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              Overview of the Internet Multicast Routing Architecture

Status of This Memo

Abstract

   This document describes multicast routing architectures that are
   currently deployed on the Internet. This document briefly describes
   those protocols and references their specifications.

   This memo also reclassifies several older RFCs to Historic. These
   RFCs describe multicast routing protocols that were never widely
   deployed or have fallen into disuse.

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1. Introduction

This document provides a brief overview of multicast routing
architectures that are currently deployed on the Internet and how
those protocols fit together. It also describes those multicast
routing protocols that were never widely deployed or have fallen into
disuse. A companion document [ADDRARCH] describes multicast
addressing architectures.

Specifically, this memo deals with:

o setting up multicast forwarding state (Section 2.1),

o distributing multicast topology information (Section 2.2),

o learning active sources (Section 2.3),

o configuring and distributing the rendezvous point (RP) information
   (Section 2.4),

o mechanisms for enhanced redundancy (Section 2.5),

o interacting with hosts (Section 2.6), and

o restricting the multicast flooding in the link layer
   (Section 2.7).

Section 2 starts by describing a simplistic example how these classes
of mechanisms fit together. Some multicast data transport issues are
also introduced in Appendix A.

This memo reclassifies to Historic [RFC2026] the following RFCs:

o Border Gateway Multicast Protocol (BGMP) [RFC3913],

o Core Based Trees (CBT) [RFC2189] [RFC2201],

o Multicast OSPF (MOSPF) [RFC1584].

For the most part, these protocols have fallen into disuse. There
may be legacy deployments of some of these protocols, which are not
affected by this reclassification. See Section 2.1 for more on each
protocol.

Further historical perspective may be found in, for example,
[RFC1458], [IMRP-ISSUES], and [IM-GAPS].

1.1. Multicast-Related Abbreviations

```
ASM             Any Source Multicast
BGMP            Border Gateway Multicast Protocol
BSR             Bootstrap Router
CBT             Core Based Trees
CGMP            Cisco Group Management Protocol
DR              Designated Router
DVMRP           Distance Vector Multicast Routing Protocol
GARP            (IEEE 802.1D-2004) Generic Attribute Registration
                Protocol
GMRP            GARP Multicast Registration Protocol
IGMP            Internet Group Management Protocol
MBGP            Multiprotocol BGP (*not* "Multicast BGP")
MLD             Multicast Listener Discovery
MRP             (IEEE 802.1ak) Multiple Registration Protocol
MMRP            (IEEE 802.1ak) Multicast Multiple Registration
                Protocol
MOSPF           Multicast OSPF
MSDP            Multicast Source Discovery Protocol
PGM             Pragmatic General Multicast
PIM             Protocol Independent Multicast
PIM-DM          PIM - Dense Mode
PIM-SM          PIM - Sparse Mode
PIM-SSM         PIM - Source-Specific Multicast
RGMP            (Cisco's) Router Group Management Protocol
RP              Rendezvous Point
RPF             Reverse Path Forwarding
SAFI            Subsequent Address Family Identifier
SDP             Session Description Protocol
SSM             Source-Specific Multicast
```

2. Multicast Routing

In order to give a simplified summary how each of these class of
mechanisms fits together, consider the following multicast receiver
scenario.

Certain protocols and configurations need to be in place before
multicast routing can work. Specifically, when ASM is employed, a
router will need to know its RP address(es) (Section 2.4,
Section 2.5). With IPv4, RPs need to be connected to other RPs using
MSDP so information about sources connected to other RPs can be
distributed (Section 2.3). Further, routers need to know if or how
multicast topology differs from unicast topology, and routing
protocol extensions can provide that information (Section 2.2).

When a host wants to receive a transmission, it first needs to find
out the multicast group address (and with SSM, source address) using
various means (e.g., SDP description file [RFC4566] or manually).
Then it will signal its interest to its first-hop router using IGMP
(IPv4) or MLD (IPv6) (Section 2.6). The router initiates setting up
hop-by-hop multicast forwarding state (Section 2.1) to the source (in
SSM) or first through the RP (in ASM). Routers use an RP to find out
all the sources for a group (Section 2.3). When multicast
transmission arrives at the receiver's LAN, it is flooded to every
Ethernet switch port unless flooding reduction such as IGMP snooping
is employed (Section 2.7).

2.1. Setting up Multicast Forwarding State

The most important part of multicast routing is setting up the
multicast forwarding state. State maintenance requires periodic
messaging because forwarding state has a timeout. This section
describes the protocols commonly used for this purpose.

2.1.1. PIM-SM

By far, the most common multicast routing protocol is PIM-SM
[RFC4601]. The PIM-SM protocol includes both Any Source Multicast
(ASM) and Source-Specific Multicast (SSM) functionality. PIM-SSM is
a subset of PIM-SM that does not use the RPs but instead requires
that receivers know the (source,group) pair and signal that
explicitly. Most current routing platforms support PIM-SM.

PIM routers elect a designated router on each LAN and the DR is
responsible for PIM messaging and source registration on behalf of
the hosts. The DR encapsulates multicast packets sourced from the
LAN in a unicast tunnel to the RP. PIM-SM builds a unidirectional,
group-specific distribution tree consisting of the interested
receivers of a group. Initially, the multicast distribution tree is
rooted at the RP but later the DRs have the option of optimizing the
delivery by building (source,group)-specific trees.

A more lengthy introduction to PIM-SM can be found in Section 3 of
[RFC4601].

2.1.2. PIM-DM

Whereas PIM-SM has been designed to avoid unnecessary flooding of
multicast data, PIM-DM [RFC3973] assumed that almost every subnet at
a site had at least one receiver for a group. PIM-DM floods
multicast transmissions throughout the network ("flood and prune")
unless the leaf parts of the network periodically indicate that they
are not interested in that particular group.

PIM-DM may be an acceptable fit in small and/or simple networks,
where setting up an RP would be unnecessary, and possibly in cases
where a large percentage of users are expected to want to receive the
transmission so that the amount of state the network has to keep is
minimal.

PIM-DM was used as a first step in transitioning away from DVMRP. It
also became apparent that most networks would not have receivers for
most groups, and to avoid the bandwidth and state overhead, the
flooding paradigm was gradually abandoned. Transitioning from PIM-DM
to PIM-SM was easy as PIM-SM was designed to use compatible packet
formats and dense-mode operation could also be satisfied by a sparse
protocol. PIM-DM is no longer in widespread use.

Many implementations also support so-called "sparse-dense"
configuration, where Sparse mode is used by default, but Dense is
used for configured multicast group ranges (such as Auto-RP in
Section 2.4.3) only. Lately, many networks have transitioned away
from sparse-dense to only sparse mode.

2.1.3. Bidirectional PIM

Bidirectional PIM [RFC5015] is a multicast forwarding protocol that
establishes a common shared-path for all sources with a single root.
It can be used as an alternative to PIM-SM inside a single domain.
It doesn't have data-driven events or data-encapsulation. As it
doesn't keep source-specific state, it may be an appealing approach
especially in sites with a large number of sources.

As of this writing, there is no inter-domain solution to configure a
group range to use bidirectional PIM.

2.1.4. DVMRP

Distance Vector Multicast Routing Protocol (DVMRP) [RFC1075]
[DVMRPv3] [DVMRPv3-AS] was the first protocol designed for
multicasting. To get around initial deployment hurdles, it also
included tunneling capabilities, which were part of its multicast
topology functions.

Currently, DVMRP is used only very rarely in operator networks,
having been replaced with PIM-SM. The most typical deployment of
DVMRP is at a leaf network, to run from a legacy firewall only
supporting DVMRP to the internal network. However, Generic Routing
Encapsulation (GRE) tunneling [RFC2784] seems to have overtaken DVMRP
in this functionality, and there is relatively little use for DVMRP
except in legacy deployments.

2.1.5. MOSPF

   MOSPF [RFC1584] was implemented by several vendors and has seen some
   deployment in intra-domain networks. However, since it is based on
   intra-domain Open Shortest Path First (OSPF) it does not scale to the
   inter-domain case, operators have found it is easier to deploy a
   single protocol for use in both intra-domain and inter-domain
   networks and so it is no longer being actively deployed.

2.1.6. BGMP

   BGMP [RFC3913] did not get sufficient support within the service
   provider community to get adopted and moved forward in the IETF
   standards process. There were no reported production implementations
   and no production deployments.

2.1.7. CBT

   CBT [RFC2201][RFC2189] was an academic project that provided the
   basis for PIM sparse mode shared trees. Once the shared tree
   functionality was incorporated into PIM implementations, there was no
   longer a need for a production CBT implementation. Therefore, CBT
   never saw production deployment.

2.1.8. Interactions and Summary

   It is worth noting that it is possible to run different protocols
   with different multicast group ranges. For example, treat some
   groups as dense or bidirectional in an otherwise PIM-SM network; this
   typically requires manual configuration of the groups or a mechanism
   like BSR (Section 2.4.3). It is also possible to interact between
   different protocols; for example, use DVMRP in the leaf network, but
   PIM-SM upstream. The basics for interactions among different
   protocols have been outlined in [RFC2715].

   The following figure gives a concise summary of the deployment status
   of different protocols as of this writing.

```
            +--------------+-------------+---------------+
            | Inter-domain | Intra-domain | Status        |
+-----------+--------------+-------------+---------------+
| PIM-SM    |     Yes      |     Yes     | Active        |
| PIM-DM    | Not anymore  | Not anymore | Little use    |
| BIDIR-PIM |     No       |     Yes     | Some uptake   |
| DVMRP     | Not anymore  |  Stub only  | Going out     |
| MOSPF     |     No       | Not anymore | Inactive      |
| CBT       |     No       |     No      | Never deployed |
| BGMP      |     No       |     No      | Never deployed |
+-----------+--------------+-------------+---------------+
```

   From this table, it is clear that PIM-Sparse Mode is the only
   multicast routing protocol that is deployed inter-domain and,
   therefore, is most frequently used within multicast domains as well.

2.2. Distributing Topology Information

   PIM has become the de-facto multicast forwarding protocol, but as its
   name implies, it is independent of the underlying unicast routing
   protocol. When unicast and multicast topologies are the same
   ("congruent"), i.e., use the same routing tables (routing information
   base, RIB), it has been considered sufficient just to distribute one
   set of reachability information to be used in conjunction with a
   protocol that sets up multicast forwarding state (e.g., PIM-SM).

   However, when PIM which by default built multicast topology based on
   the unicast topology gained popularity, it became apparent that it
   would be necessary to be able to distribute also non-congruent
   multicast reachability information in the regular unicast protocols.
   This was previously not an issue, because DVMRP built its own
   reachability information.

   The topology information is needed to perform efficient distribution
   of multicast transmissions and to prevent transmission loops by
   applying it to the Reverse Path Forwarding (RPF) check.

   This subsection introduces these protocols.

2.2.1. Multiprotocol BGP

   Multiprotocol Extensions for BGP-4 [RFC4760] (often referred to as
   "MBGP"; however, it is worth noting that "MBGP" does *not* stand for
   "Multicast BGP") specifies a mechanism by which BGP can be used to
   distribute different reachability information for unicast (SAFI=1)
   and multicast traffic (SAFI=2). Multiprotocol BGP has been widely

deployed for years, and is also needed to route IPv6. Note that
SAFI=3 was originally specified for "both unicast and multicast" but
has since then been deprecated.

These extensions are in widespread use wherever BGP is used to
distribute unicast topology information. Multicast-enabled networks
that use BGP should use Multiprotocol BGP to distribute multicast
reachability information explicitly even if the topologies are
congruent to make an explicit statement about multicast reachability.
A number of significant multicast transit providers even require
this, by doing the RPF lookups solely based on explicitly advertised
multicast address family.

2.2.2. OSPF/IS-IS Multi-Topology Extensions

Similar to BGP, some Interior Gateway Protocols (IGPs) also provide
the capability for signalling differing topologies, for example IS-IS
multi-topology extensions [M-ISIS]. These can be used for a
multicast topology that differs from unicast. Similar but not so
widely implemented work exists for OSPF [RFC4915].

It is worth noting that inter-domain incongruence and intra-domain
incongruence are orthogonal, so one doesn't require the other.
Specifically, inter-domain incongruence is quite common, while intra-
domain incongruence isn't, so you see much more deployment of MBGP
than MT-ISIS/OSPF. Commonly deployed networks have managed well
without protocols handling intra-domain incongruence. However, the
availability of multi-topology mechanisms may in part replace the
typically used workarounds such as tunnels.

2.2.3. Issue: Overlapping Unicast/Multicast Topology

An interesting case occurs when some routers do not distribute
multicast topology information explicitly while others do. In
particular, this happens when some multicast sites in the Internet
are using plain BGP while some use MBGP.

Different implementations deal with this in different ways.
Sometimes, multicast RPF mechanisms first look up the multicast
routing table, or M-RIB ("topology database") with a longest prefix
match algorithm, and if they find any entry (including a default
route), that is used; if no match is found, the unicast routing table
is used instead.

An alternative approach is to use longest prefix match on the union
of multicast and unicast routing tables; an implementation technique
here is to copy the whole unicast routing table over to the multicast
routing table. The important point to remember here, though, is to

not override the multicast-only routes; if the longest prefix match
would find both a (copied) unicast route and a multicast-only route,
the latter should be treated as preferable.

Another implemented approach is to just look up the information in
the unicast routing table, and provide the user capabilities to
change that as appropriate, using for example copying functions
discussed above.

[2.2.4](#). Summary

A congruent topology can be deployed using unicast routing protocols
that provide no support for a separate multicast topology. In intra-
domain that approach is often adequate. However, it is recommended
that if inter-domain routing uses BGP, multicast-enabled sites should
use MP-BGP SAFI=2 for multicast and SAFI=1 for unicast even if the
topology was congruent to explicitly signal "yes, we use multicast".

The following table summarizes the approaches that can be used to
distribute multicast topology information.

```
                   +----------------+--------------+
                   | Inter-domain   | Intra-domain |
   +-------------------- +----------------+--------------+
   | MP-BGP SAFI=2       |      Yes       |     Yes      |
   | MP-BGP SAFI=3       |  Doesn't work  | Doesn't work |
   | IS-IS multi-topology | Not applicable |     Yes      |
   | OSPF multi-topology  | Not applicable | Few implem.  |
   +----------------------+----------------+--------------+
```

"Not applicable" refers to the fact that IGP protocols can't be used
in inter-domain routing. "Doesn't work" means that while MP-BGP
SAFI=3 was defined and could apply, that part of the specification
has not been implemented and can't be used in practice. "Yes" lists
the mechanisms which are generally applicable and known to work.
"Few implem." means that the approach could work but is not commonly
available.

[2.3](#). Learning (Active) Sources

To build a multicast distribution tree, the routing protocol needs to
find out where the sources for the group are. In case of SSM, the
user specifies the source IP address or it is otherwise learned out
of band.

In ASM, the RPs know about all the active sources in a local PIM
domain. As a result, when PIM-SM or BIDIR-PIM is used in intra-
domain the sources are learned as a feature of the protocol itself.

Having a single PIM-SM domain for the whole Internet is an
insufficient model for many reasons, including scalability,
administrative boundaries, and different technical tradeoffs.
Therefore, it is required to be able to split up the multicast
routing infrastructures to smaller domains, and there must be a way
to share information about active sources using some mechanism if the
ASM model is to be supported.

This section discusses the options of learning active sources that
apply in an inter-domain environment.

2.3.1. SSM

Source-specific Multicast [RFC4607] (sometimes also referred to as
"single-source Multicast") does not count on learning active sources
in the network. Recipients need to know the source IP addresses
using an out of band mechanism which are used to subscribe to the
(source, group) channel. The multicast routing uses the source
address to set up the state and no further source discovery is
needed.

As of this writing, there are attempts to analyze and/or define out-
of-band source discovery functions which would help SSM in particular
[DYNSSM-REQ].

2.3.2. MSDP

Multicast Source Discovery Protocol [RFC3618] was invented as a stop-
gap mechanism, when it became apparent that multiple PIM-SM domains
(and RPs) were needed in the network, and information about the
active sources needed to be propagated between the PIM-SM domains
using some other protocol.

MSDP is also used to share the state about sources between multiple
RPs in a single domain for, e.g., redundancy purposes [RFC3446]. The
same can be achieved using PIM extensions [RFC4610]. See Section 2.5
for more information.

There is no intent to define MSDP for IPv6, but instead use only SSM
and Embedded-RP [MCAST-ISSUES].

2.3.3. Embedded-RP

Embedded-RP [RFC3956] is an IPv6-only technique to map the address of
the RP to the multicast group address. Using this method, it is
possible to avoid the use of MSDP while still allowing multiple
multicast domains (in the traditional sense).

The model works by defining a single RP address for a particular
group for all of the Internet, so there is no need to share state
about that with any other RPs. If necessary, RP redundancy can still
be achieved with Anycast-RP using PIM [RFC4610].

2.3.4. Summary

The following table summarizes the source discovery approaches and
their status.

```
                       +------+------+-----------------------------+
                       | IPv4 | IPv6 | Status                      |
   +----------------------+------+------+-----------------------------+
   | Bidir single domain  | Yes  | Yes  | OK but for intra-domain only |
   | PIM-SM single domain | Yes  | Yes  | OK                          |
   | PIM-SM with MSDP     | Yes  | No   | De-facto v4 inter-domain ASM |
   | PIM-SM w/ Embedded-RP| No   | Yes  | Best inter-domain ASM option |
   | SSM                  | Yes  | Yes  | No major uptake yet         |
   +----------------------+------+------+-----------------------------+
```

2.4. Configuring and Distributing PIM RP Information

PIM-SM and BIDIR-PIM configuration mechanisms exist, which are used
to configure the RP addresses and the groups that are to use those
RPs in the routers. This section outlines the approaches.

2.4.1. Manual RP Configuration

It is often easiest just to manually configure the RP information on
the routers when PIM-SM is used.

Originally, static RP mapping was considered suboptimal since it
required explicit configuration changes every time the RP address
changed. However, with the advent of anycast RP addressing, the RP
address is unlikely to ever change. Therefore, the administrative
burden is generally limited to initial configuration. Since there is
usually a fair amount of multicast configuration required on all
routers anyway (e.g., PIM on all interfaces), adding the RP address
statically isn't really an issue. Further, static anycast RP mapping
provides the benefits of RP load sharing and redundancy (see
Section 2.5) without the complexity found in dynamic mechanisms like
Auto-RP and Bootstrap Router (BSR).

With such design, an anycast RP uses an address that is configured on
a loopback interface of the routers currently acting as RPs, and
state is distributed using PIM [RFC4610] or MSDP [RFC3446].

Using this technique, each router might only need to be configured
with one, portable RP address.

2.4.2. Embedded-RP

Embedded-RP provides the information about the RP's address in the
group addresses that are delegated to those who use the RP, so unless
no other ASM than Embedded-RP is used, the network administrator only
needs to configure the RP routers.

While Embedded-RP in many cases is sufficient for IPv6, other methods
of RP configuration are needed if one needs to provide ASM service
for other than Embedded-RP group addresses. In particular, service
discovery type of applications may need hard-coded addresses that are
not dependent on local RP addresses.

As the RP's address is exposed to the users and applications, it is
very important to ensure it does not change often, e.g., by using
manual configuration of an anycast address.

2.4.3. BSR and Auto-RP

BSR [RFC5059] is a mechanism for configuring the RP address for
groups. It may no longer be in as wide use with IPv4 as it was
earlier, and for IPv6, Embedded-RP will in many cases be sufficient.

Cisco's Auto-RP is an older, proprietary method for distributing
group to RP mappings, similar to BSR. Auto-RP has little use today.

Both Auto-RP and BSR require some form of control at the routers to
ensure that only valid routers are able to advertise themselves as
RPs. Further, flooding of BSR and Auto-RP messages must be prevented
at PIM borders. Additionally, routers require monitoring that they
are actually using the RP(s) the administrators think they should be
using, for example, if a router (maybe in customer's control) is
advertising itself inappropriately. All in all, while BSR and
Auto-RP provide easy configuration, they also provide very
significant configuration and management complexity.

It is worth noting that both Auto-RP and BSR were deployed before the
use of a manually configured anycast-RP address became relatively
commonplace, and there is actually relatively little need for them
today unless there is a need to configure different properties (e.g.,
sparse, dense, bidirectional) in a dynamic fashion.

2.4.4. Summary

The following table summarizes the RP discovery mechanisms and their
status. With the exception of Embedded-RP, each mechanism operates
within a PIM domain.

```
                    +------+------+-----------------------+
                    | IPv4 | IPv6 | Deployment            |
+-------------------+------+------+-----------------------+
| Static RP         | Yes  | Yes  | Especially in ISPs    |
| Auto-RP           | Yes  | No   | Legacy deployment     |
| BSR               | Yes  | Yes  | Some, anycast simpler |
| Embedded-RP       | No   | Yes  | Growing               |
+-------------------+------+------+-----------------------+
```

2.5. Mechanisms for Enhanced Redundancy

Having only one RP in a PIM-SM domain would be a single point of
failure for the whole multicast domain. As a result, a number of
mechanisms have been developed to either eliminate the RP
functionality or to enhance RPs' redundancy, resilience against
failures, and to recover from failures quickly. This section
summarizes these techniques explicitly.

2.5.1. Anycast RP

As mentioned in Section 2.3.2, MSDP is also used to share the state
about sources between multiple RPs in a single domain, e.g., for
redundancy purposes [RFC3446]. The purpose of MSDP in this context
is to share the same state information on multiple RPs for the same
groups to enhance the robustness of the service.

Recent PIM extensions [RFC4610] also provide this functionality. In
contrast to MSDP, this approach works for both IPv4 and IPv6.

2.5.2. Stateless RP Failover

While Anycast RP shares state between RPs so that RP failure causes
only small disturbance, stateless approaches are also possible with a
more limited resiliency. A traditional mechanism has been to use
Auto-RP or BSR (see Section 2.4.3) to select another RP when the
active one failed. However, the same functionality could be achieved
using a shared-unicast RP address ("anycast RP without state
sharing") without the complexity of a dynamic mechanism. Further,
Anycast RP offers a significantly more extensive failure mitigation
strategy, so today there is actually very little need to use
stateless failover mechanisms, especially dynamic ones, for
redundancy purposes.

2.5.3. Bidirectional PIM

Because bidirectional PIM (see Section 2.1.3) does not switch to
shortest path tree (SPT), the final multicast tree may be established
faster. On the other hand, PIM-SM or SSM may converge more quickly
especially in scenarios (e.g., unicast routing change) where
bidirectional needs to re-do the Designated Forwarder election.

2.5.4. Summary

The following table summarizes the techniques for enhanced
redundancy.

```
                    +------+------+----------------------+
                    | IPv4 | IPv6 | Deployment           |
   +--------------------+------+------+----------------------+
   | Anycast RP w/ MSDP | Yes  | No   | De-facto approach    |
   | Anycast RP w/ PIM  | Yes  | Yes  | Newer approach       |
   | Stateless RP fail. | Yes  | Yes  | Causes disturbance   |
   | BIDIR-PIM          | Yes  | Yes  | Deployed at some sites|
   +--------------------+------+------+----------------------+
```

2.6. Interactions with Hosts

Previous sections have dealt with the components required by routers
to be able to do multicast routing. Obviously, the real users of
multicast are the hosts: either sending or receiving multicast. This
section describes the required interactions with hosts.

2.6.1. Hosts Sending Multicast

After choosing a multicast group through a variety of means, hosts
just send the packets to the link-layer multicast address, and the
designated router will receive all the multicast packets and start
forwarding them as appropriate. A host does not need to be a member
of the group in order to send to it [RFC1112].

In intra-domain or Embedded-RP scenarios, ASM senders may move to a
new IP address without significant impact on the delivery of their
transmission. SSM senders cannot change the IP address unless
receivers join the new channel or the sender uses an IP mobility
technique that is transparent to the receivers.

2.6.2. Hosts Receiving Multicast

Hosts signal their interest in receiving a multicast group or channel
by the use of IGMP [RFC3376] and MLD [RFC3810]. IGMPv2 and MLDv1 are
still commonplace, but are also often used in new deployments. Some

vendors also support SSM mapping techniques for receivers which use
an older IGMP/MLD version where the router maps the join request to
an SSM channel based on various, usually complex means of
configuration.

2.6.3. Summary

The following table summarizes the techniques host interaction.

```
                    +-------+------+----------------------------+
                    | IPv4  | IPv6 | Notes                      |
 +-------------------+-------+------+----------------------------+
 | Host sending      | Yes   | Yes  | No support needed          |
 | Host receiving ASM | IGMP  | MLD  | Any IGMP/MLD version        |
 | Host receiving SSM | IGMPv3| MLDv2| Any version w/ SSM-mapping |
 +-------------------+-------+------+----------------------------+
```

2.7. Restricting Multicast Flooding in the Link Layer

Multicast transmission in the link layer, for example Ethernet,
typically includes some form of flooding the packets through a LAN.
This causes unnecessary bandwidth usage and discarding unwanted
frames on those nodes which did not want to receive the multicast
transmission.

Therefore a number of techniques have been developed, to be used in
Ethernet switches between routers, or between routers and hosts, to
limit the flooding.

Some mechanisms operate with IP addresses, others with MAC addresses.
If filtering is done based on MAC addresses, hosts may receive
unnecessary multicast traffic (filtered out in the hosts' IP layer)
if more than one IP multicast group addresses maps into the same MAC
address, or if IGMPv3/MLDv2 source filters are used. Filtering based
on IP destination addresses, or destination and sources addresses,
will help avoid these but requires parsing of the Ethernet frame
payload.

These options are discussed in this section.

2.7.1. Router-to-Router Flooding Reduction

A proprietary solution, Cisco's RGMP [RFC3488] has been developed to
reduce the amount of flooding between routers in a switched networks.
This is typically only considered a problem in some Ethernet-based
Internet Exchange points or VPNs.

There have been proposals to observe and possibly react ("snoop") PIM
messages [PIM-SNOOP].

2.7.2. **Host/Router Flooding Reduction**

There are a number of techniques to help reduce flooding both from a
router to hosts, and from a host to the routers (and other hosts).

Cisco's proprietary CGMP [CGMP] provides a solution where the routers
notify the switches, but also allows the switches to snoop IGMP
packets to enable faster notification of hosts no longer wishing to
receive a group. Implementations of CGMP do not support fast leave
behaviour with IGMPv3. Due to IGMP report suppression in IGMPv1 and
IGMPv2, multicast is still flooded to ports which were once members
of a group as long as there is at least one receiver on the link.
Flooding restrictions are done based on multicast MAC addresses.
Implementations of CGMP do not support IPv6.

IEEE 802.1D-2004 specification describes Generic Attribute
Registration Protocol (GARP), and GARP Multicast Registration
Protocol (GMRP) [GMRP] is a link-layer multicast group application of
GARP that notifies switches about MAC multicast group memberships.
If GMRP is used in conjunction with IP multicast, then the GMRP
registration function would become associated with an IGMP "join".
However, this GMRP-IGMP association is beyond the scope of GMRP.
GMRP requires support at the host stack and it has not been widely
implemented. Further, IEEE 802.1 considers GARP and GMRP obsolete
being replaced by Multiple Registration Protocol (MRP) and Multicast
Multiple Registration Protocol (MMRP) that are being specified in
IEEE 802.1ak [802.1ak]. MMRP is expected to be mainly used between
bridges. Some further information about GARP/GMRP is also available
in Appendix B of [RFC3488].

IGMP snooping [RFC4541] appears to be the most widely implemented
technique. IGMP snooping requires that the switches implement a
significant amount of IP-level packet inspection; this appears to be
something that is difficult to get right, and often the upgrades are
also a challenge. Snooping support is commonplace for IGMPv1 and
IGMPv2, but fewer switches support IGMPv3 or MLD (any version)
snooping. In the worst case, enabling IGMP snooping on a switch that
does not support IGMPv3 snooping breaks multicast capabilities of
nodes using IGMPv3.

Snooping switches also need to identify the ports where routers
reside and therefore where to flood the packets. This can be
accomplished using Multicast Router Discovery protocol [RFC4286],
looking at certain IGMP queries [RFC4541], looking at PIM Hello and
possibly other messages, or by manual configuration. An issue with

PIM snooping at LANs is that PIM messages can't be turned off or
encrypted, leading to security issues [PIM-THREATS].

IGMP proxying [RFC4605] is sometimes used either as a replacement of
a multicast routing protocol on a small router, or to aggregate IGMP/
MLD reports when used with IGMP snooping.

2.7.3. Summary

The following table summarizes the techniques for multicast flooding
reduction inside a single link for router-to-router and last-hop
LANs.

```
                        +--------+-----+----------------------------+
                        | R-to-R | LAN | Notes                      |
+-----------------------+--------+-----+----------------------------+
| Cisco's RGMP          |  Yes   | No  | Replaced by PIM snooping   |
| PIM snooping          |  Yes   | No  | Security issues in LANs    |
| IGMP/MLD snooping     |  No    | Yes | Common, IGMPv3 or MLD rare |
| Multicast Router Disc |  No    | Yes | Few if any implem. yet     |
| IEEE GMRP and MMRP    |  No    | No  | No host/router deployment  |
| Cisco's CGMP          |  No    | Yes | Replaced by other snooping |
+-----------------------+--------+-----+----------------------------+
```

3. Acknowledgements

Tutoring a couple multicast-related papers, the latest by Kaarle
Ritvanen [RITVANEN] convinced the author that up-to-date multicast
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improving this document.

4. IANA Considerations

IANA has updated the following registries by adding a reference to
this document:

o OSPFv2 Options Registry: MC-bit

o OSPFv2 Link State (LS) Type: Group-membership-LSA

o OSPFv2 Router Properties Registry: W-bit

o OSPFv3 Options Registry: MC-bit

o OSPFv3 LSA Function Code Registry: Group-membership-LSA

o OSPFv3 Prefix Options Registry: MC-bit

5. Security Considerations

   This memo only describes different approaches to multicast routing,
   and this has no security considerations; the security analysis of the
   mentioned protocols is out of scope of this memo.

   However, there has been analysis of the security of multicast routing
   infrastructures [RFC4609], IGMP/MLD [MLD-SEC], and PIM last-hop
   issues [PIM-THREATS].

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Appendix A. Multicast Payload Transport Extensions

   A couple of mechanisms have been specified to improve the
   characteristics of the data that can be transported over multicast.

   We describe those mechanisms that have impact on the multicast
   routing infrastructure, e.g., require or specify router assistance or
   involvement in some form. Purely end-to-end or host-based protocols
   are out of scope.

A.1. Reliable Multicast

   There has been some work on reliable multicast delivery so that
   applications with reliability requirements could use multicast
   instead of simple unreliable UDP.

   Most of the mechanisms are host-based and as such out of scope of
   this document, but one relevant from multicast routing perspective is
   Pragmatic Generic Multicast (PGM) [RFC3208]. It does not require
   support from the routers, bur PGM-aware routers may act in router
   assistance role in the initial delivery and potential retransmission
   of missing data.

A.2. Multicast Group Security

   Multicast Security Working Group has been working on methods how the
   integrity, confidentiality, and authentication of data sent to
   multicast groups can be ensured using cryptographic techniques
   [RFC3740].

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