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P. Marques
R. Bonica
Juniper Networks
L. Fang
L. Martini
R. Raszuk
K. Patel
J. Guichard
Cisco Systems, Inc.

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Constrained Route Distribution for Border Gateway Protocol/MultiProtocol Label Switching (BGP/MPLS) Internet Protocol (IP) Virtual Private Networks (VPNs)

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Abstract

This document defines Multi-Protocol BGP (MP-BGP) procedures that allow BGP speakers to exchange Route Target reachability information. This information can be used to build a route distribution graph in order to limit the propagation of Virtual Private Network (VPN) Network Layer Reachability Information (NLRI) between different autonomous systems or distinct clusters of the same autonomous system. This document updates RFC 4364.

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1. Introduction

In BGP/MPLS IP VPNs, PE routers use Route Target (RT) extended communities to control the distribution of routes into VRFs. Within a given iBGP mesh, PE routers need only hold routes marked with Route Targets pertaining to VRFs that have local CE attachments.

It is common, however, for an autonomous system to use route reflection [2] in order to simplify the process of bringing up a new PE router in the network and to limit the size of the iBGP peering mesh.

In such a scenario, as well as when VPNs may have members in more than one autonomous system, the number of routes carried by the inter-cluster or inter-as distribution routers is an important consideration.

In order to limit the VPN routing information that is maintained at a given route reflector, RFC 4364 [3] suggests, in Section 4.3.3, the use of "Cooperative Route Filtering" [7] between route reflectors. This document extends the RFC 4364 [3] Outbound Route Filtering (ORF) work to include support for multiple autonomous systems and asymmetric VPN topologies such as hub-and-spoke.

Although it would be possible to extend the encoding currently defined for the extended-community ORF in order to achieve this purpose, BGP itself already has all the necessary machinery for dissemination of arbitrary information in a loop-free fashion, both within a single autonomous system, as well as across multiple autonomous systems.

This document builds on the model described in RFC 4364 [3] and on the concept of cooperative route filtering by adding the ability to propagate Route Target membership information between iBGP meshes. It is designed to supersede "cooperative route filtering" for VPN related applications.

By using MP-BGP UPDATE messages to propagate Route Target membership information, it is possible to reuse all of this machinery, including route reflection, confederations, and inter-as information loop detection.

Received Route Target membership information can then be used to restrict advertisement of VPN NLRI to peers that have advertised their respective Route Targets, effectively building a route distribution graph. In this model, VPN NLRI routing information flows in the inverse direction of Route Target membership information.

This mechanism is applicable to any BGP NLRI that controls the distribution of routing information by using Route Targets, such as VPLS [9].

Throughout this document, the term NLRI, which expands to "Network Layer Reachability Information", is used to describe routing information carried via MP-BGP updates without any assumption of semantics.

An NLRI consisting of {origin-as#, route-target} will be referred to as RT membership information for the purpose of the explanation in this document.

1.1. Terminology

This document uses a number of terms and acronyms specific to Provider-Provisioned VPNs, including those specific to L2VPNs, L3VPNs and BGP. Definitions for many of these terms may be found in the VPN terminology document [10]. This section also includes some brief acronym expansion and terminology to aid the reader.

AFI	Address Family Identifier (a BGP address type)
BGP	Border Gateway Protocol
BGP/MPLS VPN	A Layer 3 VPN implementation based upon BGP and MPLS
CE	Customer Edge (router)

iBGP	Internal BGP (i.e., a BGP peering session that connects two routers within an autonomous system)
L2VPN	Layer 2 Virtual Private Network
L3VPN	Layer 3 Virtual Private Network
MP-BGP	MultiProtocol-Border Gateway Protocol
MPLS	MultiProtocol Label Switching
NLRI	Network Layer Reachability Information
ORF	Outbound Route Filtering
PE	Provider Edge (router)
RT	Route Target (i.e., a BGP extended community that conditions network layer reachability information with VPN membership)
SAFI	Subsequence Address Family Identifier (a BGP address sub-type)
VPLS	Virtual Private LAN Service
VPN	Virtual Private Network

2. Specification of Requirements

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 RFC 2119 [1].

3. NLRI Distribution

3.1. Inter-AS VPN Route Distribution

In order to better understand the problem at hand, it is helpful to divide it in to its inter-Autonomous System (AS) and intra-AS components. Figure 1 represents an arbitrary graph of autonomous systems (a through j) interconnected in an ad hoc fashion. The following discussion ignores the complexity of intra-AS route distribution.

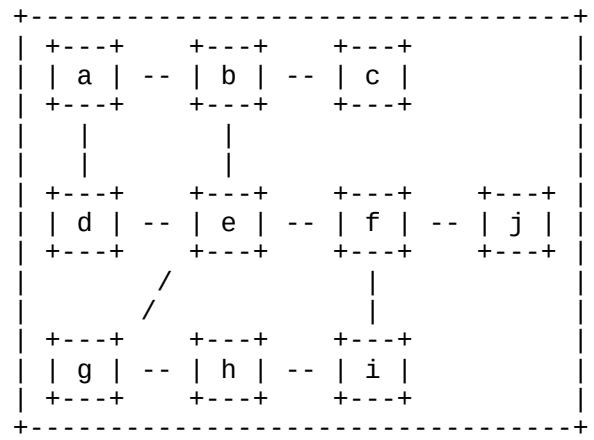


Figure 1. Topology of autonomous systems

Let's consider the simple case of a VPN with CE attachments in ASes a and i that uses a single Route Target to control VPN route distribution. Ideally we would like to build a flooding graph for the respective VPN routes that would not include nodes (c, g, h, j). Nodes (c, j) are leafs ASes that do not require this information, whereas nodes (g, h) are not in the shortest inter-as path between (e) and (i) and thus should be excluded via standard BGP path selection.

In order to achieve this, we will rely on ASa and ASi, generating a NLRI consisting of {origin-as#, route-target} (RT membership information). Receipt of such an advertisement by one of the ASes in the network will signal the need to distribute VPN routes containing this Route Target community to the peer that advertised this route.

Using RT membership information that includes both route-target and originator AS number allows BGP speakers to use standard path selection rules concerning as-path length (and other policy mechanisms) to prune duplicate paths in the RT membership information flooding graph, while maintaining the information required to reach all autonomous systems advertising the Route Target.

In the example above, AS e needs to maintain a path to AS a in order to flood VPN routing information originating from AS i and vice-versa. It should, however, as default policy, prune less preferred paths such as the longer path to ASi with as-path (g h i).

Extending the example above to include AS j as a member of the VPN distribution graph would cause AS f to advertise 2 RT Membership NLRIs to AS e, one containing origin AS i and one containing origin AS j. Although advertising a single path would be sufficient to guarantee that VPN information flows to all VPN member ASes, this is not enough for the desired path selection choices. In the example above, assume that (f j) is selected and advertised. Were that the case, the information concerning the path (f i), which is necessary to prune the arc (e g h i) from the route distribution graph, would be missing.

As with other approaches for building distribution graphs, the benefits of this mechanism are directly proportional to how "sparse" the VPN membership is. Standard RFC2547 inter-AS behavior can be seen as a dense-mode approach, to make the analogy with multicast routing protocols.

3.2. Intra-AS VPN Route Distribution

As indicated above, the inter-AS VPN route distribution graph, for a given route-target, is constructed by creating a directed arc on the inverse direction of received Route Target membership UPDATEs containing an NLRI of the form {origin-as#, route-target}.

Inside the BGP topology of a given autonomous-system, as far as external RT membership information is concerned (route-targets where the as# is not the local as), it is easy to see that standard BGP route selection and advertisement rules [4] will allow a transit AS to create the necessary flooding state.

Consider a IPv4 NLRI prefix, sourced by a single AS, which is distributed via BGP within a given transit AS. BGP protocol rules guarantee that a BGP speaker has a valid route that can be used for forwarding of data packets for that destination prefix, in the inverse path of received routing updates.

By the same token, and given that an {origin-as#, route-target} key provides uniqueness between several ASes that may be sourcing this route-target, BGP route selection and advertisement procedures guarantee that a valid VPN route distribution path exists to the origin of the Route Target membership information advertisement.

Route Target membership information that is originated within the autonomous-system, however, requires more careful examination. Several PE routers within a given autonomous-system may source the same NLRI {origin-as#, route-target}, and thus default route advertisement rules are no longer sufficient to guarantee that within the given AS each node in the distribution graph has selected a feasible path to each of the PEs that import the given route-target.

When processing RT membership NLRIs received from internal iBGP peers, it is necessary to consider all available iBGP paths for a given RT prefix, for building the outbound route filter, and not just the best path.

In addition, when advertising Route Target membership information sourced by the local autonomous system to an iBGP peer, a BGP speaker shall modify its procedure to calculate the BGP attributes such that the following apply:

i. When advertising RT membership NLRI to a route-reflector client, the Originator attribute shall be set to the router-id of the advertiser, and the Next-hop attribute shall be set of the local address for that session.

ii. When advertising an RT membership NLRI to a non-client peer, if the best path as selected by the path selection procedure described in Section 9.1 of the base BGP specification [4] is a route received from a non-client peer, and if there is an alternative path to the same destination from a client, the attributes of the client path are advertised to the peer.

The first of these route advertisement rules is designed such that the originator of an RT membership NLRI does not drop an RT membership NLRI that is reflected back to it, thus allowing the route reflector to use this RT membership NLRI in order to signal the client that it should distribute VPN routes with the specific target towards the reflector.

The second rule allows any BGP speaker present in an iBGP mesh to signal the interest of its route reflection clients in receiving VPN routes for that target.

These procedures assume that the autonomous-system route reflection topology is configured such that IPv4 unicast routing would work correctly. For instance, route reflection clusters must be contiguous.

An alternative solution to the procedure given above would have been to source different routes per PE, such as NLRI of the form {originator-id, route-target}, and to aggregate them at the edge of the network. The solution adopted is considered advantageous over the former in that it requires less routing-information within a given AS.

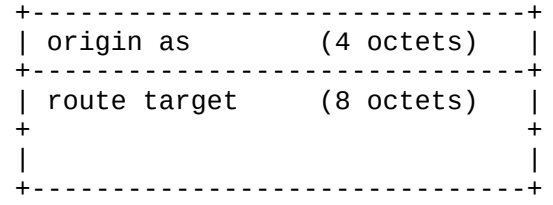
4. Route Target Membership NLRI Advertisements

Route Target membership NLRI is advertised in BGP UPDATE messages using the MP_REACH_NLRI and MP_UNREACH_NLRI attributes [5]. The [AFI, SAFI] value pair used to identify this NLRI is (AFI=1, SAFI=132).

The Next Hop field of MP_REACH_NLRI attribute shall be interpreted as an IPv4 address whenever the length of NextHop address is 4 octets, and as a IPv6 address whenever the length of the NextHop address is 16 octets.

The NLRI field in the MP_REACH_NLRI and MP_UNREACH_NLRI is a prefix of 0 to 96 bits, encoded as defined in Section 4 of [5].

This prefix is structured as follows:



Except for the default route target, which is encoded as a zero-length prefix, the minimum prefix length is 32 bits. As the origin-as field cannot be interpreted as a prefix.

Route targets can then be expressed as prefixes, where, for instance, a prefix would encompass all route target extended communities assigned by a given Global Administrator [6].

The default route target can be used to indicate to a peer the willingness to receive all VPN route advertisements such as, for instance, the case of a route reflector speaking to one of its PE router clients.

5. Capability Advertisement

A BGP speaker that wishes to exchange Route Target membership information must use the Multiprotocol Extensions Capability Code, as defined in RFC 2858 [5], to advertise the corresponding (AFI, SAFI) pair.

A BGP speaker MAY participate in the distribution of Route Target information without using the learned information for purposes of VPN NLRI output route filtering, although this is discouraged.

6. Operation

A VPN NLRI route should be advertised to a peer that participates in the exchange of Route Target membership information if that peer has advertised either the default Route Target membership NLRI or a Route Target membership NLRI containing any of the targets contained in the extended communities attribute of the VPN route in question.

When a BGP speaker receives a BGP UPDATE that advertises or withdraws a given Route Target membership NLRI, it should examine the RIB-OUTs of VPN NLRIs and re-evaluate the advertisement status of routes that match the Route Target in question.

A BGP speaker should generate the minimum set of BGP VPN route updates (advertisements and/or withdrawls) necessary to transition between the previous and current state of the route distribution graph that is derived from Route Target membership information.

As a hint that initial RT membership exchange is complete, implementations SHOULD generate an End-of-RIB marker, as defined in [8], for the Route Target membership (afi, safi), regardless of whether graceful-restart is enabled on the BGP session. This allows the receiver to know when it has received the full contents of the peer's membership information. The exchange of VPN NLRI should follow the receipt of the End-of-RIB markers.

If a BGP speaker chooses to delay the advertisement of BGP VPN route updates until it receives this End-of-RIB marker, it MUST limit that delay to an upper bound. By default, a 60 second value should be used.

7. Deployment Considerations

This mechanism reduces the scaling requirements that are imposed on route reflectors by limiting the number of VPN routes and events that a reflector has to process to the VPN routes used by its direct clients. By default, a reflector must scale in terms of the total number of VPN routes present on the network.

This also means that it is now possible to reduce the load imposed on a given reflector by dividing the PE routers present on its cluster into a new set of clusters. This is a localized configuration change that need not affect any system outside this cluster.

The effectiveness of RT-based filtering depends on how sparse the VPN membership is.

The same policy mechanisms applicable to other NLRIs are also applicable to RT membership information. This gives a network operator the option of controlling which VPN routes get advertised in an inter-domain border by filtering the acceptable RT membership advertisements inbound.

For instance, in the inter-as case, it is likely that a given VPN is connected only to a subset of all participating ASes. The only current mechanism to limit the scope of VPN route flooding is through manual filtering on the external BGP border routers. With the current proposal, such filtering can be performed according to the dynamic Route Target membership information.

In some inter-as deployments, not all RTs used for a given VPN have external significance. For example, a VPN can use a hub RT and a spoke RT internally to an autonomous-system. The spoke RT does not have meaning outside this AS, so it may be stripped at an external border router. The same policy rules that result in extended community filtering can be applied to RT membership information in order to avoid advertising an RT membership NLRI for the spoke-RT in the example above.

Throughout this document, we assume that autonomous-systems agree on an RT assignment convention. RT translation at the external border router boundary is considered a local implementation decision, as it should not affect inter-operability.

8. Security Considerations

This document does not alter the security properties of BGP-based VPNs. However, note that output route filters built from RT membership information NLRIs are not intended for security purposes. When exchanging routing information between separate administrative domains, it is a good practice to filter all incoming and outgoing NLRIs by some other means in addition to RT membership information. Implementations SHOULD also provide means to filter RT membership information.

9. Acknowledgements

This proposal is based on the extended community route filtering mechanism defined in [7].

Ahmed Guetari was instrumental in defining requirements for this proposal.

The authors would also like to thank Yakov Rekhter, Dan Tappan, Dave Ward, John Scudder, and Jerry Ash for their comments and suggestions.

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Authors' Addresses

Pedro Marques
Juniper Networks
1194 N. Mathilda Ave.
Sunnyvale, CA 94089
US

EMail: roque@juniper.net

Ronald Bonica
Juniper Networks
1194 N. Mathilda Ave.
Sunnyvale, CA 94089
US

EMail: rbonica@juniper.net

Luyuan Fang
Cisco Systems, Inc.
300 Beaver Brook Road
Boxborough, MA 01719
US

EMail: lufang@cisco.com

Luca Martini
Cisco Systems, Inc.
9155 East Nichols Avenue, Suite 400
Englewood, CO 80112
US

EMail: lmartini@cisco.com

Robert Raszuk
Cisco Systems, Inc.
170 West Tasman Dr
San Jose, CA 95134
US

EMail: rraszuk@cisco.com

Keyur Patel
Cisco Systems, Inc.
170 West Tasman Dr
San Jose, CA 95134
US

EMail: keyupate@cisco.com

Jim Guichard
Cisco Systems, Inc.
300 Beaver Brook Road
Boxborough, MA 01719
US

EMail: jguichar@cisco.com

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