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BGP Extensions for Routing Policy Distribution (RPD)

Abstract

It is hard to adjust traffic in a traditional IP network from time
to time through manual configurations. It is desirable to have a
mechanism for setting up routing policies, which adjusts traffic
automatically. This document describes BGP Extensions for Routing
Policy Distribution (BGP RPD) to support this with a controller.

Requirements Language

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] [RFC8174]
when, and only when, they appear in all capitals, as shown here.

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1. **Introduction**

   Providers have the requirement to adjust their business traffic from time to time in a number of cases including:

     *Link congestion and overload caused by a network failure such as a link or node failure, or a live event such as a world cup.

     *Poor network transmission quality as the result of traffic delay or loss in some part of a network.

*Some unused network resources such as idle links because of
    business changes or network additions.

To adjust the traffic flowing to a destination (or adjust traffic
for short) is to move the traffic from a overloaded path to another
lightly used path. The move keeps the quality of the traffic
transmission and uses the network resources optimally.

It is difficult to adjust traffic in a traditional IP network where
an operator configures routing policies using command lines or
configuration files. Traffic can only be adjusted device by device.
All the routers that the traffic traverses need to be reconfigured.

Using a configuration automation system for adjusting traffic
affects network performance when the number of routers the traffic
may traverse is big. The system has to keep its connections live to
all these routers. This consumes network resources.

It is desirable to have an automatic mechanism for setting up
routing policies to adjust traffic, which is simple and efficient.
This document describes extensions to BGP for Routing Policy
Distribution (RPD) for this mechanism with a controller.

2. Terminology

The following terminology is used in this document.

   *AFI: Address Family Identifier

   *SAFI: Subsequent Address Family Identifier

   *MED: Multiple Exit Discriminator (or MULTI_EXIT_DISC)

   *RPD: Routing Policy Distribution

3. An Example of Traffic Adjustment

Figure 1 illustrates a simple scenario, where RPD is used by a
controller with a Route Reflector (RR) to adjust traffic
automatically.

```
                +--------------+
                |  Controller  |
                +-------+------+
                         \
                          \ RPD
           +--+._.--\._.+--+                      ___..._
         __(            \        '.---...        (          )
        /              RR o -------- A o) ---------- (o X    AS2  )
      (o E             |\            )      _____//(___    ___)
       (   PrefixA      | _____ B o) ____/     /      '''
        (o F            \          )        ____/
         (               \_____ C o) _____/        ___..._
          '        AS1           _)  \_____         (          )
           '---._.-._.           )        _____ (o Y    AS3  )
               '___'---'                           (___    ___)
                                                       '''
```
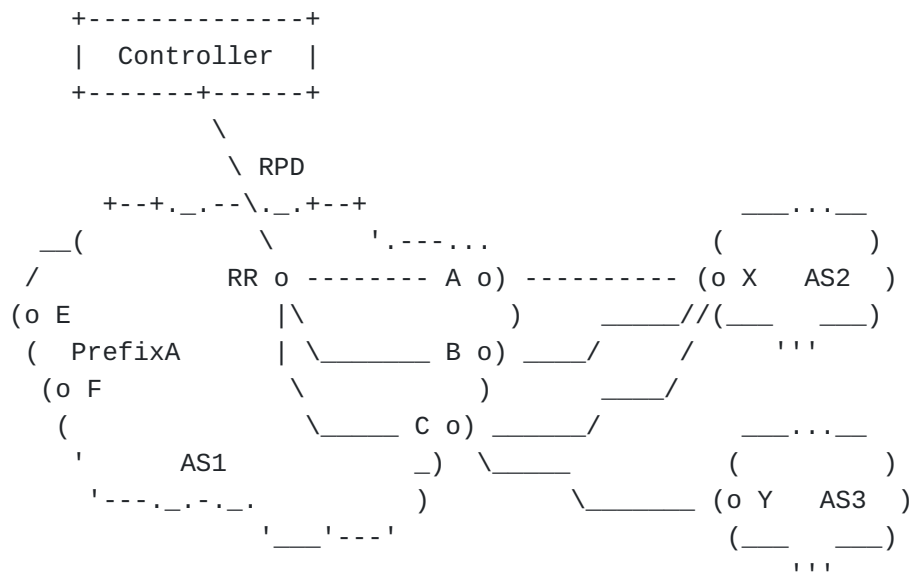
Figure 1: Controller with RR Adjusts Traffic

AS1, AS2 and AS3 belong to provider P1, P2 and P3 respectively.
Routers A, B and C are in AS1. Router X is in AS2. There is a BGP
session between X and each of routers A, B and C. Router Y is in
AS3. There is a BGP session between Y and router C.

AS1 has an IP address prefix named PrefixA, which is advertised to
AS2 from AS1. Provider P1 of AS1 wants to adjust the traffic to
PrefixA from AS2 automatically. For the traffic to PrefixA from AS2
via link X--A, once link X--A gets congested, P1 wants to move the
traffic to link X--B, which is lightly used.

The controller peers with the RR using a BGP session. There is a BGP
session between the RR and each of routers A, B and C in AS1, which
are shown in the figure. Other sessions in AS1 are not shown in the
figure.

The controller obtains the information about traffic flows including
the traffic flow to PrefixA. When it decides that the traffic to
PrefixA needs to be moved from link X--A to link X--B from the
information, it sends a RPD routing policy to A or B for changing
MED attribute in the IP route with PrefixA, which is advertised to
AS2. Router X in AS2 moves the traffic to link X--B after receiving
the IP route with PrefixA having the changed attribute. (Note: how
the controller gets the information and makes decision is out of
scope of this document).

Suppose that MED of the IP unicast route with PrefixA sent to X by
A, B and C is 50, 100 and 150 respectively. To move the traffic to
PrefixA in AS1 from link X--A to X--B, the controller sends a RPD
routing policy to A. After receiving the RPD routing policy, router

A sends the IP unicast route with PrefixA in AS1 to router X in AS2
and changes the MED to 160 before sending the IP route.

The RPD routing policy includes:

   *Peer IP = the IP address of router X,

   *Match conditions: prefix matching PrefixA exact and AS_PATH
    matching AS1, and

   *Action: set MED to 160.

After receiving the RPD routing policy, router A sets the MED to 160
for the IP unicast route with PrefixA in AS1 and sends the IP
unicast route to router X. The IP unicast route sent to X from A, B
and C has MED 160, 100 and 150 respectively. Router X sends the
traffic to PrefixA using link X--B since MED 100 from B is the
smallest.

4. Protocol Extensions

This document specifies a solution using a new <AFI, SAFI>[RFC4760]
with the BGP Wide Community [I-D.ietf-idr-wide-bgp-communities] for
encoding and distributing a routing policy. This routing policy is
called a RPD routing policy.

4.1. Using a New <AFI, SAFI>

A new <AFI, SAFI> pair is defined, where the Routing Policy AFI has
codepoint 16398 and SAFI has codepoint 75. This new pair is called
RPD <AFI, SAFI>.

The RPD <AFI, SAFI> uses a new Network Layer Reachability
Information (NLRI) defined as follows:

```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+
| NLRI Length   |
+-+-+-+-+-+-+-+-+
| Policy Type   |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
| Distinguisher (4 octets)                                     |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
| Peer IP (4/16 octets)                                        ~
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```
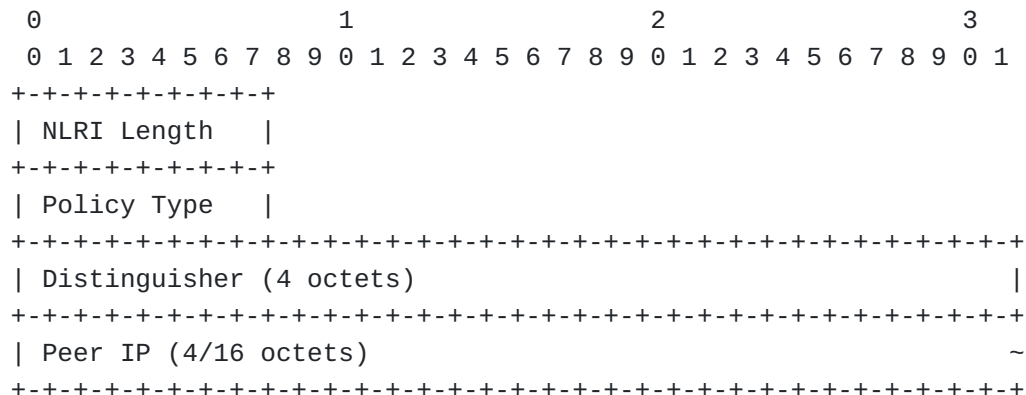
                   Figure 2: NLRI of RPD <AFI, SAFI>

Where:

NLRI Length: 1 octet represents the length of NLRI in octets as
     defined in [RFC4760]. If the Length is anything other than 9 or
     21 octets, the NLRI is corrupt and the enclosing UPDATE message
     MUST be ignored.

Policy Type: 1 octet indicates the type of a policy. 1 is for
     Export policy. If the Policy Type is any other value, the NLRI is
     corrupt and the enclosing UPDATE message MUST be ignored.

Distinguisher: 4 octet unsigned integer that uniquely identifies
     the content/policy. It is used to sort/order the polices from the
     lower to higher Distinguisher. They are applied in ascending
     order. A policy with a lower/smaller Distinguisher is applied
     before the policies with a higher/larger Distinguisher.

Peer IP: 4/16 octet value indicates IPv4/IPv6 peers. Its default
     value is 0. If the value is not a valid IP address and not 0, the
     NLRI is corrupt and the enclosing UPDATE message MUST be ignored.

The NLRI of RPD <AFI, SAFI> is carried in an MP_REACH_NLRI attribute
in a BGP UPDATE message. The "Length of Next Hop Network Address"
field of the MP_REACH_NLRI attribute MUST be set to zero.

The RPD routing policies in the UPDATE messages received are stored
under the RPD <AFI, SAFI>. Before advertising an IPv4/IPv6 Unicast
route (IP route for short), a BGP speaker MUST apply the routing
policies to the route.

The content of the Routing Policy is encoded in a BGP Wide
Community.

4.2. Atoms

This section defines three Atoms. For your reference, the format of
the Atoms is illustrated below:

```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|     Type      |             Length             |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                      Value (variable)                        ~
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```
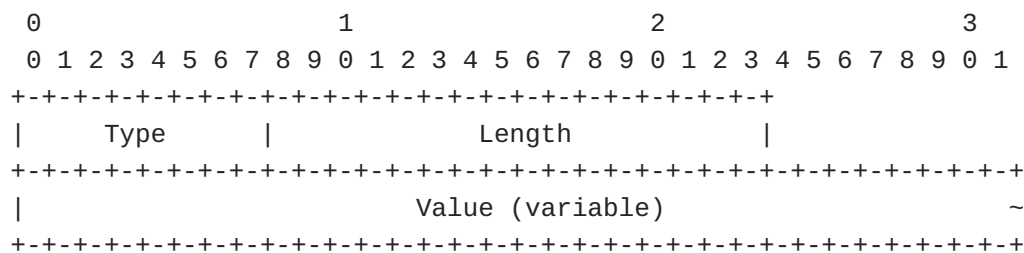
                   Figure 3: Format of Atoms TLVs

4.2.1. Atom Type TBD1, The Route Attributes (RouteAttr)

A RouteAttr Atom TLV (or RouteAttr Atom for short) specifies one or two groups of conditions. The first group of conditions states a set of IPv4/IPv6 address prefix ranges. The second group identifies a list of route attributes. The Atom has the following format.

```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
| Type (TBD1) |        Length (variable)        |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                       Value (sub-TLVs)                      ~
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```
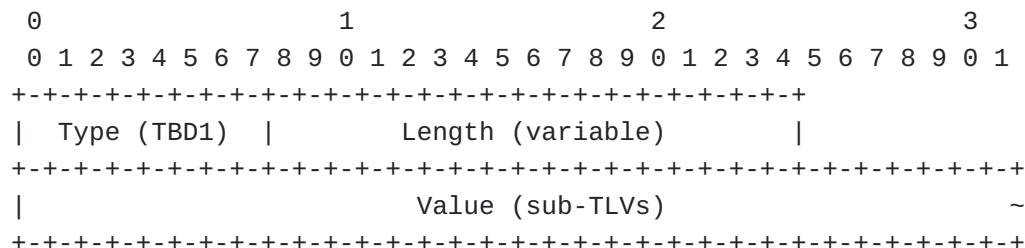
Figure 4: Format of RouteAttr Atom TLV

The Type for RouteAttr Atom is TBD1.

In RouteAttr Atom, four sub-TLVs are defined: IPv4 Address Prefix Range List, IPv6 Address Prefix Range List, AS_PATH RegEx, and Community List sub-TLV. The first two state IPv4 and IPv6 address prefix ranges respectively. The last two identify AS_PATH and Community attributes respectively. Each of these sub-TLVs has the format as follows.

```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|     Type     |        Length (variable)        |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                       Value (variable)                      ~
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```
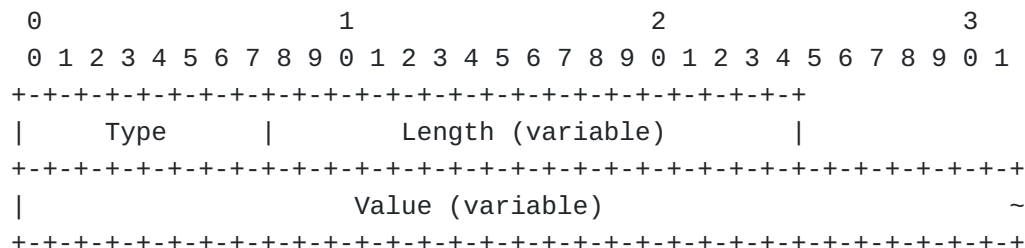
Figure 5: Format of sub-TLV in RouteAttr Atom

4.2.1.1. IPv4 Address Prefix Range List sub-TLV

The IPv4 Address Prefix Range List sub-TLV contains a list of IPv4 address prefix ranges. Each range describes an IPv4 address prefix or group of Pv4 address prefixes and is represented by a tuple <M-Type, IPv4 Address, Prefix Length, PL-Lower-Bound, PL-Upper-Bound>, where PL is short for prefix length. Its format is illustrated below:

```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
| Type (TBDa)  |         Length (N x 8)         |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|M-Type | Resv  |                IPv4 Address                   |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
| IPv4 Address  | Prefix-Length | PL-Lower-Bound| PL-Upper-Bound|
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
~       . . .
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|M-Type | Resv  |                IPv4 Address                   |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
| IPv4 Address  | Prefix-Length | PL-Lower-Bound| PL-Upper-Bound|
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

         Figure 6: Format of IPv4 Address Prefix Range List sub-TLV

   Type: The Type for IPv4 Address Prefix Range List is TBDa.

   Length: N x 8, where N is the number of IPv4 address prefix ranges
      in the sub-TLV. If Length is not a multiple of 8, the Atom is
      corrupt and the enclosing UPDATE message MUST be ignored.

   Resv: 4 bits. They MUST be sent as zero and ignored on receipt.

   IPv4 Address: 4 octets that describe an IPv4 prefix. This field,
      together with the Prefix-Length follows the same semantics as the
      NLRI encoding from [RFC4271], except that the trailing bits in
      the IPv4 Address fill the 4-octet field.

   Prefix-Length: 1 octet field that represents the Prefix Length of
      the IPv4 Address, as specified in [RFC4271].

   PL-Lower-Bound: 1-octet field that represents the lower bound of
      the IPv4 Address's prefix length. This field MUST be greater
      than, or equal to, the Prefix-Length, or be 0. If this field is
      less than the Prefix-Length and not 0, the enclosing UPDATE
      message MUST be ignored.

   PL-Upper-Bound: 1-octet field that represents the upper bound of
      the IPv4 Address's prefix length. This field MUST be greater
      than, or equal to, the Prefix-Length, or be 0. If this field is
      less than the Prefix-Length and not 0, the enclosing UPDATE
      message MUST be ignored.

   M-Type: 4-bit field specifying the IPv4 address prefix range format
      type. The values are specified below.

      M-Type = 0:

The IPv4 address prefix described corresponds to the IPv4
Address with the specified Prefix-Length. PL-Lower-Bound and
PL-Upper-Bound MUST be sent as zero and ignored on receipt.

M-Type = 1: Describes a set of IPv4 address prefixes that
correspond to the IPv4 Address/Prefix-Length combination and a
prefix length greater than or equal to PL-Lower-Bound. PL-
Upper-Bound MUST be sent as zero and ignored on receipt.

M-Type = 2: Describes a set of IPv4 address prefixes that
correspond to the IPv4 Address/Prefix-Length combination and a
prefix length less than or equal to PL-Upper-Bound. PL-Lower-
Bound MUST be sent as zero and ignored on receipt.

M-Type = 3: Describes a set of IPv4 address prefixes that
correspond to the IPv4 Address/Prefix-Length combination and a
prefix length greater than or equal to PL-Lower-Bound and less
than or equal to PL-Upper-Bound.

For example, tuple <M-Type=0, IPv4 Address = 10.1.0.0, Prefix-Length
= 16, PL-Lower-Bound = 0, PL-Upper-Bound = 0> represents
10.1.0.0/16.

<M-Type=1, IPv4 Address = 10.1.1.0, Prefix-Length = 24, PL-Lower-
Bound = 28, PL-Upper-Bound = 0> represents the set of IPv4 address
prefixes that correspond to 10.1.1.0/24 with a prefix length greater
than, or equal to, 28 bits (up to and including 32 bits). That is
that it represents any IPv4 address prefix that matches 10.1.1.0/24
and 28 <= whose prefix length <= 32.

<M-Type=2, IPv4 Address = 10.1.1.0, Prefix-Length = 24, PL-Lower-
Bound = 0, PL-Upper-Bound = 26> represents the set of IPv4 address
prefixes that correspond to 10.1.1.0/24 with a prefix length less
than, or equal to, 26 bits (up to and including 24 bits). That is
that it represents any IPv4 address prefix that matches 10.1.1.0/24
and 24 <= whose prefix length <= 26.

<M-Type=3, IPv4 Address = 10.1.1.0, Prefix-Length = 24, PL-Lower-
Bound = 26, PL-Upper-Bound = 30> represents the set of IPv4 address
prefixes that correspond to 10.1.1.0/24 with a prefix length greater
than, or equal to, 26 bits, and less than, or equal to, 30 bits.
That is that it represents any IPv4 address prefix that matches
10.1.1.0/24 and 26 <= whose prefix length <= 30.

4.2.1.2. IPv6 Address Prefix Range List sub-TLV

Similarly, an IPv6 Address Prefix Range List sub-TLV contains a list
of IPv6 address prefix ranges. Each range describes an IPv6 address
prefix or group of IPv6 address prefixes and is represented by a

tuple <M-Type, IPv6 Address, Prefix Length, PL-Lower-Bound, PL-
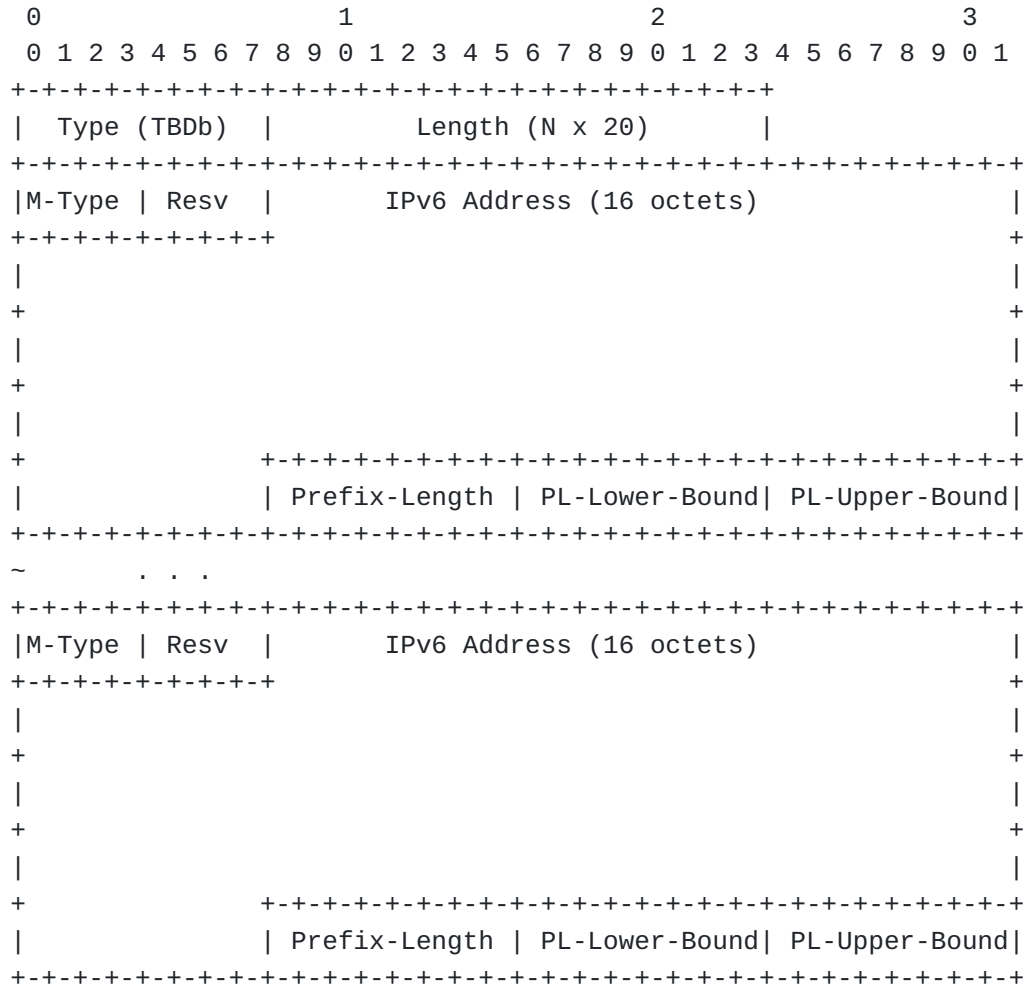   Upper-Bound>. Its format is illustrated below:


```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|  Type (TBDb)  |          Length (N x 20)       |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|M-Type | Resv  |        IPv6 Address (16 octets)             |
+-+-+-+-+-+-+-+-+                                              +
|                                                             |
+                                                             +
|                                                             |
+                                                             +
|                                                             |
+               +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|               | Prefix-Length | PL-Lower-Bound| PL-Upper-Bound|
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
~        . . .
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|M-Type | Resv  |       IPv6 Address (16 octets)              |
+-+-+-+-+-+-+-+-+                                              +
|                                                             |
+                                                             +
|                                                             |
+                                                             +
|                                                             |
+               +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|               | Prefix-Length | PL-Lower-Bound| PL-Upper-Bound|
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

        Figure 7: Format of IPv6 Address Prefix Range List sub-TLV

   Type: The Type for IPv6 Address Prefix Range List is TBDb.

   Length: N x 20, where N is the number of IPv6 address prefix ranges
      in the sub-TLV. If Length is not a multiple of 20, the enclosing
      UPDATE message MUST be ignored.

   The other fields are similar to those described in Section 4.2.1.1.

   For example, tuple <M-Type=0, IPv6 Address = 2001:db8:0:0:0:0:0:0,
   Prefix-Length = 32, PL-Lower-Bound = 0, PL-Upper-Bound = 0>
   represents 2001:db8:0:0:0:0:0:0/32.

   <M-Type=1, IPv6 Address = 2001:db8:0:0:0:0:0:0, Prefix-Length = 32,
   PL-Lower-Bound = 32, PL-Upper-Bound = 0> represents the set of IPv6
   address prefixes that correspond to 2001:db8:0:0:0:0:0:0/32 with a

prefix length greater than, or equal to, 32 bits (up to and
including 128 bits).

<M-Type=2, IPv6 Address = 2001:db8:0:0:0:0:0:0, Prefix-Length = 32,
PL-Lower-Bound = 0, PL-Upper-Bound = 64> represents the set of IPv6
address prefixes that correspond to 2001:db8:0:0:0:0:0:0/32 with a
prefix length less than, or equal to, 64 bits (up to and including
32 bits).

<M-Type=3, IPv6 Address = 2001:db8:0:0:0:0:0:0, Prefix-Length = 32,
PL-Lower-Bound = 48, PL-Upper-Bound = 64> represents the set of IPv6
address prefixes that correspond to 2001:db8:0:0:0:0:0:0/32 with a
prefix length greater than, or equal to, 48 bits, and less than, or
equal to, 64 bits.

4.2.1.3. AS_PATH RegEx sub-TLV

An AS_PATH RegEx sub-TLV represents any AS_PATH specified by a
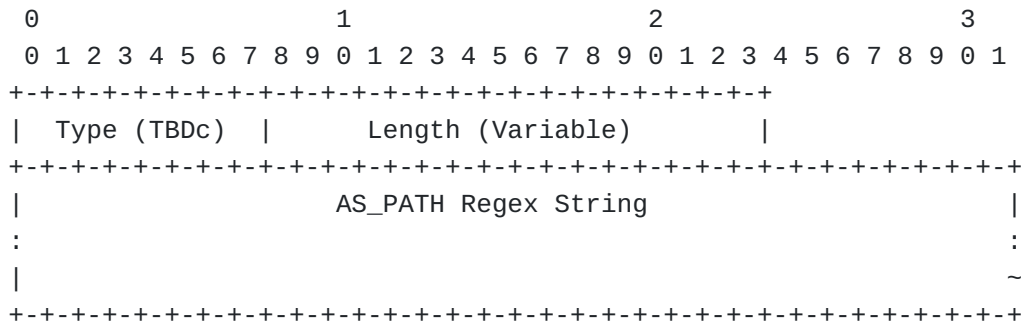regular expression [RegExIEEE]. Its format is illustrated below:

```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|  Type (TBDc)  |       Length (Variable)       |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                   AS_PATH Regex String                        |
:                                                               :
|                                                               ~
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Figure 8: Format of AS_PATH RegEx sub-TLV

Type: The Type for AS_PATH RegEx is TBDc.

Length: Variable, maximum is 1024.

AS_PATH Regex String: It is a regular expression as defined in
   [RegExIEEE].

For example, regular expression "12345$" represents any AS_PATH that
end with 12345.

4.2.1.4. Community List sub-TLV

A Community List sub-TLV represents a list of communities in the BGP
COMMUNITIES defined by [RFC1997]. Its format is illustrated below:

```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
| Type (TBDd)   |        Length (N x 4 + 1)     |     Resv      |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                      Community 1 Value                        |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
~                          . . .                                ~
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                      Community N Value                        |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Figure 9: Format of Community List sub-TLV

Type: The Type for Community List is TBDd.

Length: N x 4 + 1, where N is the number of communities. If Length
   is not a multiple of 4 plus 1, the Atom is corrupt and the
   enclosing UPDATE message MUST be ignored.

Resv: 1 octet. These bits MUST be sent as zero and ignored on
   receipt.

Community Value: The Community List contains a list of Community
   Values. Each Community Value is a 4-octet field for a community
   defined by [RFC1997].

4.2.2. Atom Type TBD2, The MED Change

A MULTI_EXIT_DISC (MED) Change Atom indicates an action to change
the MED. Its format is illustrated as a TLV (Type Length Value)
below. The Value field consists of an OP field of 1 octet and an
Argument field of 4 octets.

```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
| Type (TBD2)   |        Length (5)             |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|      OP       |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                         Argument                             |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Figure 10: Format of MED Change Atom

Type:

> The Type for MED Change Atom is TBD2.

Length: 5. If Length is any other value, the Atom is corrupt and
the enclosing UPDATE message MUST be ignored.

Argument: 4 octet unsigned integer.

OP: 1 octet. Three values are defined:

> **OP = 0:** assign the Value of the Argument to the existing MED. If
> the MED attribute does not exist for an IP route, add a MED
> attribute with the value.

> **OP = 1:** add the Value of the Argument to the existing MED. If
> the sum is greater than the maximum allowed value, use that
> maximum value instead. If the MED attribute does not exist for
> an IP route, the action specified by the Atom to the route is
> not taken.

> **OP = 2:** subtract the Value of the Argument from the existing
> MED. If the result is less than 0, use 0 instead. If the MED
> attribute does not exist for an IP route, the action specified
> by the Atom to the route is not taken.

> **If OP is any other value, the Atom is corrupt and the enclosing
> UPDATE message MUST be ignored.**

4.2.3. Atom Type TBD3, The AS_PATH Change

An AS_PATH Change Atom indicates an action to change the AS_PATH.
Its format is illustrated below:

```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
| Type (TBD3)  |        Length (n x 5)          |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                             AS1                               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|   Count1    |
+-+-+-+-+-+-+-+-+
~       . . .
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                             ASn                               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|   Countn    |
+-+-+-+-+-+-+-+-+
```
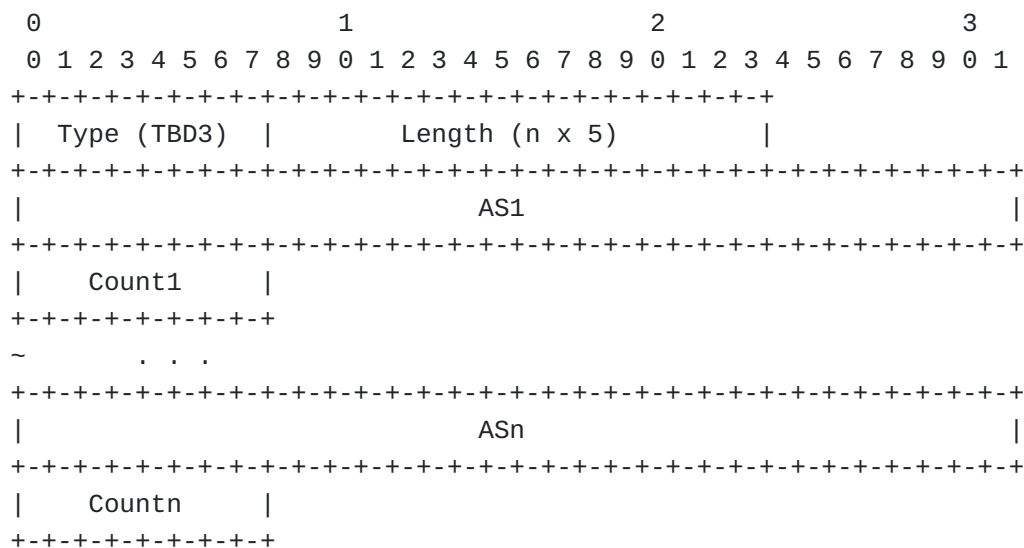
Figure 11: Format of AS_PATH Change Atom

Type:
>   The Type for AS_PATH Change Atom is TBD3.

Length: n x 5. If Length is not a multiple of 5, the Atom is
>   corrupt and the enclosing UPDATE message MUST be ignored.

AS and Count: The Atom contains a list of AS and Count pairs. Each
>   AS and Count pair has an AS field of 4 octets for an AS number
>   and a Count field of 1 octet for an unsigned integer indicating
>   the number of times the AS number repeats.

The sequence of AS numbers specified by the Atom is added to the
existing AS_PATH. The AS numbers SHOULD be local AS numbers.

4.3. Community Value in BGP Wide Community

[I-D.ietf-idr-wide-bgp-communities] defines the Type 1 BGP Community
Container, the BGP Wide Community. It contains a Community Value of
4 octets indicating what set of actions a router is requested to
take upon reception of an IP route matching the conditions in this
community. This section specifies two Community Values:

   *MATCH AND SET ATTR (TBDx)

   *MATCH AND NOT ADVERTISE (TBDy)

4.3.1. MATCH AND SET ATTR (TBDx)

For the BGP Wide Community with Community Value MATCH AND SET ATTR
(TBDx), its Targets TLV MUST contain a RouteAttr Atom, its
Parameters TLV MUST include a MED Change Atom and/or a AS_PATH
Change Atom. The RouteAttr Atom MUST contain an IPv4/IPv6 (IP for
short) Address Prefix Range List and may contain a Community List
and/or AS_PATH sub-TLVs. The Prefix Range List states a set of IP
address prefix ranges. The Community List and/or AS_PATH identify a
set of path attributes.

After a BGP speaker receives the BGP Wide Community in a BGP UPDATE
message for it, the speaker extracts the routing policy from the BGP
Wide Community. For any IP route to a peer of the speaker, if the IP
address prefix of the route is in any prefix range stated by the
Prefix Range List and the route has the attributes identified by the
Community List and/or AS_PATH, then the attributes of the IP route
are modified per the actions specified by the MED Change and/or
AS_PATH Change Atom before sending it to the peer.

4.3.2. MATCH AND NOT ADVERTISE (TBDy)

For the BGP Wide Community with Community Value MATCH AND NOT
ADVERTISE (TBDy), its Targets TLV MUST contain a RouteAttr Atom. The

Atom has the same contents and semantic as the one described in
Section 4.3.1.

After a BGP speaker receives the BGP Wide Community in a BGP UPDATE
message for it, the speaker extracts the routing policy from the BGP
Wide Community. For any IP route to a peer of the speaker, if the IP
address prefix of the route is in any prefix range stated by the
Prefix Range List and the route has the attributes identified by the
Community List and/or AS_PATH, then the IP route will not be
advertised to the peer.

5. Operational Considerations

To adjust the traffic flowing to an AS with a controller, an
operator needs to create a BGP RPD session between the controller
and a RR in the AS. This session SHOULD be independent of routing
information. The controller can distribute a RPD routing policy to
any BGP speaker in the AS using this session. The speaker applies
the policy to the IP routes to be sent to its peers as specified.

For the session between the controller and the RR, some existing
mechanisms such as BGP Graceful Restart (GR) [RFC4724] and BGP Long-
lived Graceful Restart (LLGR) SHOULD be used to let the RR keep the
RPD routing policies from the controller for some time. With support
of "Long-lived Graceful Restart Capability"
[I-D.ietf-idr-long-lived-gr], the RPD routing policies can be
retained for a longer time after the controller fails. When the
controller recovers from its failure within the graceful period, the
RR still have the RPD routing policies from the controller before
the failure.

For the sessions between the speaker and its peers, the mechanisms
mentioned above are not necessary. When the speaker goes down, the
traffic to the AS through the speaker from its peers needs take
another path without going through the speaker. The peers withdraw
the routes from the speaker and adjust (reroute) the traffic to use
another path without the speaker. This is expected.

For the traffic to an IP address prefix in the AS from an neighbor
AS, the operator needs make sure that the traffic can be adjusted
through changing the MED and/or AS_PATH attribute in the IP route
with the prefix to be sent to the neighbor AS.

In a BGP speaker, there are routing policies from different sources,
including RPD and others such as configuration and PCE. The speaker
applies all the policies as needed. It applies the RPD routing
policies after applying the other routing policies. In order to
adjust traffic using RPD routing policies with MED change and/or

AS_PATH change, the operator needs make sure that the RPD policies are not superseded by any policy from other sources.

When a RPD routing policy is to be applied by a BGP speaker to only one of its peers, the Peer field SHOULD be the IP address of this peer. After receiving the RPD routing policy, the BGP speaker applies the policy to the IP routes to be sent to this peer.

When a RPD routing policy is to be applied by a BGP speaker to all its peers in some of its neighbor ASs, the Autonomous System Number (ANS) List Atom can be used in the Targets TLV to select these neighbor ASs while the Peer field is 0. After receiving the RPD routing policy, the BGP speaker applies the policy to the IP routes to be sent to the peers in these selected neighbor ASs.

When a RPD routing policy is to be applied by a BGP speaker to some of its peers, the IP Prefix List Atom can be used in the Targets TLV to select these peers while the Peer field is 0. After receiving the RPD routing policy, the BGP speaker applies the policy to the IP routes to be sent to these selected peers.

There are already lots of existing policies configured on the routers in an operational network. There are different types of policies, which include security, management and control policies. These policies are relatively stable. However, the policies for adjusting traffic are dynamic. Whenever the traffic through a path is not expected, the policies to adjust the traffic for that path are configured on the related routers. Some users would like to separate the stable policies from the dynamic ones even though they have configuration automation systems (including YANG models). In this case, RPD with a controller (RPD for short) should be considered over others. Using RPD, the stable policies and dynamic ones are separated from users' view.

When the number of routers to be configured for adjusting traffic is big and keeping all the connections live between a configuration automation system and these routers affects network performance, RPD should be considered over this system. Using RPD, there is one connection between the controller and a RR in an AS. There is almost no impact on the network performance.

When it takes a long time for a configuration automation system to adjust traffic, RPD should be considered over this system. Using RPD, the policies for adjusting traffic are distributed to the related routers and applied in routing speed.

6. IANA Considerations

6.1. Existing Assignments

IANA has assigned an AFI of value 16398 from the registry "Address Family Numbers" for Routing Policy.

IANA has assigned the Routing Policy SAFI of value 75 from the registry "Subsequent Address Family Identifiers (SAFI) Parameters".

IANA has assigned a Code Point of value 72 from the registry "Capability Codes" for Routing Policy Distribution.

6.2. BGP Wide Community Community Types

IANA is requested to assign from the registry "Registered Type 1 BGP Wide Community Community Types" the following values:

Community Type Value	Description	Reference
TBDx (0x80000018 suggested)	MATCH AND SET ATTR	This document
TBDy (0x80000019 suggested)	MATCH AND NOT ADVERTISE	This document

6.3. BGP Community Container Atom Types

IANA is requested to assign from the registry "BGP Community Container Atom Types" as follows:

Type Value	Name	Reference
TBD1 (0x09 suggested)	RouteAttr	This document
TBD2 (0x0A suggested)	MED Change	This document
TBD3 (0x0B suggested)	AS_PATH Change	This document
TBDa (0x0C suggested)	IPv4 Prefix Range List	This document
TBDb (0x0D suggested)	IPv6 Prefix Range List	This document
TBDc (0x0E suggested)	AS-Path RegEx	This document
TBDd (0x0F suggested)	Community List	This document

7. Security Considerations

All the security considerations for base BGP [RFC4271][RFC4272] and
BGP Wide Community [I-D.ietf-idr-wide-bgp-communities] apply to the
BGP extensions defined in this document.

This document depends on the BGP Multiprotocol extension [RFC4760],
which states that the extension does not change the underlying
security issues inherent in the existing BGP. It does not
fundamentally change the security behavior of BGP deployments. It
may be observed that the RPD is used only within a well-defined
scope, for example, within a single AS or a set of ASes that are
administrated by a single service provider.

This document defines two community values in the BGP Wide Community
to distribute and apply routing policies. One is MATCH AND SET ATTR
(TBDx) and the other is MATCH AND NOT ADVERTISE (TBDy). Using the
former changes one or more best IP routes distributed by BGP and
redirects a certain traffic flows in a network. Using the latter
drops one or more IP routes distributed by BGP and redirects some
traffic flows in a network. The potential effects of the
distribution and use of a undesired routing policy from a (rogue)
router include causing network congestions and reducing the quality
of the services. They can also have the effect of dropping traffic.
Note that a rogue node can use these to attack the network, but a
misconfigured policy could have the same effect. It is necessary to
prevent a (rogue) router from advertising an incorrect or undesired
routing policy through BGP sessions. The risk can be mitigated by
using the techniques such as those discussed in [RFC5925] to help
authenticate BGP sessions.

Note that a typical RPD deployment requires a BGP session between a
controller and a route reflector in a network administrated by a
single service provider. The controller distributes RPD routing
policies to some routers in the network through this BGP session.
There is concern that a rogue controller might be introduced into
the network. The rogue controller may inject false RPD routing
policies or take over and change existing RPD routing policies. This
corresponds to a rogue BGP speaker entering the network, or a route
reflector being subverted. It is strongly recommended that the
techniques such as those in [RFC5925] be used to secure this BGP
session, the route reflector be configured with the identity of the
controller, and software loads on the controller be protected.

8. References

8.1. Normative References

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