b and H2b, respectively. Each of the home agents has an interface in a private address space in addition to address space B: HA1 has H1c on C, and HA2 has H2d on D. MN1 and MN2 are two mobile nodes with home addresses Mc and Md, corresponding to address space C and D, respectively.

If Mc and Md are private addresses as defined in RFC1918, they may be numerically equivalent (both equal to M). Because of this, the foreign agent can no longer rely on only the mobile node’s home address to disambiguate amongst its different bindings.

A.2. Terminating Forward Tunnels at the Foreign Agent

In figure A1, suppose the correspondent node Y sends a packet to the mobile node at address Mc. The packet is intercepted by the home agent at Hc and tunneled towards the mobile node via address Fb.

Once the packet reaches FA (via address Fb), the foreign agent must identify which of its registered mobile nodes is the ultimate destination for the internal packet. In order to do so, it needs to identify the proper binding via a tuple guaranteed to be unique among all of its mobile nodes.

The unique tuple sufficient for demultiplexing IP in IP packets [IPIP] (protocol 4) is:

- destination IP address of the encapsulated (internal) header

  This is mobile node MN's home address (Mc in the above example). At first glance, it seems like this is unique among all mobile nodes, but as mentioned above, with private addresses another mobile may have an address Md numerically equivalent to Mc.

- source IP address of the external header

  This, the remote end of the tunnel, is Hb in the above example.

- destination IP address of the external header

  This, the local end of the tunnel, is Fb in the above example.

The three values above are learned from a successful registration and are the mobile node's home address, the home agent's address and the care-of address. Thus, it is possible to identify the right binding. Once FA identifies the ultimate destination of the packet, Mc, it delivers the internal packet using link layer mechanisms.

GRE packets [10] (protocol 47) are only handled if their Protocol Type field has a value of 0x800 (other values are outside the scope of this document), and are demultiplexed based on the same tuple as IP in IP packets. In GRE terminology, the tuple is:

- destination IP address of the payload (internal) packet

- source IP address of the delivery (external) packet

- destination IP address of the delivery (external) packet

Notice that the Routing, Sequence Number, Strict Source Route and Key fields have been deprecated from GRE [10]. However, a separate document specifies their use [13].

The above tuples work for IP-in-IP or GRE encapsulation, and assume that the inner packet is in the clear. Encapsulations which encrypt the inner packet header are outside the scope of this document.

A.3. Initiating Reverse Tunnels at the Foreign Agent

In figure A3, suppose mobile node M1 sends a packet to a correspondent node in its home address space, C, and mobile node M2 sends a packet to a correspondent node in its home address space, D.

At FA, the source addresses for both packets will be seen as M, thus this is not sufficient information. The unique tuple required to identify the proper binding is:

- link-layer information related to the MN

  This may be in the form of a MAC address, a PPP session (or incoming interface) or channel coding for a digital cellular service. Device ID's can also be used in this context.

- source IP address of the IP header.

  As was pointed out, this by itself is not guaranteed to be unique.

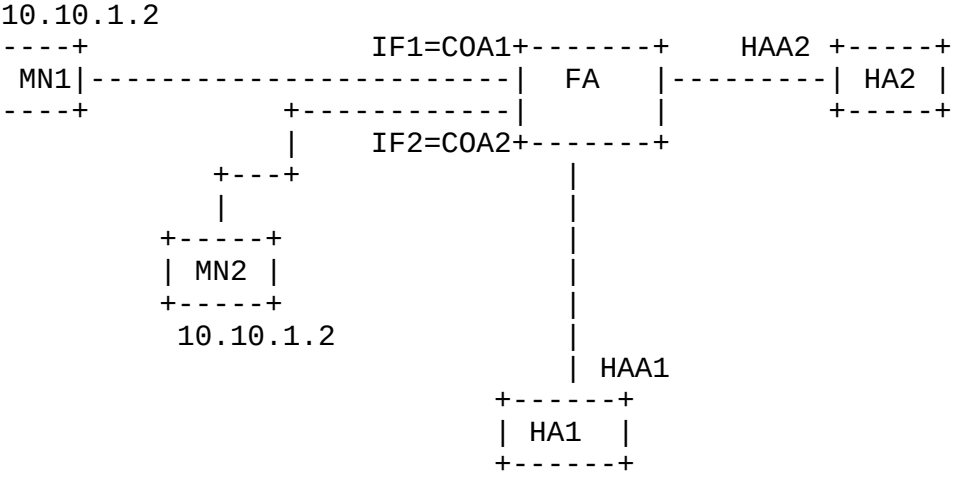
This information must be established and recorded at registration time. The above items are sufficient for the foreign agent to select the proper binding to use. This, in turn, produces the address of the home agent, and the reverse tunneling options negotiated during the registration process. The foreign agent can now proceed with reverse tunneling.

A.4. Limited Private Address Scenario

The Limited Private Address Scenario (LPAS) has received much attention from the cellular wireless industry, so it is useful to define it and to clarify what its requirements are.

LPAS is a subset of the disparate address space scenario discussed in this appendix. This section explains how LPAS could be deployed given the current state of the Mobile IP specifications.

Figure A4: EXAMPLE PRIVATE ADDRESS SCENARIO



The above figure presents a very simple scenario in which private addresses are used. Here, "private addresses" are strictly those defined in RFC 1918 [12]. In this deployment scenario, the only entities that have private addresses are the mobile nodes. Foreign agent and home agent addresses are publicly routable on the general Internet. More specifically, the care-of addresses advertised by the foreign agents (COA1 and COA2 in Figure A4) and the home agent addresses used by mobile nodes in registration requests (HAA1 and HAA2 in Figure A4) are publicly routable on the general Internet. As a consequence, any Mobile IP tunnels can be established between any home agent home address and any foreign agent care-of address.

Also, note that two different mobile nodes (MN1 and MN2) with the same private address (10.10.1.2) are visiting the same foreign agent FA. This is supported as long as MN1 and MN2 are serviced by different home agents. Hence, from any given home agent's perspective, each mobile node has a unique IP address, even if it happens to be a private address as per RFC 1918.

Operation in the presence of route optimization [4] is outside the scope of this document.

Requirements for the above private address scenario:

Mobile node requirements:

Mobile nodes intending to use private addresses with Mobile IP MUST set the 'T' bit and employ reverse tunneling. Mobile node's private addresses within a given address space MUST be unique. Thus two mobile nodes belonging to a single home agent

cannot have the same private addresses. Thus, when receiving or sending tunneled traffic for a mobile node, the tunnel endpoints are used to disambiguate amongst conflicting mobile node addresses.

If the mobile node happens to register with multiple home agents simultaneously through the same foreign agent, there must be some link-layer information that is distinct for each mobile node. If no such distinct link-layer information is available, the mobile nodes MUST use unique address.

Foreign agent requirements:

All advertising interfaces of the foreign agent MUST have publicly routable care-of address. Thus, a mobile node with a private address visits the foreign agent only in its publicly routable network.

Foreign agents MUST support reverse tunneling in order to support private addressed mobile nodes. If a foreign agent receives a registration request from a mobile node with a private address, and the mobile node has not set the 'T' bit, the foreign agent SHOULD reject it.

When delivering packets to or receiving packets from mobile nodes, foreign agents MUST disambiguate among mobile node with conflicting private addresses by using link-layer information as mentioned previously (Appendix section A.2 and A.3). A foreign agent in absence of route optimization, should make sure that two mobile nodes visiting the same foreign agent corresponds with each other through their respective home agents.

If a foreign agent supports reverse tunneling, then it MUST support the simple scenario of private address support described in this section.

Home agent requirements:

Any home agent address used by mobile nodes in registration request MUST be a publicly routable address. Home agents will not support overlapping private home addresses, thus each private home address of a mobile node registered with a home agent is unique. When the 'T' bit is set in the registration request from the mobile node, the home agent MUST recognize and accept registration request from mobile nodes with private

addresses. Also, the home agent SHOULD be able to assign private addresses out of its address pool to mobile nodes for use as home addresses. This does not contravene home agent processing in section 3.8 of [1].

Appendix B: Changes from RFC2344

This section lists the changes with respect to the previous version of this document (RFC2344).

- Added Appendix A on support for Disparate Addresses spaces and private addresses.

- Added the corresponding section (6.3) under 'Security Considerations'.

- Made Encapsulating Delivery Support optional by demoting from a MUST to a should. This also required defining a new error code 79 (assigned by IANA).

- Mentioned the possibility of an admissible authentication extension which may be different from the Mobile-Home authentication extension.

- An IANA considerations section was added.

Full Copyright Statement

Acknowledgement

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