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Embedding the Rendezvous Point (RP) Address in an IPv6 Multicast Address

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Abstract

This memo defines an address allocation policy in which the address of the Rendezvous Point (RP) is encoded in an IPv6 multicast group address. For Protocol Independent Multicast - Sparse Mode (PIM-SM), this can be seen as a specification of a group-to-RP mapping mechanism. This allows an easy deployment of scalable inter-domain multicast and simplifies the intra-domain multicast configuration as well. This memo updates the addressing format presented in RFC 3306.

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1. Introduction

1.1. Background

As has been noticed [V6MISSUES], there exists a deployment problem with global, interdomain IPv6 multicast: PIM-SM [PIM-SM] RPs have no way of communicating the information about (active) multicast sources to other multicast domains, as Multicast Source Discovery Protocol (MSDP) [MSDP] has deliberately not been specified for IPv6. Therefore the whole interdomain Any Source Multicast (ASM) model is rendered unusable; Source-Specific Multicast (SSM) [SSM] avoids these problems but is not a complete solution for several reasons, as noted below.

Further, it has been noted that there are some problems with the support and deployment of mechanisms SSM would require [V6MISSUES]: it seems unlikely that SSM could be usable as the only interdomain multicast routing mechanism in the short term.

1.2. Solution

This memo describes a multicast address allocation policy in which the address of the RP is encoded in the IPv6 multicast group address, and specifies a PIM-SM group-to-RP mapping to use the encoding, leveraging, and extending unicast-prefix-based addressing [RFC3306].

This mechanism not only provides a simple solution for IPv6 interdomain Any Source Multicast but can be used as a simple solution for IPv6 intra-domain ASM with scoped multicast addresses as well.

It can also be used as an automatic RP discovery mechanism in those deployment scenarios that would have previously used the Bootstrap Router protocol (BSR) [BSR].

The solution consists of three elements:

- A specification of a subrange of [RFC3306] IPv6 multicast group addresses defined by setting one previously unused bit of the Flags field to "1",
- a specification of the mapping by which such a group address encodes the RP address that is to be used with this group, and
- a description of operational procedures to operate ASM with PIM-SM on these IPv6 multicast groups.

Addresses in the subrange will be called embedded-RP addresses.

This scheme obviates the need for MSDP, and the routers are not required to include any multicast configuration, except when they act as an RP.

This memo updates the addressing format presented in RFC 3306.

Some design tradeoffs are discussed in Appendix A.

1.3. Assumptions and Scope

A 128-bit RP address can't be embedded into a 128-bit group address with space left to carry the group identity itself. An appropriate form of encoding is thus defined by requiring that the Interface-IDs of RPs in the embedded-RP range can be assigned to be a specific value.

If these assumptions can't be followed, operational procedures and configuration must be slightly changed, or this mechanism can't be used.

The assignment of multicast addresses is outside the scope of this document; it is up to the RP and applications to ensure that group addresses are unique by using some unspecified method. However, the mechanisms are probably similar to those used with [RFC3306].

Similarly, RP failure management methods, such as Anycast-RP, are out of scope for this document. These do not work without additional specification or deployment. This is covered briefly in Section 6.1.

1.4. Terminology

Embedded-RP behaves as if all the members of the group were intra-domain to the information distribution. However, as it gives a solution for the global IPv6 multicast Internet, spanning multiple administrative domains, we say it is a solution for inter-domain multicast.

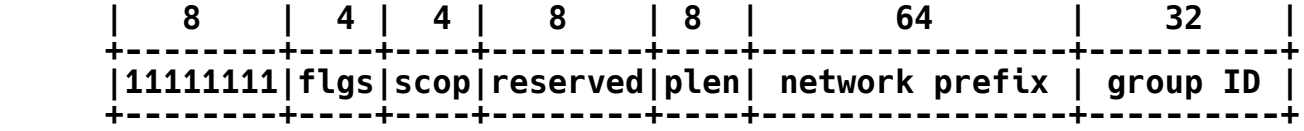
The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in [RFC2119].

1.5. Abbreviations

ASM	Any Source Multicast
BSR	Bootstrap Router
DR	Designated Router
IGP	Interior Gateway Protocol
MLD	Multicast Listener Discovery
MSDP	Multicast Source Discovery Protocol
PIM	Protocol Independent Multicast
PIM-SM	Protocol Independent Multicast - Sparse Mode
RIID	RP Interface ID (as specified in this memo)
RP	Rendezvous Point
RPF	Reverse Path Forwarding
SPT	Shortest Path Tree
SSM	Source-Specific Multicast

2. Unicast-Prefix-based Address Format

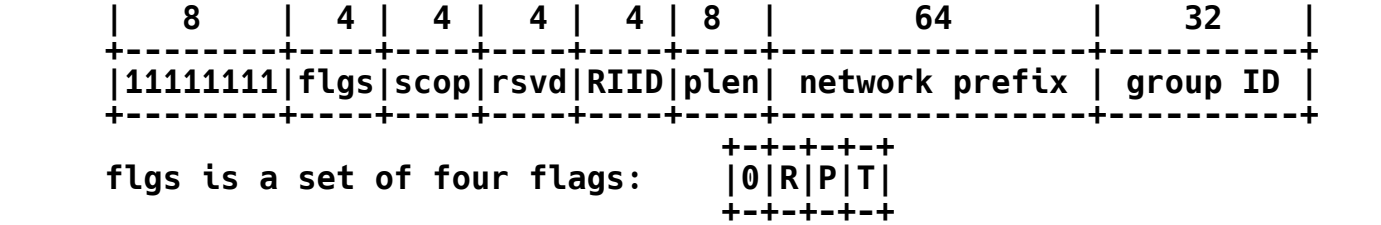
As described in [RFC3306], the multicast address format is as follows:



Where flgs are "0011". (The first two bits are as yet undefined, sent as zero and ignored on receipt.)

3. Modified Unicast-Prefix-based Address Format

This memo specifies a modification to the unicast-prefix-based address format by specifying the second high-order bit ("R-bit") as follows:



When the highest-order bit is 0, R = 1 indicates a multicast address that embeds the address on the RP. Then P MUST be set to 1, and consequently T MUST be set to 1, as specified in [RFC3306]. In effect, this implies the prefix FF70::/12. In this case, the last 4 bits of the previously reserved field are interpreted as embedding the RP interface ID, as specified in this memo.

The behavior is unspecified if P or T is not set to 1, as then the prefix would not be FF70::/12. Likewise, the encoding and the protocol mode used when the two high-order bits in "flgs" are set to 11 ("FFF0::/12") is intentionally unspecified until such time that the highest-order bit is defined. Without further IETF specification, implementations SHOULD NOT treat the FFF0::/12 range as Embedded-RP.

R = 0 indicates a multicast address that does not embed the address of the RP and follows the semantics defined in [ADDRARCH] and [RFC3306]. In this context, the value of "RIID" MUST be sent as zero and MUST be ignored on receipt.

4. Embedding the Address of the RP in the Multicast Address

The address of the RP can only be embedded in unicast-prefix-based ASM addresses.

That is, to identify whether it is a multicast address as specified in this memo and to be processed any further, an address must satisfy all of the following:

- It MUST be a multicast address with "flgs" set to 0111, that is, to be of the prefix FF70::/12,
- "plen" MUST NOT be 0 (i.e., not SSM), and

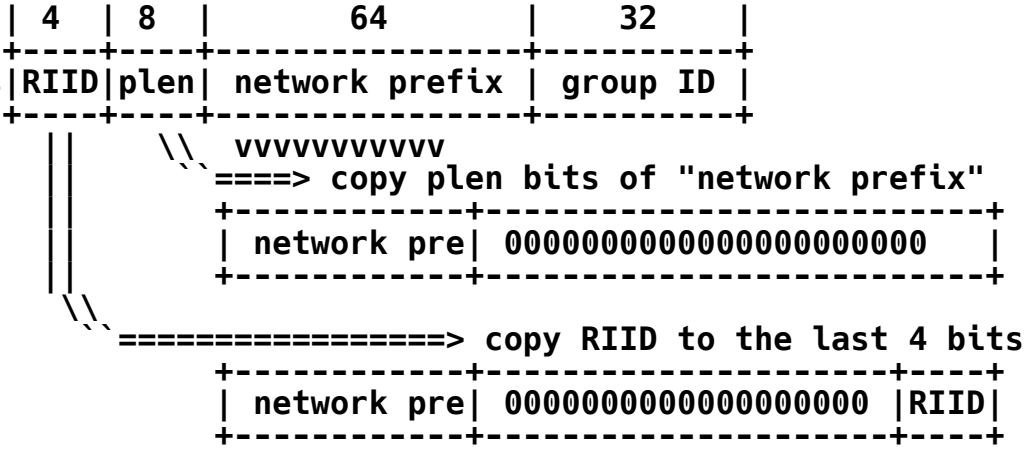
o "plen" MUST NOT be greater than 64.

The address of the RP can be obtained from a multicast address satisfying the above criteria by taking the following two steps:

1. Copy the first "plen" bits of the "network prefix" to a zeroed 128-bit address structure, and

2. replace the last 4 bits with the contents of "RIID".

These two steps could be illustrated as follows:



One should note that there are several operational scenarios (see Example 3 below) when the [RFC3306] statement "all non-significant bits of the network prefix field SHOULD be zero" is ignored. This is to allow multicast group address allocations to be consistent with unicast prefixes; the multicast addresses would still use the RP associated with the network prefix.

"plen" higher than 64 MUST NOT be used, as that would overlap with the high-order bits of multicast group-id.

When processing an encoding to get the RP address, the multicast routers MUST perform at least the same address validity checks to the calculated RP address as to one received via other means (like BSR [BSR] or MSDP for IPv4). At least fe80::/10, ::/16, and ff00::/8 MUST be excluded. This is particularly important, as the information is obtained from an untrusted source, i.e., any Internet user's input.

One should note that the 4 bits reserved for "RIID" set the upper bound for RPs for the combination of scope, network prefix, and group ID -- without varying any of these, one can have 2^4-1 = 15 different

RPs (as RIID=0 is reserved, see section 6.3). However, each of these is an IPv6 group address of its own (i.e., there can be only one RP per multicast address).

5. Examples

Four examples of multicast address allocation and resulting group-to-RP mappings are described here to better illustrate the possibilities provided by the encoding.

5.1. Example 1

The network administrator of 2001:DB8::/32 wants to set up an RP for the network and all the customers, by placing it on an existing subnet, e.g., 2001:DB8:BEEF:FEED::/64.

In that case, the group addresses would be something like "FF7x:y40:2001:DB8:BEEF:FEED::/96", and then their RP address would be "2001:DB8:BEEF:FEED::y". There are still 32 bits of multicast group-ids to assign to customers and self ("y" could be anything from 1 to F, as 0 must not be used).

5.2. Example 2

As in Example 1, the network administrator of 2001:DB8::/32 wants to set up the RP but, to make it more flexible, wants to place it on a specifically routed subnet and wants to keep larger address space for group allocations. That is, the administrator selects the least specific part of the unicast prefix, with plen=32, and the group addresses will be from the multicast prefix:

FF7x:y20:2001:DB8::/64

where "x" is the multicast scope, "y" is the interface ID of the RP address, and there are 64 bits for group-ids or assignments. In this case, the address of the RP would be:

2001:DB8::y

The address 2001:DB8::y/128 is assigned to a router as a loopback address and is injected into the routing system; if the network administrator sets up only one or two RPs (and, e.g., not one RP per subnet), this approach may be preferable to the one described in Example 1.

5.3. Example 3

As in Example 2, the network administrator can also assign multicast prefixes such as "FF7x:y20:2001:DB8:DEAD::/80" to some of customers. In this case the RP address would still be "2001:DB8::y". (Note that this is just a more specific subcase of Example 2, where the administrator assigns a multicast prefix, not just individual group-ids.)

Note the second rule of deriving the RP address: the "plen" field in the multicast address, 0x20 = 32, refers to the length of "network prefix" field considered when obtaining the RP address. In this case, only the first 32 bits of the network prefix field, "2001:DB8", are preserved: the value of "plen" takes no stance on actual unicast/multicast prefix lengths allocated or used in the networks, here from 2001:DB8:DEAD::/48.

In short, this distinction allows more flexible RP address configuration in the scenarios where it is desirable to have the group addresses be consistent with the unicast prefix allocations.

5.4. Example 4

In the network of Examples 1, 2, and 3, the network admin sets up addresses for use by customers, but an organization wants to have its own PIM-SM domain. The organization can pick multicast addresses such as "FF7x:y30:2001:DB8:BEEF::/80", and then the RP address would be "2001:DB8:BEEF::y".

6. Operational Considerations

This section describes the major operational considerations for those deploying this mechanism.

6.1. RP Redundancy

A technique called "Anycast RP" is used within a PIM-SM domain to share an address and multicast state information between a set of RPs mainly for redundancy purposes. Typically, MSDP has been used for this as well [ANYCASTRP]. There are also other approaches, such as using PIM for sharing this information [ANYPIMRP].

The most feasible candidate for RP failover is using PIM for Anycast RP or "anycasting" (i.e., the shared-unicast model [ANYCAST]) the RP address in the Interior Gateway Protocol (IGP) without state sharing (although depending on the redundancy requirements, this may or may not be enough). However, the redundancy mechanisms are outside of the scope of this memo.

6.2. RP Deployment

As there is no need to share inter-domain state with MSDP, each Designated Router connecting multicast sources could act as an RP without scalability concerns about setting up and maintaining MSDP sessions.

This might be particularly attractive when one is concerned about RP redundancy. In the case where the DR close to a major source for a group acts as the RP, a certain amount of fate-sharing properties can be obtained without using any RP failover mechanisms: if the DR goes down, the multicast transmission may not work anymore in any case.

Along the same lines, its may also be desirable to distribute the RP responsibilities to multiple RPs. As long as different RPs serve different groups, this is trivial: each group could map to a different RP (or sufficiently many different RPs that the load on one RP is not a problem). However, load sharing challenges one group faces are similar to those of Anycast-RP.

6.3. Guidelines for Assigning IPv6 Addresses to RPs

With this mechanism, the RP can be given basically any unicast network prefix up to /64. The interface identifier will have to be manually configured to match "RIID".

RIID = 0 must not be used, as using it would cause ambiguity with the Subnet-Router Anycast Address [ADDRARCH].

If an administrator wishes to use an RP address that does not conform to the addressing topology but is still from the network provider's unicast prefix (e.g., an additional loopback address assigned on a router, as described in Example 2 in Section 5.1), that address can be injected into the routing system via a host route.

6.4. Use as a Substitute for BSR

With embedded-RP, use of BSR or other RP configuration mechanisms throughout the PIM domain is not necessary, as each group address specifies the RP to be used.

6.5. Controlling the Use of RPs

Compared to the MSDP inter-domain ASM model, the control and management of who can use an RP, and how, changes slightly and deserves explicit discussion.

MSDP advertisement filtering typically includes at least two capabilities: filtering who is able to create a global session ("source filtering") and filtering which groups should be globally accessible ("group filtering"). These are done to prevent local groups from being advertised to the outside or unauthorized senders from creating global groups.

However, such controls do not yet block the outsiders from using such groups, as they could join the groups even without Source Active advertisement with a (Source, Group) or (S,G) Join by guessing/learning the source and/or the group address. For proper protection, one should set up, for example, PIM multicast scoping borders at the border routers. Therefore, embedded-RP has by default a roughly equivalent level of "protection" as MSDP with SA filtering.

A new issue with control is that nodes in a "foreign domain" may register to an RP, or send PIM Join to an RP. (These have been possible in the past as well, to a degree, but only through willful attempts or purposeful RP configuration at DRs.) The main threat in this case is that an outsider may illegitimately use the RP to host his/hers own group(s). This can be mitigated to an extent by filtering which groups or group ranges are allowed at the RP; more specific controls are beyond the scope of this memo. Note that this does not seem to be a serious threat in the first place, as anyone with a /64 unicast prefix can create their own RP without having to illegitimately get it from someone else.

7. The Embedded-RP Group-to-RP Mapping Mechanism

This section specifies the group-to-RP mapping mechanism for Embedded RP.

7.1. PIM-SM Group-to-RP Mapping

The only PIM-SM modification required is implementing this mechanism as one group-to-RP mapping method.

The implementation will have to recognize the address format and derive and use the RP address by using the rules in Section 4. This information is used at least when performing Reverse Path Forwarding (RPF) lookups, when processing Join/Prune messages, or performing Register-encapsulation.

To avoid loops and inconsistencies, for addresses in the range FF70::/12, the Embedded-RP mapping MUST be considered the longest possible match and higher priority than any other mechanism.

It is worth noting that compared to the other group-to-RP mapping mechanisms, which can be precomputed, the embedded-RP mapping must be redone for every new IPv6 group address that would map to a different RP. For efficiency, the results may be cached in an implementation-specific manner, to avoid computation for every embedded-RP packet.

This group-to-RP mapping mechanism must be supported by the RP, the DR adjacent to the senders, and any router on the path from any receiver to the RP. Paths for Shortest Path Tree (SPT) formation and Register-Stop do not require the support, as those are accomplished with an (S,G) Join.

7.2. Overview of the Model

This section gives a high-level, non-normative overview of how Embedded RP operates, as specified in the previous section.

The steps when a receiver wishes to join a group are as follows:

1. A receiver finds out a group address by some means (e.g., SDR or a web page).

2. The receiver issues an Multicast Listener Discovery (MLD) Report, joining the group.

3. The receiver's DR will initiate the PIM-SM Join process towards the RP encoded in the multicast address, irrespective of whether it is in the "local" or "remote" PIM domain.

The steps when a sender wishes to send to a group are as follows:

1. A sender finds out a group address by using an unspecified method (e.g., by contacting the administrator for group assignment or using a multicast address assignment protocol).

2. The sender sends to the group.

3. The sender's DR will send the packets unicast-encapsulated in PIM-SM Register-messages to the RP address encoded in the multicast address (in the special case that DR is the RP, such sending is only conceptual).

In fact, all the messages go as specified in [PIM-SM]; embedded-RP just acts as a group-to-RP mapping mechanism. Instead of obtaining the address of the RP from local configuration or configuration protocols (e.g., BSR), the algorithm derives it transparently from the encoded multicast address.

8. Scalability Analysis

Interdomain MSDP model for connecting PIM-SM domains is mostly hierarchical in configuration and deployment, but flat with regard to information distribution. The embedded-RP inter-domain model behaves as if every group formed its own Internet-wide PIM domain, with the group mapping to a single RP, wherever the receivers or senders are located. Hence, the inter-domain multicast becomes a flat, RP-centered topology. The scaling issues are described below.

Previously, foreign sources sent the unicast-encapsulated data to their "local" RP; now they are sent to the "foreign" RP responsible for the specific group. This is especially important with large multicast groups where there are a lot of heavy senders -- particularly if implementations do not handle unicast-decapsulation well.

With IPv4 ASM multicast, there are roughly two kinds of Internet-wide state: MSDP (propagated everywhere), and multicast routing state (on the receiver or sender branches). The former is eliminated, but the backbone routers might end up with (*, G) and (S, G, rpt) state between receivers (and past receivers, for PIM Prunes) and the RP, in addition to (S, G) states between the receivers and senders, if SPT is used. However, the total amount of state is smaller.

In both inter-domain and intra-domain cases, the embedded-RP model is practically identical to the traditional PIM-SM in intra-domain. On the other hand, PIM-SM has been deployed (in IPv4) in inter-domain using MSDP; compared to that inter-domain model, this specification simplifies the tree construction (i.e., multicast routing) by removing the RP for senders and receivers in foreign domains and eliminating the MSDP information distribution.

As the address of the RP is tied to the multicast address, the RP failure management becomes more difficult, as the deployed failover or redundancy mechanisms (e.g., BSR, Anycast-RP with MSDP) cannot be used as-is. However, Anycast-RP using PIM provides equal redundancy; this described briefly in Section 6.1.

The PIM-SM specification states, "Any RP address configured or learned MUST be a domain-wide reachable address". What "reachable" precisely means is not clear, even without embedded-RP. This statement cannot be proven, especially with the foreign RPs, as one cannot even guarantee that the RP exists. Instead of manually configuring RPs and DRs (configuring a non-existent RP was possible, though rare), with this specification the hosts and users using multicast indirectly specify the RP themselves, lowering the expectancy of the RP reachability. This is a relatively significant

problem but not much different from the current multicast deployment: e.g., MLDv2 (S,G) joins, whether ASM or SSM, yield the same result [PIMSEC].

Being able to join/send to remote RPs raises security concerns that are considered separately, but it has an advantage too: every group has a "responsible RP" that is able to control (to some extent) who is able to send to the group.

A more extensive description and comparison of the inter-domain multicast routing models (traditional ASM with MSDP, embedded-RP, SSM) and their security properties has been described in [PIMSEC].

9. Acknowledgements

Jerome Durand commented on an early version of this memo. Marshall Eubanks noted an issue regarding short plen values. Tom Pusateri noted problems with an earlier SPT-join approach. Rami Lehtonen pointed out issues with the scope of SA-state and provided extensive commentary. Nidhi Bhaskar gave the document a thorough review. Toerless Eckert, Hugh Holbrook, and Dave Meyer provided very extensive feedback. In particular, Pavlin Radoslavov, Dino Farinacci, Nidhi Bhaskar, and Jerome Durand provided good comments during and after WG last call. Mark Allman, Bill Fenner, Thomas Narten, and Alex Zinin provided substantive comments during the IESG evaluation. The whole MboneD working group is also acknowledged for continued support and comments.

10. Security Considerations

The addresses of RPs are encoded in the multicast addresses, thus becoming more visible as single points of failure. Even though this does not significantly affect the multicast routing security, it may expose the RP to other kinds of attacks. The operators are encouraged to pay special attention to securing these routers. See Section 6.1 for considerations regarding failover and Section 6.2 for placement of RPs leading to a degree of fate-sharing properties.

As any RP will have to accept PIM-SM Join/Prune/Register messages from any DR, this might cause a potential Denial of Service attack scenario. However, this can be mitigated, as the RP can discard all such messages for all multicast addresses that do not encode the address of the RP. Both the sender- and receiver-based attacks are described at greater length in [PIMSEC].

Additionally, the implementation SHOULD also allow manual configuration of which multicast prefixes are allowed to be used. This can be used to limit the use of the RP to designated groups only. In some cases, being able to restrict (at the RP) which unicast addresses are allowed to send or join to a group is desirable. (However, note that Join/Prune messages would still leave state in the network, and Register messages can be spoofed [PIMSEC].) Obviously, these controls are only possible at the RP, not at the intermediate routers or the DR.

It is RECOMMENDED that routers supporting this specification do not act as RPs unless explicitly configured to do so, as becoming an RP does not require any advertisement (e.g., through BSR or manually). Otherwise, any router could potentially become an RP (and be abused as such). Further, multicast groups or group ranges to-be-served MAY need to be explicitly configured at the RPs, to protect them from being used unwillingly. Note that the more specific controls (e.g., "insider-must-create" or "invite-outsiders" models) as to who is allowed to use the groups are beyond the scope of this memo.

Excluding internal-only groups from MSDP advertisements does not protect the groups from outsiders but only offers security by obscurity; embedded-RP offers similar level of protection. When real protection is desired, PIM scoping for example, should be set up at the borders. This is described at more length in Section 6.5.

One should observe that the embedded-RP threat model is actually rather similar to SSM; both mechanisms significantly reduce the threats at the sender side. On the receiver side, the threats are somewhat comparable, as an attacker could do an MLDv2 (S,G) join towards a non-existent source, which the local RP could not block based on the MSDP information.

The implementation MUST perform at least the same address validity checks to the embedded-RP address as it would to one received via other means; at least fe80::/10, ::/16, and ff00::/8 should be excluded. This is particularly important, as the information is derived from the untrusted source (i.e., any user in the Internet), not from the local configuration.

A more extensive description and comparison of the inter-domain multicast routing models (traditional ASM with MSDP, embedded-RP, SSM) and their security properties has been done separately in [PIMSEC].

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11.1. Normative References

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A. Discussion about Design Tradeoffs

The document only specifies FF70::/12 for now; if/when the upper-most bit is used, one must specify how FFF0::/12 applies to Embedded-RP. For example, a different mode of PIM or another protocol might use that range, in contrast to FF70::/12, as currently specified, being for PIM-SM only.

Instead of using flags bits ("FF70::/12"), one could have used the leftmost reserved bits instead ("FF3x:8000::/17").

It has been argued that instead of allowing the operator to specify RIID, the value could be pre-determined (e.g., "1"). However, this has not been adopted, as this eliminates address assignment flexibility from the operator.

Values 64 < "plen" < 96 would overlap with upper bits of the multicast group-id; due to this restriction, "plen" must not exceed 64 bits. This is in line with RFC 3306.

The embedded-RP addressing could be used to convey other information (other than RP address) as well, for example, what should be the RPT threshold for PIM-SM. These could be, whether feasible or not, encoded in the RP address somehow, or in the multicast group address. In any case, such modifications are beyond the scope of this memo.

For the cases where the RPs do not exist or are unreachable, or too much state is being generated to reach in a resource exhaustion Denial of Service attack, some forms of rate-limiting or other mechanisms could be deployed to mitigate the threats while trying not to disturb the legitimate usage. However, as the threats are generic, they are considered out of scope and discussed separately in [PIMSEC].

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