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Realm Specific IP: Framework

Status of this Memo

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IESG Note

   The IESG notes that the set of documents describing the RSIP
   technology imply significant host and gateway changes for a complete
   implementation. In addition, the floating of port numbers can cause
   problems for some applications, preventing an RSIP-enabled host from
   interoperating transparently with existing applications in some cases
   (e.g., IPsec). Finally, there may be significant operational
   complexities associated with using RSIP. Some of these and other
   complications are outlined in section 6 of RFC 3102, as well as in
   the Appendices of RFC 3104. Accordingly, the costs and benefits of
   using RSIP should be carefully weighed against other means of
   relieving address shortage.

Abstract

   This document examines the general framework of Realm Specific IP
   (RSIP). RSIP is intended as a alternative to NAT in which the end-
   to-end integrity of packets is maintained. We focus on
   implementation issues, deployment scenarios, and interaction with
   other layer-three protocols.

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1. Introduction

   Network Address Translation (NAT) has become a popular mechanism of
   enabling the separation of addressing spaces. A NAT router must
   examine and change the network layer, and possibly the transport
   layer, header of each packet crossing the addressing domains that the
   NAT router is connecting. This causes the mechanism of NAT to
   violate the end-to-end nature of the Internet connectivity, and
   disrupts protocols requiring or enforcing end-to-end integrity of
   packets.

While NAT does not require a host to be aware of its presence, it
requires the presence of an application layer gateway (ALG) within
the NAT router for each application that embeds addressing
information within the packet payload. For example, most NATs ship
with an ALG for FTP, which transmits IP addresses and port numbers on
its control channel. RSIP (Realm Specific IP) provides an
alternative to remedy these limitations.

RSIP is based on the concept of granting a host from one addressing
realm a presence in another addressing realm by allowing it to use
resources (e.g., addresses and other routing parameters) from the
second addressing realm. An RSIP gateway replaces the NAT router,
and RSIP-aware hosts on the private network are referred to as RSIP
hosts. RSIP requires ability of the RSIP gateway to grant such
resources to RSIP hosts. ALGs are not required on the RSIP gateway
for communications between an RSIP host and a host in a different
addressing realm.

RSIP can be viewed as a "fix", of sorts, to NAT. It may ameliorate
some IP address shortage problems in some scenarios without some of
the limitations of NAT. However, it is not a long-term solution to
the IP address shortage problem. RSIP allows a degree of address
realm transparency to be achieve between two differently-scoped, or
completely different addressing realms. This makes it a useful
architecture for enabling end-to-end packet transparency between
addressing realms. RSIP is expected to be deployed on privately
addresses IPv4 networks and used to grant access to publically
addressed IPv4 networks. However, in place of the private IPv4
network, there may be an IPv6 network, or a non-IP network. Thus,
RSIP allows IP connectivity to a host with an IP stack and IP
applications but no native IP access. As such, RSIP can be used, in
conjunction with DNS and tunneling, to bridge IPv4 and IPv6 networks,
such that dual-stack hosts can communicate with local or remote IPv4
or IPv6 hosts.

It is important to note that, as it is defined here, RSIP does NOT
require modification of applications. All RSIP-related modifications
to an RSIP host can occur at layers 3 and 4. However, while RSIP
does allow end-to-end packet transparency, it may not be transparent
to all applications. More details can be found in the section "RSIP
complications", below.

1.1. Document Scope

   This document provides a framework for RSIP by focusing on four
   particular areas:

      - Requirements of an RSIP host and RSIP gateway.

      - Likely initial deployment scenarios.

      - Interaction with other layer-three protocols.

      - Complications that RSIP may introduce.

   The interaction sections will be at an overview level. Detailed
   modifications that would need to be made to RSIP and/or the
   interacting protocol are left for separate documents to discuss in
   detail.

   Beyond the scope of this document is discussion of RSIP in large,
   multiple-gateway networks, or in environments where RSIP state would
   need to be distributed and maintained across multiple redundant
   entities.

   Discussion of RSIP solutions that do not use some form of tunnel
   between the RSIP host and RSIP gateway are also not considered in
   this document.

   This document focuses on scenarios that allow privately-addressed
   IPv4 hosts or IPv6 hosts access to publically-addressed IPv4
   networks.

1.2. Terminology

   Private Realm

      A routing realm that uses private IP addresses from the ranges
      (10.0.0.0/8, 172.16.0.0/12, 192.168.0.0/16) specified in
      [RFC1918], or addresses that are non-routable from the Internet.

   Public Realm

      A routing realm with globally unique network addresses.

   RSIP Host

      A host within an addressing realm that uses RSIP to acquire
      addressing parameters from another addressing realm via an RSIP
      gateway.

RSIP Gateway

   A router or gateway situated on the boundary between two
   addressing realms that is assigned one or more IP addresses in at
   least one of the realms. An RSIP gateway is responsible for
   parameter management and assignment from one realm to RSIP hosts
   in the other realm. An RSIP gateway may act as a normal NAT
   router for hosts within the a realm that are not RSIP enabled.

RSIP Client

   An application program that performs the client portion of the
   RSIP client/server protocol. An RSIP client application MUST
   exist on all RSIP hosts, and MAY exist on RSIP gateways.

RSIP Server

   An application program that performs the server portion of the
   RSIP client/server protocol. An RSIP server application MUST
   exist on all RSIP gateways.

RSA-IP: Realm Specific Address IP

   An RSIP method in which each RSIP host is allocated a unique IP
   address from the public realm.

RSAP-IP: Realm Specific Address and Port IP

   An RSIP method in which each RSIP host is allocated an IP address
   (possibly shared with other RSIP hosts) and some number of per-
   address unique ports from the public realm.

Demultiplexing Fields

   Any set of packet header or payload fields that an RSIP gateway
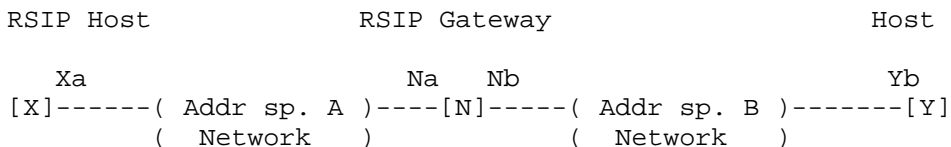   uses to route an incoming packet to an RSIP host.

All other terminology found in this document is consistent with that
of [RFC2663].

1.3. Specification of Requirements

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

2. Architecture

    In a typical scenario where RSIP is deployed, there are some number
    of hosts within one addressing realm connected to another addressing
    realm by an RSIP gateway. This model is diagrammatically represented
    as follows:

          RSIP Host   RSIP Gateway   Host

            Xa   Na   Nb   Yb
         [X]------(Addr sp. A)----[N]-----(Addr sp. B)-------[Y]
                  (Network   )   (Network   )

    Hosts X and Y belong to different addressing realms A and B,
    respectively, and N is an RSIP gateway (which may also perform NAT
    functions). N has two interfaces: Na on address space A, and Nb on
    address space B. N may have a pool of addresses in address space B
    which it can assign to or lend to X and other hosts in address space
    A. These addresses are not shown above, but they can be denoted as
    Nb1, Nb2, Nb3 and so on.

    As is often the case, the hosts within address space A are likely to
    use private addresses while the RSIP gateway is multi-homed with one
    or more private addresses from address space A in addition to its
    public addresses from address space B. Thus, we typically refer to
    the realm in which the RSIP host resides as "private" and the realm
    from which the RSIP host borrows addressing parameters as the
    "public" realm. However, these realms may both be public or private
    - our notation is for convenience. In fact, address space A may be
    an IPv6 realm or a non-IP address space.

    Host X, wishing to establish an end-to-end connection to a network
    entity Y situated within address space B, first negotiates and
    obtains assignment of the resources (e.g., addresses and other
    routing parameters of address space B) from the RSIP gateway. Upon
    assignment of these parameters, the RSIP gateway creates a mapping,
    referred as a "bind", of X's addressing information and the assigned
    resources. This binding enables the RSIP gateway to correctly de-
    multiplex and forward inbound traffic generated by Y for X. If
    permitted by the RSIP gateway, X may create multiple such bindings on
    the same RSIP gateway, or across several RSIP gateways. A lease time
    SHOULD be associated with each bind.

    Using the public parameters assigned by the RSIP gateway, RSIP hosts
    tunnel data packets across address space A to the RSIP gateway. The
    RSIP gateway acts as the end point of such tunnels, stripping off the
    outer headers and routing the inner packets onto the public realm.
    As mentioned above, an RSIP gateway maintains a mapping of the

assigned public parameters as demultiplexing fields for uniquely
mapping them to RSIP host private addresses. When a packet from the
public realm arrives at the RSIP gateway and it matches a given set
of demultiplexing fields, then the RSIP gateway will tunnel it to the
appropriate RSIP host. The tunnel headers of outbound packets from X
to Y, given that X has been assigned Nb, are as follows:

```
            +---------+---------+---------+
            | X -> Na | Nb -> Y | payload |
            +---------+---------+---------+
```

There are two basic flavors of RSIP: RSA-IP and RSAP-IP. RSIP hosts
and gateways MAY support RSA-IP, RSAP-IP, or both.

When using RSA-IP, an RSIP gateway maintains a pool of IP addresses
to be leased by RSIP hosts. Upon host request, the RSIP gateway
allocates an IP address to the host. Once an address is allocated to
a particular host, only that host may use the address until the
address is returned to the pool. Hosts MAY NOT use addresses that
have not been specifically assigned to them. The hosts may use any
TCP/UDP port in combination with their assigned address. Hosts may
also run gateway applications at any port and these applications will
be available to the public network without assistance from the RSIP
gateway. A host MAY lease more than one address from the same or
different RSIP gateways. The demultiplexing fields of an RSA-IP
session MUST include the IP address leased to the host.

When using RSAP-IP, an RSIP gateway maintains a pool of IP addresses
as well as pools of port numbers per address. RSIP hosts lease an IP
address and one or more ports to use with it. Once an address / port
tuple has been allocated to a particular host, only that host may use
the tuple until it is returned to the pool(s). Hosts MAY NOT use
address / port combinations that have not been specifically assigned
to them. Hosts may run gateway applications bound to an allocated
tuple, but their applications will not be available to the public
network unless the RSIP gateway has agreed to route all traffic
destined to the tuple to the host. A host MAY lease more than one
tuple from the same or different RSIP gateways. The demultiplexing
fields of an RSAP-IP session MUST include the tuple(s) leased to the
host.

3. Requirements

3.1. Host and Gateway Requirements

An RSIP host MUST be able to maintain one or more virtual interfaces
for the IP address(es) that it leases from an RSIP gateway. The host
MUST also support tunneling and be able to serve as an end-point for

one or more tunnels to RSIP gateways. An RSIP host MUST NOT respond
to ARPs for a public realm address that it leases.

An RSIP host supporting RSAP-IP MUST be able to maintain a set of one
or more ports assigned by an RSIP gateway from which choose ephemeral
source ports. If the host's pool does not have any free ports and
the host needs to open a new communication session with a public
host, it MUST be able to dynamically request one or more additional
ports via its RSIP mechanism.

An RSIP gateway is a multi-homed host that routes packets between two
or more realms. Often, an RSIP gateway is a boundary router between
two or more administrative domains. It MUST also support tunneling
and be able to serve as an end-point for tunnels to RSIP hosts. The
RSIP gateway MAY be a policy enforcement point, which in turn may
require it to perform firewall and packet filtering duties in
addition to RSIP. The RSIP gateway MUST reassemble all incoming
packet fragments from the public network in order to be able to route
and tunnel them to the proper host. As is necessary for fragment
reassembly, an RSIP gateway MUST timeout fragments that are never
fully reassembled.

An RSIP gateway MAY include NAT functionality so that hosts on the
private network that are not RSIP-enabled can still communicate with
the public network. An RSIP gateway MUST manage all resources that
are assigned to RSIP hosts. This management MAY be done according to
local policy.

3.2. Processing of Demultiplexing Fields

Each active RSIP host must have a unique set of demultiplexing fields
assigned to it so that an RSIP gateway can route incoming packets
appropriately. Depending on the type of mapping used by the RSIP
gateway, demultiplexing fields have been defined to be one or more of
the following:

    - destination IP address

    - IP protocol

    - destination TCP or UDP port

    - IPSEC SPI present in ESP or AH header (see [RFC3104])

    - others

Note that these fields may be augmented by source IP address and
source TCP or UDP port.

Demultiplexing of incoming traffic can be based on a decision tree.
The process begins with the examination of the IP header of the
incoming packet, and proceeds to subsequent headers and then the
payload.

- In the case where a public IP address is assigned for each
  host, a unique public IP address is mapped to each RSIP host.

- If the same IP address is used for more than one RSIP host,
  then subsequent headers must have at least one field that will
  be assigned a unique value per host so that it is usable as a
  demultiplexing field. The IP protocol field SHOULD be used to
  determine what in the subsequent headers these demultiplexing
  fields ought to be.

- If the subsequent header is TCP or UDP, then destination port
  number can be used. However, if the TCP/UDP port number is the
  same for more than one RSIP host, the payload section of the
  packet must contain a demultiplexing field that is guaranteed
  to be different for each RSIP host. Typically this requires
  negotiation of said fields between the RSIP host and gateway so
  that the RSIP gateway can guarantee that the fields are unique
  per-host

- If the subsequent header is anything other than TCP or UDP,
  there must exist other fields within the IP payload usable as
  demultiplexing fields. In other words, these fields must be
  able to be set such that they are guaranteed to be unique per-
  host. Typically this requires negotiation of said fields
  between the RSIP host and gateway so that the RSIP gateway can
  guarantee that the fields are unique per-host.

It is desirable for all demultiplexing fields to occur in well-known
fixed locations so that an RSIP gateway can mask out and examine the
appropriate fields on incoming packets. Demultiplexing fields that
are encrypted MUST NOT be used for routing.

3.3. RSIP Protocol Requirements and Recommendations

RSIP gateways and hosts MUST be able to negotiate IP addresses when
using RSA-IP, IP address / port tuples when using RSAP-IP, and
possibly other demultiplexing fields for use in other modes.

In this section we discuss the requirements and implementation issues
of an RSIP negotiation protocol.

For each required demultiplexing field, an RSIP protocol MUST, at the
very least, allow for:

- RSIP hosts to request assignments of demultiplexing fields

- RSIP gateways to assign demultiplexing fields with an
  associated lease time

- RSIP gateways to reclaim assigned demultiplexing fields

Additionally, it is desirable, though not mandatory, for an RSIP
protocol to negotiate an RSIP method (RSA-IP or RSAP-IP) and the type
of tunnel to be used across the private network. The protocol SHOULD
be extensible and facilitate vendor-specific extensions.

If an RSIP negotiation protocol is implemented at the application
layer, a choice of transport protocol MUST be made. RSIP hosts and
gateways may communicate via TCP or UDP. TCP support is required in
all RSIP gateways, while UDP support is optional. In RSIP hosts,
TCP, UDP, or both may be supported. However, once an RSIP host and
gateway have begun communicating using either TCP or UDP, they MAY
NOT switch to the other transport protocol. For RSIP implementations
and deployments considered in this document, TCP is the recommended
transport protocol, because TCP is known to be robust across a wide
range of physical media types and traffic loads.

It is recommended that all communication between an RSIP host and
gateway be authenticated. Authentication, in the form of a message
hash appended to the end of each RSIP protocol packet, can serve to
authenticate the RSIP host and gateway to one another, provide
message integrity, and (with an anti-replay counter) avoid replay
attacks. In order for authentication to be supported, each RSIP host
and the RSIP gateway MUST either share a secret key (distributed, for
example, by Kerberos) or have a private/public key pair. In the
latter case, an entity's public key can be computed over each message
and a hash function applied to the result to form the message hash.

3.4. Interaction with DNS

An RSIP-enabled network has three uses for DNS: (1) public DNS
services to map its static public IP addresses (i.e., the public
address of the RSIP gateway) and for lookups of public hosts, (2)
private DNS services for use only on the private network, and (3)
dynamic DNS services for RSIP hosts.

With respect to (1), public DNS information MUST be propagated onto
the private network. With respect to (2), private DNS information
MUST NOT be propagated into the public network.

With respect to (3), an RSIP-enabled network MAY allow for RSIP hosts
with FQDNs to have their A and PTR records updated in the public DNS.
These updates are based on address assignment facilitated by RSIP,
and should be performed in a fashion similar to DHCP updates to
dynamic DNS [DHCP-DNS]. In particular, RSIP hosts should be allowed
to update their A records but not PTR records, while RSIP gateways
can update both. In order for the RSIP gateway to update DNS records
on behalf on an RSIP host, the host must provide the gateway with its
FQDN.

Note that when using RSA-IP, the interaction with DNS is completely
analogous to that of DHCP because the RSIP host "owns" an IP address
for a period of time. In the case of RSAP-IP, the claim that an RSIP
host has to an address is only with respect to the port(s) that it
has leased along with an address. Thus, two or more RSIP hosts'
FQDNs may map to the same IP address. However, a public host may
expect that all of the applications running at a particular address
are owned by the same logical host, which would not be the case. It
is recommended that RSAP-IP and dynamic DNS be integrated with some
caution, if at all.

3.5. Locating RSIP Gateways

When an RSIP host initializes, it requires (among other things) two
critical pieces of information. One is a local (private) IP address
to use as its own, and the other is the private IP address of an RSIP
gateway. This information can be statically configured or
dynamically assigned.

In the dynamic case, the host's private address is typically supplied
by DHCP. A DHCP option could provide the IP address of an RSIP
gateway in DHCPOFFER messages. Thus, the host's startup procedure
would be as follows: (1) perform DHCP, (2) if an RSIP gateway option
is present in the DHCPOFFER, record the IP address therein as the
RSIP gateway.

Alternatively, the RSIP gateway can be discovered via SLP (Service
Location Protocol) as specified in [SLP-RSIP]. The SLP template
defined allows for RSIP service provisioning and load balancing.

3.6. Implementation Considerations

RSIP can be accomplished by any one of a wide range of implementation
schemes. For example, it can be built into an existing configuration
protocol such as DHCP or SOCKS, or it can exist as a separate
protocol. This section discusses implementation issues of RSIP in
general, regardless of how the RSIP mechanism is implemented.

Note that on a host, RSIP is associated with a TCP/IP stack
implementation. Modifications to IP tunneling and routing code, as
well as driver interfaces may need to be made to support RSA-IP.
Support for RSAP-IP requires modifications to ephemeral port
selection code as well. If a host has multiple TCP/IP stacks or
TCP/IP stacks and other communication stacks, RSIP will only operate
on the packets / sessions that are associated with the TCP/IP
stack(s) that use RSIP. RSIP is not application specific, and if it
is implemented in a stack, it will operate beneath all applications
that use the stack.

4. Deployment

When RSIP is deployed in certain scenarios, the network
characteristics of these scenarios will determine the scope of the
RSIP solution, and therefore impact the requirements of RSIP. In
this section, we examine deployment scenarios, and the impact that
RSIP may have on existing networks.

4.1. Possible Deployment Scenarios

In this section we discuss a number of potential RSIP deployment
scenarios. The selection below are not comprehensive and other
scenarios may emerge.

4.1.1. Small / Medium Enterprise

Up to several hundred hosts will reside behind an RSIP-enabled
router. It is likely that there will be only one gateway to the
public network and therefore only one RSIP gateway. This RSIP
gateway may control only one, or perhaps several, public IP
addresses. The RSIP gateway may also perform firewall functions, as
well as routing inbound traffic to particular destination ports on to
a small number of dedicated gateways on the private network.

4.1.2. Residential Networks

This category includes both networking within just one residence, as
well as within multiple-dwelling units. At most several hundred
hosts will share the gateway's resources. In particular, many of
these devices may be thin hosts or so-called "network appliances" and
therefore not require access to the public Internet frequently. The
RSIP gateway is likely to be implemented as part of a residential
firewall, and it may be called upon to route traffic to particular
destination ports on to a small number of dedicated gateways on the
private network. It is likely that only one gateway to the public

network will be present and that this gateway's RSIP gateway will
control only one IP address. Support for secure end-to-end VPN
access to corporate intranets will be important.

4.1.3. Hospitality Networks

A hospitality network is a general type of "hosting" network that a
traveler will use for a short period of time (a few minutes or a few
hours). Examples scenarios include hotels, conference centers and
airports and train stations. At most several hundred hosts will
share the gateway's resources. The RSIP gateway may be implemented
as part of a firewall, and it will probably not be used to route
traffic to particular destination ports on to dedicated gateways on
the private network. It is likely that only one gateway to the
public network will be present and that this gateway's RSIP gateway
will control only one IP address. Support for secure end-to-end VPN
access to corporate intranets will be important.

4.1.4. Dialup Remote Access

RSIP gateways may be placed in dialup remote access concentrators in
order to multiplex IP addresses across dialup users. At most several
hundred hosts will share the gateway's resources. The RSIP gateway
may or may not be implemented as part of a firewall, and it will
probably not be used to route traffic to particular destination ports
on to dedicated gateways on the private network. Only one gateway to
the public network will be present (the remote access concentrator
itself) and that this gateway's RSIP gateway will control a small
number of IP addresses. Support for secure end-to-end VPN access to
corporate intranets will be important.

4.1.5. Wireless Remote Access Networks

Wireless remote access will become very prevalent as more PDA and IP
/ cellular devices are deployed. In these scenarios, hosts may be
changing physical location very rapidly - therefore Mobile IP will
play a role. Hosts typically will register with an RSIP gateway for
a short period of time. At most several hundred hosts will share the
gateway's resources. The RSIP gateway may be implemented as part of
a firewall, and it will probably not be used to route traffic to
particular destination ports on to dedicated gateways on the private
network. It is likely that only one gateway to the public network
will be present and that this gateway's RSIP gateway will control a
small number of IP addresses. Support for secure end-to-end VPN
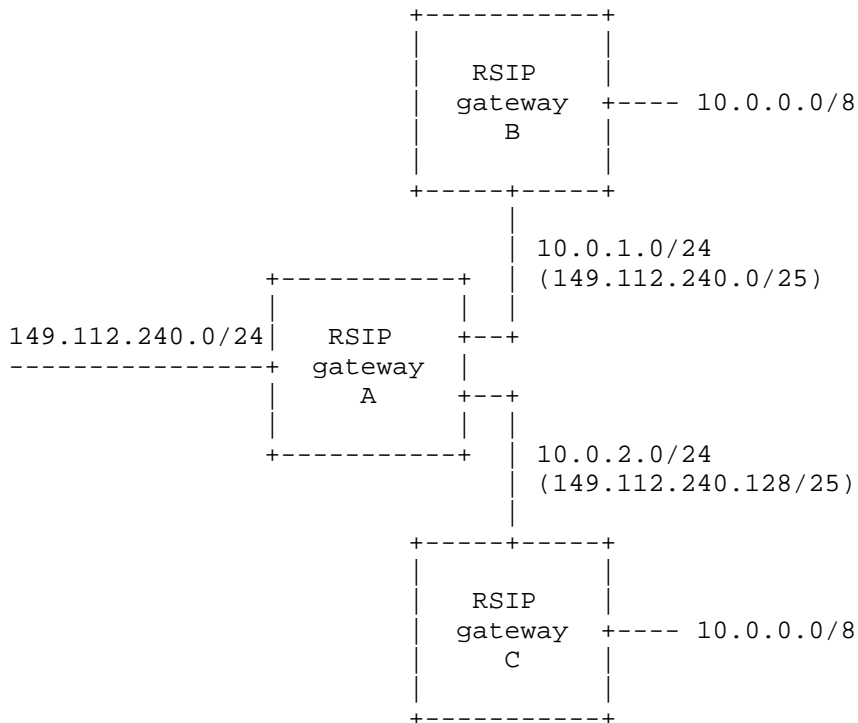access to corporate intranets will be important.

4.2. Cascaded RSIP and NAT

   It is possible for RSIP to allow for cascading of RSIP gateways as
   well as cascading of RSIP gateways with NAT boxes. For example,
   consider an ISP that uses RSIP for address sharing amongst its
   customers. It might assign resources (e.g., IP addresses and ports)
   to a particular customer. This customer may use RSIP to further
   subdivide the port ranges and address(es) amongst individual end
   hosts. No matter how many levels of RSIP assignment exists, RSIP
   MUST only assign public IP addresses.

   Note that some of the architectures discussed below may not be useful
   or desirable. The goal of this section is to explore the
   interactions between NAT and RSIP as RSIP is incrementally deployed
   on systems that already support NAT.

4.2.1. RSIP Behind RSIP

   A reference architecture is depicted below.

```
                            +-----------+
                            |           |
                            |   RSIP    |
                            | gateway   +---- 10.0.0.0/8
                            |    B      |
                            |           |
                            +-----+-----+
                                  |
                                  | 10.0.1.0/24
              +-----------+       | (149.112.240.0/25)
              |           |       | |
 149.112.240.0/24|   RSIP    +--+
 ---------------+  gateway   |
              |     A      +--+
              |           |   | |
              +-----------+   | 10.0.2.0/24
                              | (149.112.240.128/25)
                              |
                        +-----+-----+
                        |           |
                        |   RSIP    |
                        | gateway   +---- 10.0.0.0/8
                        |    C      |
                        |           |
                        +-----------+
```

RSIP gateway A is in charge of the IP addresses of subnet
149.112.240.0/24. It distributes these addresses to RSIP hosts and
RSIP gateways. In the given configuration, it distributes addresses
149.112.240.0 - 149.112.240.127 to RSIP gateway B, and addresses
149.112.240.128 - 149.112.240.254 to RSIP gateway C. Note that the
subnet broadcast address, 149.112.240.255, must remain unclaimed, so
that broadcast packets can be distributed to arbitrary hosts behind
RSIP gateway A. Also, the subnets between RSIP gateway A and RSIP
gateways B and C will use private addresses.

Due to the tree-like fashion in which addresses will be cascaded, we
will refer to RSIP gateways A as the 'parent' of RSIP gateways B and
C, and RSIP gateways B and C as 'children' of RSIP gateways A. An
arbitrary number of levels of children may exist under a parent RSIP
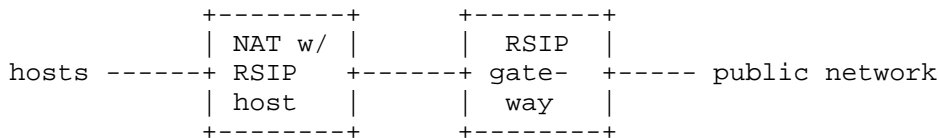gateway.

A parent RSIP gateway will not necessarily be aware that the
address(es) and port blocks that it distributes to a child RSIP
gateway will be further distributed. Thus, the RSIP hosts MUST
tunnel their outgoing packets to the nearest RSIP gateway. This
gateway will then verify that the sending host has used the proper
address and port block, and then tunnel the packet on to its parent
RSIP gateway.

For example, in the context of the diagram above, host 10.0.0.1,
behind RSIP gateway C will use its assigned external IP address (say,
149.112.240.130) and tunnel its packets over the 10.0.0.0/8 subnet to
RSIP gateway C. RSIP gateway C strips off the outer IP header.
After verifying that the source public IP address and source port
number is valid, RSIP gateway C will tunnel the packets over the
10.0.2.0/8 subnet to RSIP gateway A. RSIP gateway A strips off the
outer IP header. After verifying that the source public IP address
and source port number is valid, RSIP gateway A transmits the packet
on the public network.

While it may be more efficient in terms of computation to have a RSIP
host tunnel directly to the overall parent of an RSIP gateway tree,
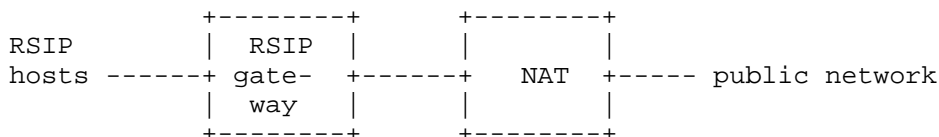this would introduce significant state and administrative
difficulties.

A RSIP gateway that is a child MUST take into consideration the
parameter assignment constraints that it inherits from its parent
when it assigns parameters to its children. For example, if a child
RSIP gateway is given a lease time of 3600 seconds on an IP address,
it MUST compare the current time to the lease time and the time that
the lease was assigned to compute the maximum allowable lease time on
the address if it is to assign the address to a RSIP host or child
RSIP gateway.

4.2.2. NAT Behind RSIP

```
              +--------+       +--------+
              | NAT w/ |       | RSIP   |
    hosts ------+ RSIP   +------+ gate-  +----- public network
              | host   |       | way    |
              +--------+       +--------+
```
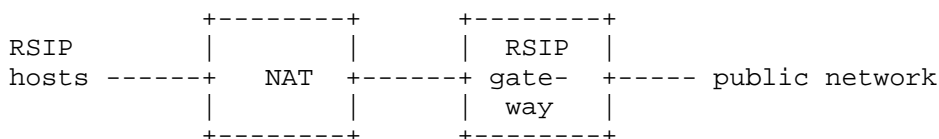
   In this architecture, an RSIP gateway is between a NAT box and the
   public network. The NAT is also equipped with an RSIP host. The NAT
   dynamically requests resources from the RSIP gateway as the hosts
   establish sessions to the public network. The hosts are not aware of
   the RSIP manipulation. This configuration does not enable the hosts
   to have end-to-end transparency and thus the NAT still requires ALGs
   and the architecture cannot support IPSEC.

4.2.3. RSIP Behind NAT

```
              +--------+       +--------+
    RSIP      | RSIP   |       |        |
    hosts ------+ gate-  +------+   NAT  +----- public network
              | way    |       |        |
              +--------+       +--------+
```

   In this architecture, the RSIP hosts and gateway reside behind a NAT.
   This configuration does not enable the hosts to have end-to-end
   transparency and thus the NAT still requires ALGs and the
   architecture cannot support IPSEC. The hosts may have transparency
   if there is another gateway to the public network besides the NAT
   box, and this gateway supports cascaded RSIP behind RSIP.

4.2.4. RSIP Through NAT

```
              +--------+       +--------+
    RSIP      |        |       | RSIP   |
    hosts ------+   NAT  +------+ gate-  +----- public network
              |        |       | way    |
              +--------+       +--------+
```

   In this architecture, the RSIP hosts are separated from the RSIP
   gateway by a NAT. RSIP signaling may be able to pass through the NAT
   if an RSIP ALG is installed. The RSIP data flow, however, will have
   its outer IP address translated by the NAT. The NAT must not
   translate the port numbers in order for RSIP to work properly.
   Therefore, only traditional NAT will make sense in this context.

5. Interaction with Layer-Three Protocols

   Since RSIP affects layer-three objects, it has an impact on other
   layer three protocols. In this section, we outline the impact of
   RSIP on these protocols, and in each case, how RSIP, the protocol, or
   both, can be extended to support interaction.

   Each of these sections is an overview and not a complete technical
   specification. If a full technical specification of how RSIP
   interacts with a layer-three protocol is necessary, a separate
   document will contain it.

5.1. IPSEC

   RSIP is a mechanism for allowing end-to-end IPSEC with sharing of IP
   addresses. Full specification of RSIP/IPSEC details are in [RSIP-
   IPSEC]. This section provides a brief summary. Since IPSEC may
   encrypt TCP/UDP port numbers, these objects cannot be used as
   demultiplexing fields. However, IPSEC inserts an AH or ESP header
   following the IP header in all IPSEC-protected packets (packets that
   are transmitted on an IPSEC Security Association (SA)). These
   headers contain a 32-bit Security Parameter Index (SPI) field, the
   value of which is determined by the receiving side. The SPI field is
   always in the clear. Thus, during SA negotiation, an RSIP host can
   instruct their public peer to use a particular SPI value. This SPI
   value, along with the assigned IP address, can be used by an RSIP
   gateway to uniquely identify and route packets to an RSIP host. In
   order to guarantee that RSIP hosts use SPIs that are unique per
   address, it is necessary for the RSIP gateway to allocate unique SPIs
   to hosts along with their address/port tuple.

   IPSEC SA negotiation takes place using the Internet Key Exchange
   (IKE) protocol. IKE is designated to use port 500 on at least the
   destination side. Some host IKE implementations will use source port
   500 as well, but this behavior is not mandatory. If two or more RSIP
   hosts are running IKE at source port 500, they MUST use different
   initiator cookies (the first eight bytes of the IKE payload) per
   assigned IP address. The RSIP gateway will be able to route incoming
   IKE packets to the proper host based on initiator cookie value.
   Initiator cookies can be negotiated, like ports and SPIs. However,
   since the likelihood of two hosts assigned the same IP address
   attempting to simultaneously use the same initiator cookie is very
   small, the RSIP gateway can guarantee cookie uniqueness by dropping
   IKE packets with a cookie value that is already in use.

5.2. Mobile IP

   Mobile IP allows a mobile host to maintain an IP address as it moves
   from network to network. For Mobile IP foreign networks that use
   private IP addresses, RSIP may be applicable. In particular, RSIP
   would allow a mobile host to bind to a local private address, while
   maintaining a global home address and a global care-of address. The
   global care-of address could, in principle, be shared with other
   mobile nodes.

   The exact behavior of Mobile IP with respect to private IP addresses
   has not be settled. Until it is, a proposal to adapt RSIP to such a
   scenario is premature. Also, such an adaptation may be considerably
   complex. Thus, integration of RSIP and Mobile IP is a topic of
   ongoing consideration.

5.3. Differentiated and Integrated Services

   To attain the capability of providing quality of service between two
   communicating hosts in different realms, it is important to consider
   the interaction of RSIP with different quality of service
   provisioning models and mechanisms. In the section, RSIP interaction
   with the integrated service and differentiated service frameworks is
   discussed.

5.3.1. Differentiated Services

   The differentiated services architecture defined in [RFC2475] allows
   networks to support multiple levels of best-effort service through
   the use of "markings" of the IP Type-of-Service (now DS) byte. Each
   value of the DS byte is termed a differentiated services code point
   (DSCP) and represents a particular per-hop behavior. This behavior
   may not be the same in all administrative domains. No explicit
   signaling is necessary to support differentiated services.

   For outbound packets from an edge network, DSCP marking is typically
   performed and/or enforced on a boundary router. The marked packet is
   then forwarded onto the public network. In an RSIP-enabled network,
   a natural place for DSCP marking is the RSIP gateway. In the case of
   RSAP-IP, the RSIP gateway can apply its micro-flow (address/port
   tuple) knowledge of RSIP assignments in order to provide different
   service levels to different RSIP host. For RSA-IP, the RSIP gateway
   will not necessarily have knowledge of micro-flows, so it must rely
   on markings made by the RSIP hosts (if any) or apply a default policy
   to the packets.

When differentiated services is to be performed between RSIP hosts
and gateways, it must be done over the tunnel between these entities.
Differentiated services over a tunnel is considered in detail in
[DS-TUNN], the key points that need to be addressed here are the
behaviors of tunnel ingress and egress for both incoming and going
packets.

For incoming packets arriving at an RSIP gateway tunnel ingress, the
RSIP gateway may either copy the DSCP from the inner header to the
outer header, leave the inner header DSCP untouched, but place a
different DSCP in the outer header, or change the inner header DSCP
while applying either the same or a different DSCP to the outer
header.

For incoming packets arriving at an RSIP host tunnel egress, behavior
with respect to the DSCP is not necessarily important if the RSIP
host not only terminates the tunnel, but consumes the packet as well.
If this is not the case, as per some cascaded RSIP scenarios, the
RSIP host must apply local policy to determine whether to leave the
inner header DSCP as is, overwrite it with the outer header DSCP, or
overwrite it with a different value.

For outgoing packets arriving at an RSIP host tunnel ingress, the
host may either copy the DSCP from the inner header to the outer
header, leave the inner header DSCP untouched, but place a different
DSCP in the outer header, or change the inner header DSCP while
applying either the same or a different DSCP to the outer header.

For outgoing packets arriving at an RSIP gateway tunnel egress, the
RSIP gateway must apply local policy to determine whether to leave
the inner header DSCP as is, overwrite it with the outer header DSCP,
or overwrite it with a different value.

It is reasonable to assume that in most cases, the diffserv policy
applicable on a site will be the same for RSIP and non-RSIP hosts.
For this reason, a likely policy is that the DSCP will always be
copied between the outer and inner headers in all of the above cases.
However, implementations should allow for the more general case.

5.3.2. Integrated Services

The integrated services model as defined by [RFC2205] requires
signalling using RSVP to setup a resource reservation in intermediate
nodes between the communicating endpoints. In the most common
scenario in which RSIP is deployed, receivers located within the
private realm initiate communication sessions with senders located
within the public realm. In this section, we discuss the interaction
of RSIP architecture and RSVP in such a scenario. The less common

case of having senders within the private realm and receivers within
the public realm is not discussed although concepts mentioned here
may be applicable.

With senders in the public realm, RSVP PATH messages flow downstream
from sender to receiver, inbound with respect to the RSIP gateway,
while RSVP RESV messages flow in the opposite direction. Since RSIP
uses tunneling between the RSIP host and gateway within the private
realm, how the RSVP messages are handled within the RSIP tunnel
depends on situations elaborated in [RFC2746].

Following the terminology of [RFC2476], if Type 1 tunnels exist
between the RSIP host and gateway, all intermediate nodes inclusive
of the RSIP gateway will be treated as a non-RSVP aware cloud without
QoS reserved on these nodes. The tunnel will be viewed as a single
(logical) link on the path between the source and destination. End-
to-end RSVP messages will be forwarded through the tunnel
encapsulated in the same way as normal IP packets. We see this as
the most common and applicable deployment scenario.

However, should Type 2 or 3 tunnels be deployed between the tunneling
endpoints , end-to-end RSVP session has to be statically mapped (Type
2) or dynamically mapped (Type 3) into the tunnel sessions. While
the end-to-end RSVP messages will be forwarded through the tunnel
encapsulated in the same way as normal IP packets, a tunnel session
is established between the tunnel endpoints to ensure QoS reservation
within the tunnel for the end-to-end session. Data traffic needing
special QoS assurance will be encapsulated in a UDP/IP header while
normal traffic will be encapsulated using the normal IP-IP
encapsulation. In the type 2 deployment scenario where all data
traffic flowing to the RSIP host receiver are given QoS treatment,
UDP/IP encapsulation will be rendered in the RSIP gateway for all
data flows. The tunnel between the RSIP host and gateway could be
seen as a "hard pipe". Traffic exceeding the QoS guarantee of the
"hard pipe" would fall back to the best effort IP-IP tunneling.

In the type 2 deployment scenario where data traffic could be
selectively channeled into the UDP/IP or normal IP-IP tunnel, or for
type 3 deployment where end-to-end sessions could be dynamically
mapped into tunnel sessions, integration with the RSIP model could be
complicated and tricky. (Note that these are the cases where the
tunnel link could be seen as a expandable soft pipe.) Two main
issues are worth considering.

     - For RSIP gateway implementations that does encapsulation of the
        incoming stream before passing to the IP layer for forwarding,
        the RSVP daemon has to be explicitly signaled upon reception of
        incoming RSVP PATH messages. The RSIP implementation has to

recognize RSVP PATH messages and pass them to the RSVP daemon
instead of doing the default tunneling. Handling of other RSVP
messages would be as described in [RFC2746].

-   RSIP enables an RSIP host to have a temporary presence at the
    RSIP gateway by assuming one of the RSIP gateway's global
    interfaces. As a result, the RSVP PATH messages would be
    addressed to the RSIP gateway. Also, the RSVP SESSION object
    within an incoming RSVP PATH would carry the global destination
    address, destination port (and protocol) tuples that were
    leased by the RSIP gateway to the RSIP host. Hence the realm
    unaware RSVP daemon running on the RSIP gateway has to be
    presented with a translated version of the RSVP messages.
    Other approaches are possible, for example making the RSVP
    daemon realm aware.

A simple mechanism would be to have the RSIP module handle the
necessary RSVP message translation. For an incoming RSVP signalling
flow, the RSIP module does a packet translation of the IP header and
RSVP SESSION object before handling the packet over to RSVP. The
global address leased to the host is translated to the true private
address of the host. (Note that this mechanism works with both RSA-
IP and RSAP-IP.) The RSIP module also has to do an opposite
translation from private to global parameter (plus tunneling) for
end-to-end PATH messages generated by the RSVP daemon towards the
RSIP host receiver. A translation on the SESSION object also has to
be done for RSVP outbound control messages. Once the RSVP daemon
gets the message, it maps them to an appropriate tunnel sessions.

Encapsulation of the inbound data traffic needing QoS treatment would
be done using UDP-IP encapsulation designated by the tunnel session.
For this reason, the RSIP module has to be aware of the UDP-IP
encapsulation to use for a particular end-to-end session.
Classification and scheduling of the QoS guaranteed end-to-end flow
on the output interface of the RSIP gateway would be based on the
UDP/IP encapsulation. Mapping between the tunnel session and end-
to-end session could continue to use the mechanisms proposed in
[RFC2746]. Although [RFC2746] proposes a number of approaches for
this purpose, we propose using the SESSION_ASSOC object introduced
because of its simplicity.

5.4. IP Multicast

The amount of specific RSIP/multicast support that is required in
RSIP hosts and gateways is dependent on the scope of multicasting in
the RSIP-enabled network, and the roles that the RSIP hosts will
play. In this section, we discuss RSIP and multicast interactions in
a number of scenarios.

   Note that in all cases, the RSIP gateway MUST be multicast aware
   because it is on an administrative boundary between two domains that
   will not be sharing their all of their routing information. The RSIP
   gateway MUST NOT allow private IP addresses to be propagated on the
   public network as part of any multicast message or as part of a
   routing table.

5.4.1. Receiving-Only Private Hosts, No Multicast Routing on
        Private Network

   In this scenario, private hosts will not source multicast traffic,
   but they may join multicast groups as recipients. In the private
   network, there are no multicast-aware routers, except for the RSIP
   gateway.

   Private hosts may join and leave multicast groups by sending the
   appropriate IGMP messages to an RSIP gateway (there may be IGMP proxy
   routers between RSIP hosts and gateways). The RSIP gateway will
   coalesce these requests and perform the appropriate actions, whether
   they be to perform a multicast WAN routing protocol, such as PIM, or
   to proxy the IGMP messages to a WAN multicast router. In other
   words, if one or more private hosts request to join a multicast
   group, the RSIP gateway MUST join in their stead, using one of its
   own public IP addresses.

   Note that private hosts do not need to acquire demultiplexing fields
   and use RSIP to receive multicasts. They may receive all multicasts
   using their private addresses, and by private address is how the RSIP
   gateway will keep track of their group membership.

5.4.2. Sending and Receiving Private Hosts, No Multicast Routing
        on Private Network

   This scenarios operates identically to the previous scenario, except
   that when a private host becomes a multicast source, it MUST use RSIP
   and acquire a public IP address (note that it will still receive on
   its private address). A private host sending a multicast will use a
   public source address and tunnel the packets to the RSIP gateway.
   The RSIP gateway will then perform typical RSIP functionality, and
   route the resulting packets onto the public network, as well as back
   to the private network, if there are any listeners on the private
   network.

   If there is more than one sender on the private network, then, to the
   public network it will seem as if all of these senders share the same
   IP address. If a downstream multicasting protocol identifies sources

based on IP address alone and not port numbers, then it is possible
that these protocols will not be able to distinguish between the
senders.

6. RSIP Complications

   In this section we document the know complications that RSIP may
   cause. While none of these complications should be considered "show
   stoppers" for the majority of applications, they may cause unexpected
   or undefined behavior. Where it is appropriate, we discuss potential
   remedial procedures that may reduce or eliminate the deleterious
   impact of a complication.

6.1. Unnecessary TCP TIME_WAIT

   When TCP disconnects a socket, it enters the TCP TIME_WAIT state for
   a period of time. While it is in this state it will refuse to accept
   new connections using the same socket (i.e., the same source
   address/port and destination address/port). Consider the case in
   which an RSIP host (using RSAP-IP) is leased an address/port tuple
   and uses this tuple to contact a public address/port tuple. Suppose
   that the host terminates the session with the public tuple and
   immediately returns its leased tuple to the RSIP gateway. If the
   RSIP gateway immediately allocates this tuple to another RSIP host
   (or to the same host), and this second host uses the tuple to contact
   the same public tuple while the socket is still in the TIME_WAIT
   phase, then the host's connection may be rejected by the public host.

   In order to mitigate this problem, it is recommended that RSIP
   gateways hold recently deallocated tuples for at least two minutes,
   which is the greatest duration of TIME_WAIT that is commonly
   implemented. In situations where port space is scarce, the RSIP
   gateway MAY choose to allocate ports in a FIFO fashion from the pool
   of recently deallocated ports.

6.2. ICMP State in RSIP Gateway

   Like NAT, RSIP gateways providing RSAP-IP must process ICMP responses
   from the public network in order to determine the RSIP host (if any)
   that is the proper recipient. We distinguish between ICMP error
   packets, which are transmitted in response to an error with an
   associated IP packet, and ICMP response packets, which are
   transmitted in response to an ICMP request packet.

   ICMP request packets originating on the private network will
   typically consist of echo request, timestamp request and address mask
   request. These packets and their responses can be identified by the
   tuple of source IP address, ICMP identifier, ICMP sequence number,

and destination IP address. An RSIP host sending an ICMP request
packet tunnels it to the RSIP gateway, just as it does TCP and UDP
packets. The RSIP gateway must use this tuple to map incoming ICMP
responses to the private address of the appropriate RSIP host. Once
it has done so, it will tunnel the ICMP response to the host. Note
that it is possible for two RSIP hosts to use the same values for the
tuples listed above, and thus create an ambiguity. However, this
occurrence is likely to be quite rare, and is not addressed further
in this document.

Incoming ICMP error response messages can be forwarded to the
appropriate RSIP host by examining the IP header and port numbers
embedded within the ICMP packet. If these fields are not present,
the packet should be silently discarded.

Occasionally, an RSIP host will have to send an ICMP response (e.g.,
port unreachable). These responses are tunneled to the RSIP gateway,
as is done for TCP and UDP packets. All ICMP requests (e.g., echo
request) arriving at the RSIP gateway MUST be processed by the RSIP
gateway and MUST NOT be forwarded to an RSIP host.

6.3. Fragmentation and IP Identification Field Collision

If two or more RSIP hosts on the same private network transmit
outbound packets that get fragmented to the same public gateway, the
public gateway may experience a reassembly ambiguity if the IP header
ID fields of these packets are identical.

For TCP packets, a reasonably small MTU can be set so that
fragmentation is guaranteed not to happen, or the likelihood or
fragmentation is extremely small. If path MTU discovery works
properly, the problem is mitigated. For UDP, applications control
the size of packets, and the RSIP host stack may have to fragment UDP
packets that exceed the local MTU. These packets may be fragmented
by an intermediate router as well.

The only completely robust solution to this problem is to assign all
RSIP hosts that are sharing the same public IP address disjoint
blocks of numbers to use in their IP identification fields. However,
whether this modification is worth the effort of implementing is
currently unknown.

6.4. Application Servers on RSAP-IP Hosts

RSAP-IP hosts are limited by the same constraints as NAT with respect
to hosting servers that use a well-known port. Since destination
port numbers are used as routing information to uniquely identify an
RSAP-IP host, typically no two RSAP-IP hosts sharing the same public

IP address can simultaneously operate publically-available gateways
on the same port. For protocols that operate on well-known ports,
this implies that only one public gateway per RSAP-IP IP address /
port tuple is used simultaneously. However, more than one gateway
per RSAP-IP IP address / port tuple may be used simultaneously if and
only if there is a demultiplexing field within the payload of all
packets that will uniquely determine the identity of the RSAP-IP
host, and this field is known by the RSIP gateway.

In order for an RSAP-IP host to operate a publically-available
gateway, the host must inform the RSIP gateway that it wishes to
receive all traffic destined to that port number, per its IP address.
Such a request MUST be denied if the port in question is already in
use by another host.

In general, contacting devices behind an RSIP gateway may be
difficult. A potential solution to the general problem would be an
architecture that allows an application on an RSIP host to register a
public IP address / port pair in a public database. Simultaneously,
the RSIP gateway would initiate a mapping from this address / port
tuple to the RSIP host. A peer application would then be required to
contact the database to determine the proper address / port at which
to contact the RSIP host's application.

6.5. Determining Locality of Destinations from an RSIP Host

In general, an RSIP host must know, for a particular IP address,
whether it should address the packet for local delivery on the
private network, or if it has to use an RSIP interface to tunnel to
an RSIP gateway (assuming that it has such an interface available).

If the RSIP hosts are all on a single subnet, one hop from an RSIP
gateway, then examination of the local network and subnet mask will
provide the appropriate information. However, this is not always the
case.

An alternative that will work in general for statically addressed
private networks is to store a list of the network and subnet masks
of every private subnet at the RSIP gateway. RSIP hosts may query
the gateway with a particular target IP address, or for the entire
list.

If the subnets on the local side of the network are changing more
rapidly than the lifetime of a typical RSIP session, the RSIP host
may have to query the location of every destination that it tries to
communicate with.

If an RSIP host transmits a packet addressed to a public host without
using RSIP, then the RSIP gateway will apply NAT to the packet (if it
supports NAT) or it may discard the packet and respond with and
appropriate ICMP message.

A robust solution to this problem has proven difficult to develop.
Currently, it is not known how severe this problem is. It is likely
that it will be more severe on networks where the routing information
is changing rapidly that on networks with relatively static routes.

6.6. Implementing RSIP Host Deallocation

An RSIP host MAY free resources that it has determined it no longer
requires. For example, on an RSAP-IP subnet with a limited number of
public IP addresses, port numbers may become scarce. Thus, if RSIP
hosts are able to dynamically deallocate ports that they no longer
need, more hosts can be supported.

However, this functionality may require significant modifications to
a vanilla TCP/IP stack in order to implement properly. The RSIP host
must be able to determine which TCP or UDP sessions are using RSIP
resources. If those resources are unused for a period of time, then
the RSIP host may deallocate them. When an open socket's resources
are deallocated, it will cause some associated applications to fail.
An analogous case would be TCP and UDP sessions that must terminate
when an interface that they are using loses connectivity.

On the other hand, this issue can be considered a resource allocation
problem. It is not recommended that a large number (hundreds) of
hosts share the same IP address, for performance purposes. Even if,
say, 100 hosts each are allocated 100 ports, the total number of
ports in use by RSIP would be still less than one-sixth the total
port space for an IP address. If more hosts or more ports are
needed, more IP addresses should be used. Thus, it is reasonable,
that in many cases, RSIP hosts will not have to deallocate ports for
the lifetime of their activity.

Since RSIP demultiplexing fields are leased to hosts, an
appropriately chosen lease time can alleviate some port space
scarcity issues.

6.7. Multi-Party Applications

Multi-party applications are defined to have at least one of the
following characteristics:

   - A third party sets up sessions or connections between two
      hosts.

- Computation is distributed over a number of hosts such that the individual hosts may communicate with each other directly.

RSIP has a fundamental problem with multi-party applications. If some of the parties are within the private addressing realm and others are within the public addressing realm, an RSIP host may not know when to use private addresses versus public addresses. In particular, IP addresses may be passed from party to party under the assumption that they are global endpoint identifiers. This may cause multi-party applications to fail.

There is currently no known solution to this general problem. Remedial measures are available, such as forcing all RSIP hosts to always use public IP addresses, even when communicating only on to other RSIP hosts. However, this can result in a socket set up between two RSIP hosts having the same source and destination IP addresses, which most TCP/IP stacks will consider as intra-host communication.

6.8. Scalability

The scalability of RSIP is currently not well understood. While it is conceivable that a single RSIP gateway could support hundreds of RSIP hosts, scalability depends on the specific deployment scenario and applications used. In particular, three major constraints on scalability will be (1) RSIP gateway processing requirements, (2) RSIP gateway memory requirements, and (3) RSIP negotiation protocol traffic requirements. It is advisable that all RSIP negotiation protocol implementations attempt to minimize these requirements.

7. Security Considerations

RSIP, in and of itself, does not provide security. It may provide the illusion of security or privacy by hiding a private address space, but security can only be ensured by the proper use of security protocols and cryptographic techniques.

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