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IP Router Alert Considerations and Usage
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Abstract

The IP Router Alert Option is an IP option that alerts transit routers to more closely examine the contents of an IP packet. RSVP, PGM, IGMP/MLD, MRD and GIST are some of the protocols that make use of the IP Router Alert option. This document discusses security aspects and usage guidelines around the use of the current IP Router Alert option. Specifically, it provides recommendation against using the Router Alert in the end-to-end open Internet as well as identify controlled environments where protocols depending on Router Alert can be used safely. It also provides recommendation about protection approaches for Service Providers. Finally it provides brief guidelines for Router Alert implementation on routers.

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1. Terminology

For readability, this document uses the following loosely defined terms:

- Slow path : Software processing path for packets
- Fast path : ASIC/Hardware processing path for packets

1.1. Conventions Used in This Document

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 [RFC2119].

2. Introduction

[RFC2113] and [RFC2711] respectively define the IPv4 and IPv6 Router Alert Option (RAO). In this document, we collectively refer to those as the IP Router Alert. The IP Router Alert Option is an IP option that alerts transit routers to more closely examine the contents of an IP packet.

RSVP ([RFC2205], [RFC3175], [RFC3209]), PGM ([RFC3208]), IGMP ([RFC3376]), MLD ([RFC2710], [RFC3810]), MRD ([RFC4286]) and NSIS General Internet Signalling Transport (GIST) ([I-D.ietf-nsis-ntlp]) are some of the protocols that make use of the IP Router Alert.

Section 3 describes the security concerns associated with the use of the Router Alert option.

Section 4 provides guidelines for the use of Router Alert. More specifically, Section 4.1 recommends that Router Alert not be used for end to end applications over the Internet, while Section 4.2 presents controlled environments where applications/protocols relying on IP Router Alert can be deployed effectively and safely. Section 4.3 provides recommendations on protection approaches to be used by Service Providers in order to protect their network from Router Alert based attacks.

Finally, Section 5 provides generic recommendations for router implementation of Router Alert aiming at increasing protection against attacks.

The present document discusses considerations and practises based on the current specification of IP Router Alert ([RFC2113], [RFC2711]). Possible future enhancements to the specification of IP Router Alert (in view of reducing the security risks associated with the use of IP Router Alert) are outside the scope of this document. A proposal for such enhancements can be found in [I-D.narayanan-rtg-router-alert-extension].

The IPv6 base specification [RFC2460] defines the hop-by-hop option extension header. The hop-by-hop option header is used to carry optional information that must be examined by every node along a packet's delivery path. The IPv6 Router Alert Option is one particular hop by hop option. Similar security concerns to those discussed in the present document for the IPv6 Router Alert apply more generically to the concept of IPv6 hop-by-hop option extension header. However, addressing the broader concept of IPv6 hop-by-hop option thoroughly would require additional material so as to cover additional considerations associated with it (such as the attacks effectiveness depending on how many options are included and on the

range from to which the option-type value belongs, etc.), so this is kept outside the scope of the present document. A detailed discussion about security risks and proposed remedies associated with IPv6 hop-by-hop option can be found in [I-D.krishnan-ipv6-hopbyhop].

The IPv4 base specification [RFC0791] defines a general notion of IPv4 options that can be included in the IPv4 header (without distinguishing between hop-by-hop versus end-to-end option). The IPv4 Router Alert Option is one particular IPv4 option. Similar security concerns to those discussed in the present document for the IPv4 Router Alert apply more generically to the concept of IPv4 option. However, addressing the broader concept of IPv4 option thoroughly would require additional material so as to cover additional considerations associated with it (such as lack of option ordering, etc.), so this is kept outside the scope of the present document.

3. Security Concerns of Router Alert

The IP Router Alert option is defined ([RFC2113], [RFC2711]) as a mechanism that alerts transit routers to more closely examine the contents of an IP packet. [RFC4081] and [RFC2711] mention the security risks associated with the use of the IP Router Alert: flooding a router with bogus (or simply undesired) IP datagrams which contain the IP Router Alert could impact operation of the router in undesirable ways. For example, assuming the router punts the datagrams containing the IP Router Alert option to the slow path, such an attack could consume a significant share of the router's slow path and could also lead to packet drops in the slow path (thus, affecting operation of all other applications and protocols operating in the slow path).

Furthermore, [RFC2113] specifies no (and [RFC2711] specifies very limited) mechanism for identifying different users of IP Router Alert. As a result, many fast switching implementations of IP Router Alert punt most/all packets marked with IP Router Alert into the slow path (unless configured to systematically ignore or drop all Router Alert packets).

Some IP Router Alert implementations may be able to take into account the IP PID [RFC0791] as a discriminator for the punting decision for different protocols using IP Router Alert. However, this still only allows very coarse triage among various protocols using IP Router Alert for two reasons. First, the IP PID is the same when IP Router Alert is used for different applications of the same protocol (e.g., RSVP vs. RSVP-TE), or when IP Router Alert is used for different contexts of the same application (e.g., different levels of RSVP aggregation [RFC3175]). Thus, it is not possible to achieve the necessary triage in the fast path across IP Router Alert packets from different applications or from different contexts of an application. Secondly, some protocols requiring punting may be carried over a transport protocol (e.g., TCP or UDP) possibly because they require the services of that transport protocol or perhaps because the protocol does not justify allocation of a scarce IP PID value. Thus, considering the PID does not allow triage in the fast path of IP Router Alert packets from different protocols sharing the same transport protocol. Therefore, It is generally not possible to ensure that only the IP Router Alert packets of interest are punted to the slow path while other IP Router Alert packets are efficiently forwarded (i.e., in fast path).

Some IP Router Alert implementations may be able to take into account the value field inside the router alert option. However, only one value (zero) was defined in [RFC2113] and no IANA registry for IPv4 Router Alert values was available until recently. So this did not

allow most IPv4 Router Alert implementation to support useful classification based on the value field in the fast path. Also, while [RFC2113] states that unknown values should be ignored (i.e. The packets should be forwarded as normal IP traffic), it has been reported that some existing implementations simply ignore the value field completely (i.e. Process any packet with an IPv4 Router Alert regardless of its option value). An IANA registry for further allocation of IPv4 Router Alert values has been introduced recently ([RFC5350]) but this would only allow coarse-grain classification, when, and if, supported by implementations. For IPv6, [RFC2711] states that "the value field can be used by an implementation to speed processing of the datagram within the transit router" and defines an IANA registry for these values. But again, this only allows coarse-grain classification. Besides, some existing IPv6 Router Alert implementations are reported to depart from that behavior.

[RFC2711] mentions that limiting, by rate or some other means, the use of IP Router Alert option is a way of protecting against a potential attack. However, if rate limiting is used as a protection mechanism but if the granularity of the rate limiting is not fine enough to distinguish among IP Router Alert packet of interest from unwanted IP Router Alert packet, a IP Router Alert attack could still severely degrade operation of protocols of interest that depend on the use of IP Router Alert.

In a nutshell, the IP router alert option does not provide a convenient universal mechanism to accurately and reliably distinguish between IP Router Alert packets of interest and unwanted IP Router Alert packets. This, in turn, creates a security concern when IP Router Alert option is used, because, short of appropriate router implementation specific mechanisms, the router slow path is at risk of being flooded by unwanted traffic.

It can be observed that opening up a hole in the control plane of Service Provider routers is commonly done for other applications such as BGP peering. However, the resulting DOS attack vector is arguably more serious with Router Alert option than with BGP peering for a number of reasons including:

- with BGP Peering, the control plane hole is only open on the edge routers and core routers are completely isolated from any direct control plane exchange with entities outside the administrative domain; with BGP, a DOS attack would only affect the edge router(s), while with Router Alert option, the attack could propagate to core routers;

- with BGP, the BGP policy control would typically prevent re-injection of undesirable information out of the attacked device, while with Router-Alert option, the non-filtered attacking messages would typically be forwarded downstream.

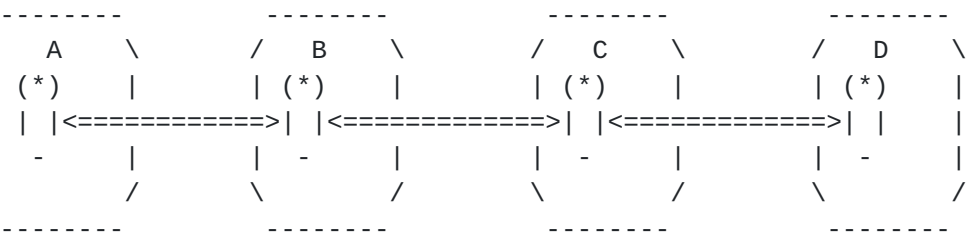
- With BGP, edge routers only exchange control plane information with pre-identified peers and can easily filter out any control plane traffic coming from other peers, while the Router-Alert option can be received in a datagram with any destination address and any destination source.

4. Guidelines for use of Router Alert

4.1. Use of Router Alert End-to-End In the Internet (Router Alert in Peer Model)

Because of the security concerns associated with Router Alert discussed in Section 3, network operators need to actively protect themselves against externally generated IP Router Alert packets. Because there is no convenient universal mechanisms to triage between desired and undesired router alert packets, network operators currently often protect themselves in ways that isolate them from externally generated IP Router Alert packets. This may (ideally) be achieved by tunneling IP Router Alert packets [I-D.dasmith-mpls-ip-options] so that the IP Router Alert option is hidden through that network, or it may be achieved via mechanisms resulting in occasional (e.g., rate limiting) or systematic drop of IP Router Alert packets.

Thus, it is RECOMMENDED that applications and protocols not be deployed with a dependency on processing of the Router Alert option (as currently specified) across independent administrative domains in the Internet. Figure 1 illustrates such a hypothetical use of Router Alert end-to-end in the Internet. We refer to such a model of Router Alert option use as a "Peer Model" Router Alert option use, since core routers in different administrative domains would partake in processing of Router Alert option datagrams associated with the same signalling flow.



(*) closer examination of Router Alert option datagrams

<==> flow of Router Alert option datagrams

Figure 1: Use of Router Alert End-to-End in the Open Internet (Router Alert in Peer Model)

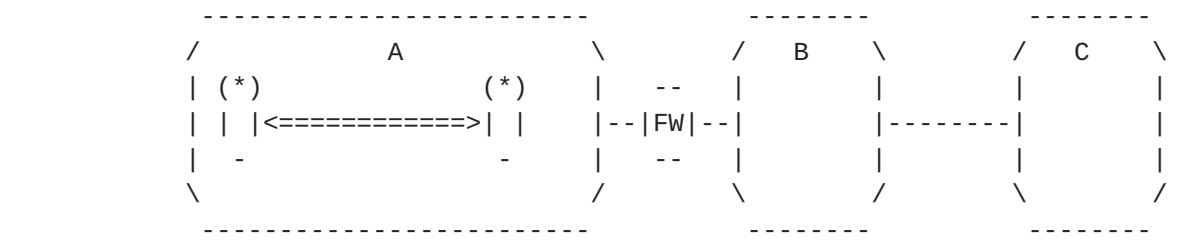
While this recommendation is framed here specifically in the context of router alert, the fundamental security risk that network operators want to preclude is to allow devices/protocols that are outside of their administrative domain (and therefore not controlled) to tap

into the control plane of their core routers. Whether this control plane access is provided through router alert option or would be provided by any other mechanism (e.g. Deep packet inspection) probably results in similar security concerns. In other words, the fundamental security concern is associated with the notion of end to end signaling in a Peer Model across domains in the Internet. As a result, it is expected that network operators would typically not want to have their core routers partake in end-to-end signalling with external uncontrolled devices through the open Internet, and therefore prevent deployment of end to end signalling in a Peer model through their network (regardless of whether that signalling uses Router Alert or not).

4.2. Use of Router Alert In Controlled Environments

4.2.1. Use of Router Alert Within an Administrative Domain

In some controlled environments such as within a given Administrative Domain, the network administrator can determine that IP Router Alert packets will only be received from trusted well-behaved devices or can establish that specific protection mechanisms (e.g., RAO filtering and rate-limiting) against the plausible RAO-based DoS attacks are sufficient. In that case, an application relying on exchange and handling of RAO packets (e.g., RSVP) MAY be safely deployed within the controlled network. A private enterprise network firewalled from the Internet and using RSVP reservations for voice and video flows may be an example of such controlled environment. Such an environment is illustrated in Figure 2.



(*) closer examination of Router Alert option datagrams

<==> flow of Router Alert option datagrams

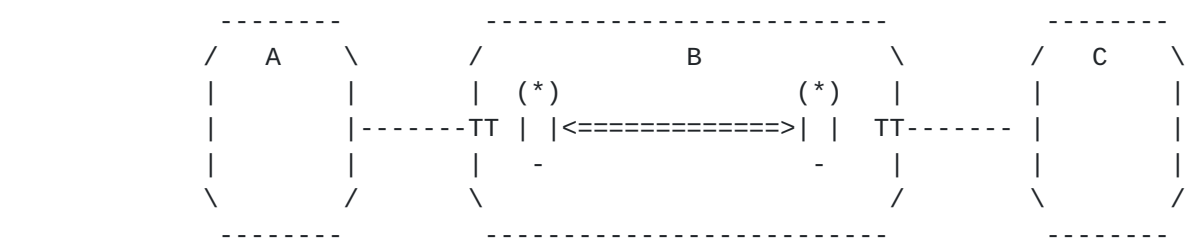
FW Firewall

Figure 2: Use of Router Alert Within an Administrative Domain

In some controlled environments, several Administrative Domains have

a special relationship whereby they cooperate very tightly and effectively operate as a single trust domain. In that case, one domain is willing to trust another with respect to the traffic injected across the boundary. In other words, a downstream domain is willing to trust that the traffic injected at the boundary has been properly validated/filtered by the upstream domain. Where it has been established that such trust can be applied to router alert option packets, an application relying on exchange and handling of RAO packets (e.g., RSVP) MAY be safely deployed within such a controlled environment. The entity within a company responsible for operating multimedia endpoints and the entity within the same company responsible for operating the network may be an example of such controlled environment. For example, they may collaborate so that RSVP reservations can be used for video flows from endpoints to endpoints through the network.

In some environments, the network administrator can reliably ensure that router alert packets from any untrusted device (e.g., from external routers) are prevented from entering a trusted area (e.g., the internal routers). For example, this may be achieved by ensuring that routers straddling the trust boundary (e.g., edge routers) always encapsulate those packets (without setting IP Router Alert -or equivalent- in the encapsulating header) through the trusted area (as discussed in [I-D.dasmith-mpls-ip-options]). In such environments, the risks of DOS attacks through the IP Router Alert vector is removed in the trusted area (or greatly reduced) even if IP Router Alert is used inside the trusted area (say for RSVP-TE). Thus an application relying on IP Router Alert MAY be safely deployed within the trusted area. A Service Provider running RSVP-TE within his network may be an example of such protected environment. Such an environment is illustrated in Figure 3.



(*) closer examination of Router Alert option datagrams

<==> flow of Router Alert option datagrams

TT Tunneling of Router Alert option datagrams

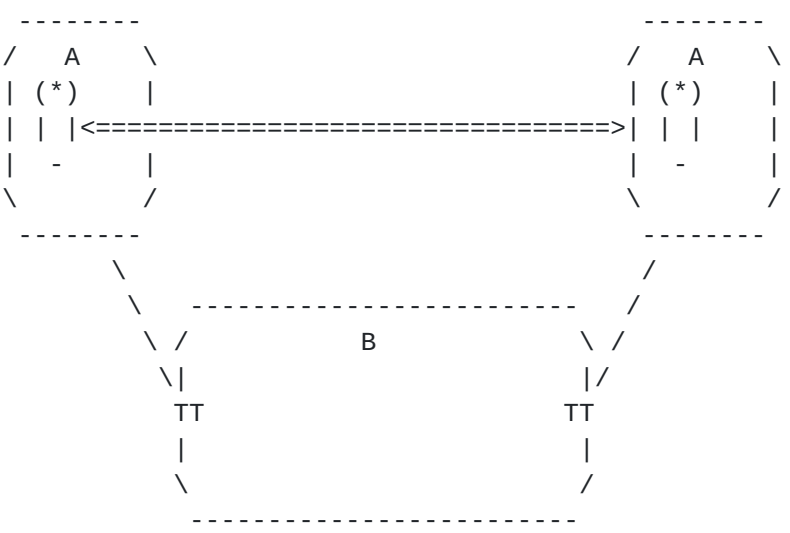
Figure 3: Use of Router Alert Within an Administrative Domain

4.2.2. Use of Router Alert In Overlay Model

In some controlled environment:

- the sites of a network A are interconnected through a service provider network B
- the service provider network B protects itself from IP Router Alert messages without dropping those when they transit over the transit network (for example using mechanisms discussed in [I-D.dasmith-mpls-ip-options])

In such controlled environment, an application relying on exchange and handling of RAO packets (e.g., RSVP) in the network A sites (but not inside network B) MAY be safely deployed. We refer to such a deployment as a use of Router Alert in a Water-Tight Overlay. "Overlay" because Router Alert option datagrams are used in network A on top of, and completely transparently to, network B. "Water-Tight" because router alert option datagrams from A cannot leak inside network B. A private enterprise intranet, whose sites are interconnected through a Service Prover network, and using RSVP to perform reservations within the enterprise sites for voice and video flows may be an example of such controlled environment. Such an environment is illustrated in Figure 4.



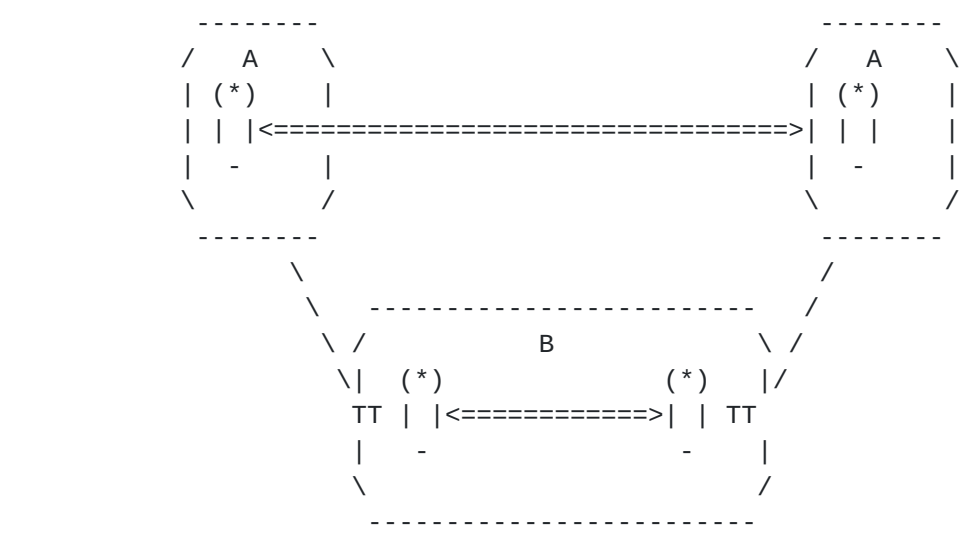
(*) closer examination of Router Alert option datagrams

<==> flow of Router Alert option datagrams

TT Tunneling of Router Alert option datagrams

Figure 4: Use of Router Alert In Water-tight Overlay

In the controlled environment described above, an application relying on exchange and handling of RAO packets (e.g. RSVP-TE) in the service provider network B (but not in network A) MAY also be safely deployed simultaneously. Such an environment with independent, isolated, deployment of router alert in overlay at two levels is illustrated in Figure 5.



(*) closer examination of Router Alert option datagrams

<==> flow of Router Alert option datagrams

TT Tunneling of Router Alert option datagrams

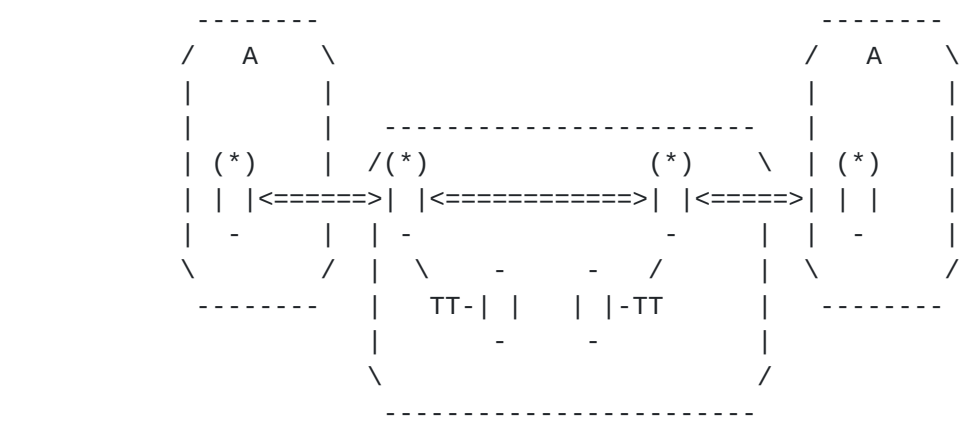
Figure 5: Use of Router Alert In Water-tight Overlay at Two Levels

In some controlled environment:

- the sites of a network A are interconnected through a service provider network B
- the service provider B processes router alert packets on the edge routers and protect these edge routers against RAO based attacks using mechanisms such as (possibly per port) RAO rate limiting and filtering
- the service provider network B protects its core routers from Router Alert messages without dropping those when they transit over the transit network (for example using mechanisms discussed in [I-D.dasmith-mpls-ip-options])

In such controlled environment, an application relying on exchange and handling of RAO packets (e.g., RSVP) in the network A sites and in network B Edges (but not in the core of network B) MAY be safely deployed. We refer to such a deployment as a use of Router Alert in a Leak-Controlled Overlay. "Overlay" because Router Alert option datagrams are used in network A on top of, and completely transparently to, network B core. "Leak-Controlled" because router alert option datagrams from A leak inside network B's B edges but not

inside network B's core. A private enterprise intranet, whose sites are interconnected through a Service Prover network, using RSVP for voice and video within network A sites as well as on Network B's edge to extend the reservation onto the attachment links between A and B (as specified in [I-D.ietf-tsvwg-rsvp-l3vpn]) may be an example of such controlled environment. Such an environment is illustrated in Figure 4.



(*) closer examination of Router Alert option datagrams

<==> flow of Router Alert option datagrams

TT Tunneling of Router Alert option datagrams

Figure 6: Use of Router Alert In Leak-Controlled Overlay

4.3. Router Alert Protection Approaches for Service Providers

Section 3 discusses the security risks associated with the use of the IP Router Alert and how it opens up a DOS vector in the router control plane. Thus, it is RECOMMENDED that a Service Provider implements strong protection of his network against attacks based on IP Router Alert.

As discussed in Section 4.2.2 some applications can benefit from the use of IP Router Alert packets in an Overlay model (i.e. Where Router Alert packets are exchanged transparently on top of a Service Provider). Thus, it is RECOMMENDED that a Service Provider protects his network from attacks based on IP Router Alert using mechanisms that avoid (or at least minimize) dropping of end to end IP Router Alert packets (other than those involved in an attack).

For example, if the Service Provider does not run any protocol depending on IP Router Alert within his network, he may elect to

simply turn-off punting/processing of IP Router Alert packet on his routers; this will ensure that end-to-end IP Router Alert packet transit transparently and safely through his network.

As another example, using protection mechanisms such selective filtering and rate-limiting (that Section 5 suggests be supported by IP Router Alert implementations) a Service Provider can protect the operation of a protocol depending on IP Router Alert within his network (e.g., RSVP-TE) while at the same time transporting IP Router Alert packets carrying another protocol that may be used end to end. Note that the Service Provider might additionally use protocol specific mechanisms that reduce the dependency on Router Alert for operation of this protocol inside the Service Provider environment; use of RSVP refresh reduction mechanisms ([RFC2961]) would be an example of such mechanisms in the case where the Service Provider is running RSVP-TE within his network since this allows refresh of existing Path and Resv states without use of the IP Router Alert option.

As yet another example, using mechanisms such as those discussed in [I-D.dasmith-mpls-ip-options] a Service Provider can safely protect the operation of a protocol depending on IP Router Alert within his network (e.g., RSVP-TE) while at the same time safely transporting IP Router Alert packets carrying another protocol that may be used end to end (e.g., IPv4/IPv6 RSVP).

As a last resort, if the SP does not have any means to safely transport end to end IP Router Alert option packets over his network, the SP MAY drop those packets. It must be noted that this has the undesirable consequence of preventing the use of the Router Alert option in the Overlay Model on top of this network, and therefore prevents users of that network from deploying a number of valid applications/protocols in their environment.

5. Guidelines for Router Alert Implementation

It is RECOMMENDED that router implementations of IP Router Alert option include protection mechanisms against Router Alert based DOS attacks appropriate for their targeted deployment environments. For example, this can include ability on an edge router to "tunnel" IP Router Alert option of received packets when forwarding those over the core as discussed in [I-D.dasmith-mpls-ip-options]. As another example, although not always available from current implementations, new implementations may include protection mechanisms such as selective (possibly dynamic) filtering and rate-limiting of IP Router Alert option packets.

If an IP packet contains the IP Router Alert option, but the payload protocol is not explicitly identified as a Payload of interest by the router examining the packet, the behavior is not explicitly defined by [RFC2113]. However, the behavior is implied and, for example, the definition of RSVP in [RFC2205] assumes that the packet will be forwarded using normal forwarding based on the destination IP address. Thus, a router implementation SHOULD forward within the "fast path" (subject to all normal policies and forwarding rules) a packet carrying the IP Router Alert option containing a payload that is not a payload of interest to that router. The "not passing" behavior protects the router from DOS attacks using IP Router Alert packets of a protocol unknown to the router. The "forwarding" behavior contributes to transparent end to end transport of IP Router Alert packets (e.g., to facilitate their use by end to end application).

6. Security Considerations

This document discusses security risks associated with current usage of the IP Router Alert Option and associated practices.

7. IANA Considerations

None.

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