IDR Working Group
Internet-Draft
Intended status: Standards Track
Expires: June 7, 2013

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December 4, 2012

BGP Optimal Route Reflection (BGP-ORR)
draft-ietf-idr-bgp-optimal-route-reflection-04

Abstract

[RFC4456] asserts that, because the Interior Gateway Protocol (IGP) cost to a given point in the network will vary across routers, "the route reflection approach may not yield the same route selection result as that of the full IBGP mesh approach." One practical implication of this assertion is that the deployment of route reflection may thwart the ability to achieve hot potato routing. Hot potato routing attempts to direct traffic to the closest AS egress point in cases where no higher priority policy dictates otherwise. As a consequence of the route reflection method, the choice of exit point for a route reflector and its clients will be the egress point closest to the route reflector - and not necessarily closest to the RR clients.

Section 11 of [RFC4456] describes a deployment approach and a set of constraints which, if satsified, would result in the deployment of route reflection yielding the same results as the iBGP full mesh approach. Such a deployment approach would make route reflection compatible with the application of hot potato routing policy.

As networks evolved to accommodate architectural requirements of new services, tunneled (LSP/IP tunneling) networks with centralized route reflectors became commonplace. This is one type of common deployment where it would be impractical to satisfy the constraints described in Section 11 of [RFC4456]. Yet, in such an environment, hot potato routing policy remains desirable.

This document proposes two new solutions which can be deployed to facilitate the application of closest exit point policy centralized route reflection deployments.

Status of this Memo

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1. Introduction

There are three types of BGP deployments within Autonomous Systems today: full mesh, confederations and route reflection.

BGP route reflection is the most popular way to distribute BGP routes between BGP speakers belonging to the same administrative domain. Traditionally route reflectors have been deployed in the forwarding path and carefully placed on the POP to core boundaries. That model of BGP route reflector placement has started to evolve. The placement of route reflectors outside the forwarding path was triggered by applications which required traffic to be tunneled from AS ingress PE to egress PE: for example L3VPN.

This evolving model of intra-domain network design has enabled deployments of centralized route reflectors. Initially this model was only employed for new address families e.g. L3VPNs, L2VPNs etc

With edge to edge MPLS or IP encapsulation also being used to carry internet traffic, this model has been gradually extended to other BGP address families including IPv4 and IPv6 Internet routing. This is also applicable to new services achieved with BGP as control plane for example 6PE.

Such centralized route reflectors can be placed on the POP to core boundaries, but they are often placed in arbitrary locations in the core of large networks.

Such deployments suffer from a critical drawback in the context of best path selection. A route reflector with knowledge of multiple paths for a given prefix will pick the best path and only advertise that best path to the the route reflector clients. If the best path for a prefix is selected on the basis of an IGP tie break, the best path advertised from the route reflector to its clients will be the exit point closest to the route reflector. But route reflector clients will be in a place in the network toplogy which is different from the route reflector. In networks with centralized route reflectors, this difference will be even more acute. It follows that the best path chosen by the route reflector is not necessarily the same as the path which would have been chosen by the client if the client considered the same set of candidate paths as the route reflector. Furthermore, the path chosen by the client might have been a better path from that chosen by the route reflector for traffic entering the network at the client. The path chosen by the client would have guaranteed the lowest cost and delay trajectory through the network.

Route reflector clients switch packets using routing information

learnt from route reflectors which are not on the forwarding path of the packet through the network even in the absence of end-to-end encapsulation. In those cases the path chosen as best and propagated to the clients will often not be the optimal path chosen by the client given all available paths.

Eliminating the IGP distance to the BGP nexthop as a tie breaker on centralized route reflectors does not address the issue. Ignoring IGP distance to the BGP next hop results in the tie breaking procedure contributing the best path by differentiating between paths using attributes otherwise considered less important than IGP cost to the BGP nexthop.

One possible valid solution or workaround to this problem requires sending all domain external paths from the RR to all its clients. This approach suffers the significant drawback of pushing a large amount of BGP state to all the edge routers. In many networks, the number of EBGP peers over which full Internet routing information is received would correlate directly to the number of paths present in each ASBR. This could easily result in tens of paths for each prefix.

Notwithstanding this drawback, there are a number of reasons for sending more than just the single best path to the clients. Improved path diversity at the edge is a requirement for fast connectivity restoration, and a requirement for effective BGP level load balancing. Protocol extensions like add-paths [I-D.ietf-idr-add-paths] or [RFC6774] diverse-path allow for such improved path diversity and can be used to address the same problems addressed by the mechanisms proposed in this draft.

In practical terms, add/diverse path deployments are expected to result in the distribution of 2, 3 or n (where n is a small number) 'good' paths rather than all domain external paths. While the route reflector chooses one set of n paths and distributes those same n paths to all its route reflector clients, those n paths may not be the right n paths for all clients. In the context of the problem described above, those n paths will not necessarily include the closest egress point out of the network for each route reflector client. The mechanisms proposed in this document are likely to be complementary to mechanisms aimed at improving path diversity.

2. Proposed solutions

This document proposes two simple solutions to the problem described above. Both of these solutions make it possible for route reflector clients to direct traffic to their closest exit point in hot potato

routing deployments, without requiring further state to be pushed out to the edge. These solutions are primarily applicable in deployments using centralized route reflectors, which are typically implemented in devices without a capable forwarding plane.

The two alternatives are:

"Best path selection for BGP hot potato routing from client's IGP network position"

"Angular distance approximation for BGP warm potato routing"

Both solutions rely upon all route reflectors learning all paths which are eligible for consideration for hot potato routing. In order to satisfy this requirement, path diversity enhancing mechanisms such as add paths/diverse paths may need to be deployed between route reflectors.

In both of these solutions the route reflector selects and distributes a route to each client based on what would be optimal from the client's perspective. By optimal we refer in this document to the decision made during best path selection at the IGP metric to BGP next hop comparison step. Clearly the overall path selection preference may be chosen based other policy step and provisions as defined in this document would not apply.

In the respective solutions the choice is made either factoring in IGP costs or the configured angular distance to the next hop. The route reflector makes different decisions for different clients only in the case where the tie breaker for path selection would have been the IGP distance to the BGP nexthop (as in hot potato routing).

A significant advantage of this approach is that the RR clients do not need to run new software or hardware.

Besides these solutions to manage hot potato routing, there are deployment scenarios where service providers want to have more control of traffic exiting the AS by assigning per client preference to gateways.

This document proposes to introduce a solution to perform a policy based route-reflection to address those scenarios. This solution has the same requirements (regarding path diversity) and advantages than the two IGP metric based solutions.

3. **Best path selection for BGP hot potato routing** from customized IGP network position

This section describes a method for calculating the order of preference of BGP paths from the point of view of each separate route reflector client. More specifically, the route reflector will compute the IGP metric to the BGP nexthop from the position of the client to which the resulting path will be distributed, if the IGP metric is the tie breaker applied to a set of possible paths. In the subsequent model authors will propose virtual reflector placement at operator's selected IGP location.

In the case of a hierarchical IGP deployment where the client is in a different level in the hierarchy to the route reflector, the route reflector will compute IGP distance to the BGP nexthop from the Area Border Routers (ABR) leading to the client in lieu of the route reflector client itself, and use the shortest distance from these ABRs to the nexthop. This provides an approximation to the desired functionality. Rather than a client picking the closest path, the client would be picking the exit point closest to the client region as defined by area or level. In cases where one or more nexthops are in the same region as the client, one of those nexthops would be preferred, with tie breaking within those nexthops performed from the route reflector's position in the network.

It is assumed that reachability through a set of ABRs is always advertised through identical prefixes from those ABRs. If a nexthop is reachable through multiple ABRs but the ABRs advertise reachability through prefixes of different length, then only the ABR advertising the longest prefix will be considered as a viable path to the nexthop.

BGP best path selection and its distribution has a natural consequence of limiting the amount of state in the network. That is not in itself a drawback. BGP speakers will rarely need to receive all available BGP paths. In network deployments with multiple upstream peerings or with very dense peering schemes, the number of available BGP paths for a given BGP prefix can be high. Real network deployments with the number of paths for a prefix ranging from 10s to 100s have been observed. It would be wasteful to propagate all of those paths to all clients, such that each client can select paths according to the position of the nexthop relative to the client.

Whenever a BGP route reflector would need to decide what path or paths need to be selected for advertisement to one of its clients, the route reflector would need to virtually position itself in its client IGP network location in order to choose the right set of paths based on the IGP metric to the next hops from the client's

perspective.

This technique applies in deployments with or without diverse paths or the various path selection modes contemplated in add-paths.

In the network architectures consisting of more then single pair of route reflectors it is required that all reflectors are fully meshed and have ability to learn and maintain all external BGP paths. In the event of constructing a hierarchy of reflectors to relax the full RR mesh requirements ORR should not be run between such route reflectors.

3.1. Client's perspective best path selection algorithm

For each centralized route reflector the proposal assumes that the route reflector participates in a common IGP with its clients. There are two scenarios to consider - flat versus hierarchical IGP network.

3.1.1. Flat IGP network

Reflectors run SPF from the client IGP node point of view such that the cost of BGP nexthops from the client can be determined if necessary. For the purpose of BGP path selection the interesting product of this calculation is the ability to determine the IGP distance from a client to a BGP next hop. This distance to a nexthop would be interesting in cases where that next hop is for a path which is contending with otherwise equally preferred paths. This approach works in tunneled as well as conventional hop-by-hop IP forwarding cores.

When the path selection tie breaker for a prefix is the IGP metric to the BGP nexthops of the contending paths, then the route reflector will determine the order of preference of the contending paths by considering the distance from the client to the path nexthops in order to decide what path/s to advertise to a client (or group of clients where feasible). It should be noted that an operator may wish to provide a distance tolerance value, such that beyond a certain granularity, differences between IGP metric are invisible to the path selection algorithm. This will allow a route reflector some leeway in selecting between paths such that rather than pick one path over another on the basis of a difference in distance which is operationally irrelevant, the route reflector can choose to optimize for update generation grouping. Furthermore, this tolerance will reduce the likelihood of generation of BGP updates when the IGP topology changes in a way which is not operationally relevant. In the case that a path is selected from a set for a given prefix while ignoring differences in distance within the tolerance figure, then that

same path must always be preferred for all clients where the paths are within the tolerance figure

3.1.2. Hierarchical IGP network

Hierarchy introduces two challenges:

The first challenge is that the RR IGP view may differ from a client IGP view by virtue of one or the other having a summarized view versus the other. Summarization, by its nature, loses information. Consider the example where a client within a PoP sees two prefixes with two metrics for two egress points within the PoP, but where the RR only sees a single summary covering reachability to both nexthops as injected by the ABR. For clarification purposes in the case of ISIS by ABR we refer to L1/L2 node. However it needs to be observed that inter area networks running LDP are required to disable summarisation of all FEC advertised in LDP (typically all loopbacks) unless [RFC5283] is deployed. Such deployments are not likely to suffer summarization difficulties.

The second challenge is that in cases where the client is in a different level of hierarchy from the RR, the RR can not build a Shortest Path First (SPF) tree with the client node as root, simply because the topology derived by the IGP will not include the client node. It will instead only include reachability to the client from one or more ABRs. In order to overcome this problem, the RR could compute an SPF tree from the ABRs in the area. The RR would then determine the shortest distance from a client which lives behind the ABRs, to a nexthop, by adding the advertised distances from an ABR to the client and the distance from the ABR to a nexthop, for each ABR, and picking the minimum. This assumes that IGP metrics on links are symmetric; i.e. that the distance from the ABR to the client or nexthop is equal to the distance from the client or nexthop to the ABR.

There are cases where the above approach does not help. If RR is trying to arbitrate amongst a set of paths for a client which is in the same hierarchy as some of those paths, and in a different hierarchy to the RR, the opaqueness of the region containing the client at the RR defeats the selection process. It is impossible to determine the relative position of the RR client and the paths within the client region.

The solution for hierarchical IGP networks also assumes that if RRs are present and are responsible for calculation of BGP best path to clients they are either placed in each local area coinciding with area containing clients or they are placed in the

core (area 0/level 2) of the network.

3.2. Aside: Configuration-based flexible route reflector placement

The ability to exploit topology information available in the IGP in ways described above can also be used to virtually place the RR at different points in the network for purposes other than hot potato routing.

A route reflector can be globally configured to "pretend" its logical location is one of any of the other nodes within a given IGP area/ level flooding scope regardless of its physical connectivity.

Such flexibility provides a useful tool for reflector virtualization, and supports moving or replacing physical route reflectors without any effect on routing. Such a change can be permanent or it could be performed during network maintenance in order to minimize network impact.

A possible variation would allow the virtual placement of RR to be effected on a per-AF or AF plus update/peer group granularity. It should be noted that this approach provides for splitting one centralized route reflector such that it is virtually positioned at various network locations, with the network location depending upon of address family or address family plus update/peer group.

Virtual slicing of a centralized route reflector relaxes the need to propagate all BGP paths between RRs in a alternative conventional distributed RR deployment. It is expected that such RRs would be deployed in redundant sets, and that those RRs would not need to be physically collocated, while still benefiting from the possibility of being logically collocated, and therefore not compromising any of the best path selection symmetry.

3.3. Route reflector client grouping

It may be appropriate to allow the operator, or the route reflector itself, to group clients together using IGP distance between clients to determine grouping. All the operation discussed above which relied upon computing best path for each client, and measuring distances from each client to different nexthops, would instead be performed for each group of clients. Configurable thresholds can be used to determine which IGP metric changes should be visible to BGP, and trigger best paths recomputation. The latter would be beneficial in existing BGP RR code too.

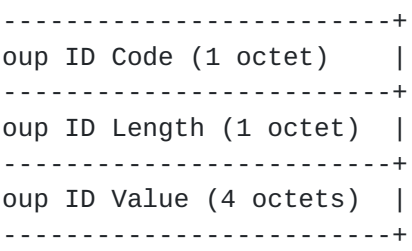
Alternatively route reflector client grouping could be accomplished statically by the operator by coloring clients belonging to a common

group (for example being part of the same POP). In order to accomplish such marking it is proposed that BGP OPEN message be augmented with an optional parameter indicating the Group ID given peer belongs to.

3.3.1. Route Reflector Client Group ID

This is an Optional Parameter in BGP OPEN message that is used by a BGP speaker to convey to its route reflectors the Group ID value. Such value will allow automatic and predictable peer grouping on the route reflectors as deemed necessary from operator's network architecture.

The parameter contains precisely one set of [Group_ID Code, Group_ID Length, Group_ID Value] encoded as shown below:



The use and meaning of these fields are as follows:

Group ID Code:

Group ID Code is a one octet field that identifies Group ID optional parameter of BGP OPEN message. Value TBD by IANA Recommended value: 3.

Group ID Length:

Group ID Length is a one octet field that contains the length of the Group ID Value field in octets. It is fixed and equals to 4.

Group ID Value:

Group ID Value is a fixed length field of size equal to four octets that contains the numerical value of group given BGP speaker should be part of on the route reflector.

Two special values are reserved:

0x00000000 - No grouping preference
0xFFFFFFFF - Do not group this BGP speaker

An implementation may allow automatic population of GROUP_ID value using IGP area identifier.

Route reflectors or EBGP speakers receiving such Group IDs from their respective BGP peers as part of the BGP OPEN procedure MAY use them when constructing update or peer groups in addition to any of the existing grouping mechanism already available. An implementation may allow operator to explicitly allow or disallow honoring such grouping or provide means for manual overwrite via explicit configuration.

3.4. Discussion

This is not the first instance where a router participating in an IGP is required to build the SPF tree using a root other than itself. Determination of loop free alternate paths as described in [RFC5714] is one such example.

Determining the shortest path and associated cost between any two arbitrary points in a network based on the IGP topology learned by a router is expected to add some extra cost in terms of CPU resource. However SPF tree generation code is now implemented efficiently in a number of implementations, and therefor this is not expected to be a major drawback. The number of SPTs computed in the general non-hierarchical case is expected to be of the order of the number of clients of an RR whenever a topology change is detected. Advanced optimizations like partial and incremental SPF may also be exploited. By the nature of route reflection, the number of clients can be split arbitrarily by the deployment of more route reflectors for a given number of clients. While this is not expected to be necessary in existing networks with best in class route reflectors available today, this avenue to scaling up the route reflection infrastructure would be available. If we consider the overall network wide cost/benefit factor, the only alternative to achieve the same level of optimality would require significantly increasing state on the edges of the network, which, in turn, will consume CPU and memory resources on all BGP speakers in the network. Building this client perspective

into the route reflectors seems appropriate.

3.5. Advantages

The solution described provides a model for integrating the client perspective into the best path computation for RRs. More specifically, the choice or BGP path factors in the IGP metric between the client and the nexthop, rather than the distance from the RR to the nexthop. The documented method does not require any BGP or IGP protocol changes as required changes are contained within the RR implementation.

This solution can be deployed in traditional hop-by-hop forwarding networks as well as in end-to-end tunneled environments. In the networks where there are multiple route reflectors and hop-by-hop forwarding without encapsulation, such optimizations should be enabled on all route reflectors. Otherwise clients may receive an inconsistent view of the network and in turn lead to intra-domain forwarding loops.

With this approach, an ISP can effect a hot potato routing policy even if route reflection has been moved from the forwarding plane to the core and hop-by-hop switching has been replaced by end to end MPLS or IP encapsulation.

As per above, the approach reduces the amount of state which needs to be pushed to the edge in order to perform hot potato routing. The memory and CPU resource required at the edge to provide hot potato routing using this approach is lower than what would be required in order to achieve the same level of optimality by pushing and retaining all available paths (potentially 10s) per each prefix at the edge.

The proposal allows for a fast and safe transition to BGP control plane route reflection without compromising an operator's closest exit operational principle. Hot potato routing is important to most ISPs. The inability to perform hot potato routing effectively stops migrations to centralized route reflection and edge-to-edge LSP/IP encapsulation for traffic to IPv4 and IPv6 prefixes.

4. Angular distance approximation for BGP warm potato routing

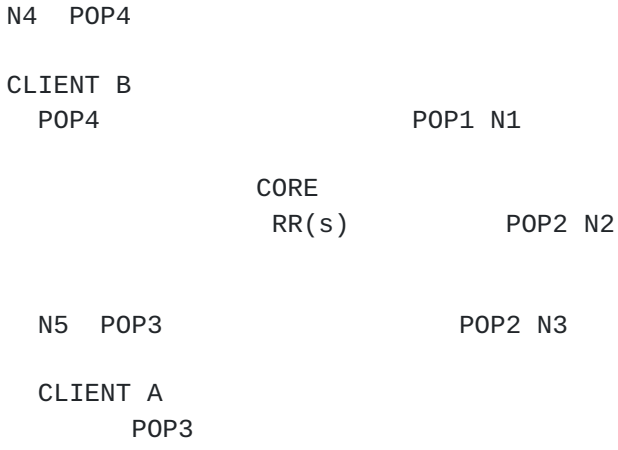
This section describes an alternative solution to the use of IGP topology information to virtually position the RR at the client location in the network. This solution involves modeling the network topology as a set of elements (regions, PoPs or routers) arranged in a circle. Route reflector clients and inter-domain exit points would

then be statically assigned to those elements such that one can compute the angular distance between route-reflector clients and the various exit points in order to infer the distance between any two elements. This measure of distance can be used as an effective alternative to the IGP distance as a tie breaker in the path selection algorithm if necessary.

4.1. Problem statement

This solution addresses the problem described in earlier sections, while attempting to minimize computational overhead. The aim of the proposed solution is to enable a route reflector to provide a route reflector client with an exit point for a prefix which is 'closest' to the client rather than the route-reflector, without having to distribute all paths to that client, or having to derive each client's view of the network topology. The measure of closest is based on a simplistic description of network topology provided by the operator.

Consider the following example of an ISP network topology drawn to reflect the location of the nodes and POPs:



N - represents the different exit points for a given prefix. POP2 is a geographically large PoP with two paths; N2 and N3.

In a deployment where the centralized RRs tie break on the basis of their IGP-based view of the network, N1 above would be advertised to all clients on the basis that it is closest to the RR. Path N4 would be a more appropriate choice for client B. Similarly, N5 would be

more appropriate for client A since path N5 is closer to client A then path N1.

4.2. Proposed solution

The proposed solution revolves around the operator establishing the angular position of the route-reflector clients and inter-domain exit points in the network. The route reflector then picks the path to advertise to a client based on the client's angular position versus the angular position of the inter-domain exit points originating the paths. The operator can choose the granularity of angular position appropriate to the desired goals. On one hand, the coarseness of the angular position will effect the operator overhead; versus the optimality of routing on the other. The finest granularity possible will be the relative position of originating clients.

Note that this solution has nothing to do with actual IGP link metrics and resulting topology in the network.

It can be shown that for each network topology, elements such as AS exit points can be mapped on to a circle. By putting POPs, Regions or individual clients onto the hypothetical circle we can identify an angular location for each element relative to some fixed direction; for example defining the angular north of the circle at 0 degrees.

The angular position of elements in the network can be conveyed to a route reflector in a number of ways:

- Assignment of angular position of each RR client through configuration on the route reflector itself; per client configuration on RR

- Assignment of angular position of an RR client at each client, then propagating it to RRs.

The proposed angular distance approximation is compatible with both flat and hierarchical IGP deployments.

In the example illustrated above the route reflector might learn or be configured with the following set of paths and corresponding angular positions:

Prefix X/Y	N1	N2	N3	N4	N5
Location in degrees	60	85	120	290	260

If the absolute angular position of clients A and B were as follows:

Client A: 260 degrees

Client B: 290 degrees

Then the corresponding angular distances for those clients versus the exit points can be calculated as follows:

Prefix X/Y	N1	N2	N3	N4	N5
Client A	200	175	140	30	0
Client B	230	205	170	0	30

With an RR running the BGP best path algorithm modified to use the angular distance from the client to the nexthops, rather than its IGP distance to the nexthops as tie breaker, each client is provided with its closest path with the measure of closeness reflecting the angular position as configured by the operator.

The model used by the operator in order to determine the angular position of a client or exit point, might involve grouping elements together by region or PoP, or might involve no grouping at all. Implementations should allow the operator to pick the appropriate granularity.

4.3. Centralized vs distributed route reflectors

In an environment where the RR clusters are distributed (yet centralized enough to make hot potato routing hard), and each RR cluster serves a subset of clients, it becomes necessary to propagate the angular position of the clients between route reflectors. This can be achieved as follows:

Deploy add-paths between route reflectors in order to maximize path diversity within the cluster.

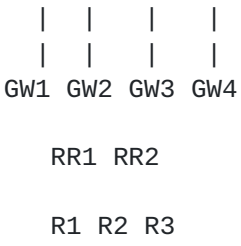
A non AS transitive BGP community of type (TBA by IANA) can be used to encode and propagate angular position between 0 and 359 of a client. This community is only relevant to the route reflectors of a given BGP domain and should be stripped either at the ASBR

boundary or when propagating updates to BGP peers which are not route reflectors.

The angular position marking could also be added by clients and advertised to the route reflector. This would require some configuration effort.

5. Client's perspective policy based best path selection

There is some deployment scenarios where a service provider wants to achieve a stronger control on traffic exiting the AS (for capacity planning) rather than using hot potato routing based on IGP metric.



Considering the figure above, all gateways have iBGP sessions to RR1 and RR2, and R1 R2 R3 have iBGP sessions as well to RR1 and RR2. Gateway routers are meshed to an external network (for example, a transit service provider).

We would like to achieve a strong control on the gateway used (primary and backup) for each router (or each set of routers) in the network (taking into account that routers do not support ADD PATHs). For example, R1 using GW1 as primary and GW2 as backup; R2 using GW2 as primary and GW3 as backup; R3 using GW3 as primary and GW4 as backup.

Basically, today a prefix P1 is received on each gateway from the external network. Each gateway will send the prefix to both route reflectors. Each route-reflector will receive four paths for P1 and choose the best one based on his own decision process. Note that RR1 and RR2 may choose a different path as best. Each route-reflector sends his best path towards R1, R2 and R3. Each router will receive the same paths from the route-reflectors for P1 (at max, only two gateways are visible from Rx routers). So default behavior does not fit our requirements in term of traffic flows.

Using current BGP mechanisms available, we could achieve our requirements using two solutions :

- Modify the BGP meshing: for example, R1 meshed directly to GW1 and GW2 and apply inbound policies on R1; R2 meshed directly to GW2 and GW3 and apply inbound policies on R2 ...

- Adding more route-reflectors (one RR per gateway used as primary) and applying inbound policies on RRs to make each RR choosing a different primary gateway and apply policies on routers to select his own primary gateway.

These solutions have many drawbacks: first one is not flexible (re-meshing needed when we want to change gateway of a router), second one requires a lot of CAPEX.

We would like to introduce a solution where a single currently deployed route-reflector chassis may take a different best path decision for different set of clients based on preferences.

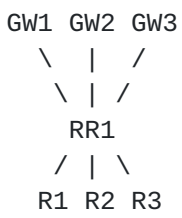
It should be noted that in simple scenarios (example: two RRs and two gateways), RFC6774 would be able to fulfill service provider needs. The solution proposed here would permit to handle more complex scenarios and fine gateway choice per client or groups of clients.

5.1. Proposal

Our proposal is to reuse the concept introduced in [I.D.ietf-idr-ix-bgp-route-server] in an iBGP context. To perform per client best path selection, the router should maintain a per client BGP local-RIB (or Adj-RIB-Out) associated with inbound policies implemented between Adj-RIB-In and client LOC-RIB.

It would not be very scalable to use a per client policy (considering hundreds of peers on a route-reflector), therefor our proposal is to group clients sharing common policies inside a client group to minimize computation/memory overhead. Client grouping could be done statically (by configuration) or dynamically using the solution described in section 3.3.1 of this document. Client grouping would be performed with a per AFI/SAFI granularity as gateway/client mapping may change in each AFI/SAFI context. A route-reflector should be able to implement multiple client groups (with associated inbound policies) as well as a default client group for clients that does not require any specific policy decision: in this case, the overall BGP best path computation would be used.

5.2. Example



In the above figure GW1, GW2, GW3 and R3 are standard ibgp route-reflector clients. R1 and R2 want to use a special gateway combination (primary GW3, backup GW2, last resort GW1). R1 and R2 are configured in a specific client group CG1 on the route-reflector while other peers are in the default client group. CG1 is associated with a policy achieving the expected GW preference for R1 and R2, and letting other paths without any change.

All routes received by RR1 (ebgp, ibgp, ibgp rr client, ibgp rr client routing context) must be evaluated using overall BGP best path computation as well as in client group, the client group policy will accept or not the route to be evaluated by the local decision process.

- Paths from GW1, GW2, GW3 are compared within default client group leading to one GW (for example GW1) to be selected as best and installed in global LOC-RIB. GW1 path will be advertised to GW2, GW3 and R3 as they are in default CG. In CG1, preference of GW paths has been modified, leading to GW3 being the best path and installed in client group LOC-RIB. GW3 path will be advertised to R1 and R2, as R1 and R2 are part of CG1.

- Paths from R3 are compared within default client group and advertised to GW1, GW2, GW3. Those paths are also compared within CG1 (as accepted by policy) and advertised to R1 and R2.

- Paths from R1 are compared within default client group and advertised to GW1, GW2, GW3 and R3. Those paths are also compared within GG1 (as accepted by policy) and advertised to R2.

- Paths from R2 are compared within default client group and advertised to GW1, GW2, GW3 and R3. Those paths are also compared within CG1 (as accepted by policy) and advertised to R1.

5.3. Avoiding routing loops

Compared to the IGP approaches described in this document, the policy based route-reflection should be limited to end-to-end encapsulation environments to avoid intra-domain forwarding loops. Using end-to-end encapsulation permit Edge routers to transport the traffic to the

targeted/preferred ASBR without any loop in the core.

To avoid a potential rerouting of the ASBR into the core (and possible loop between Edges and ASBR), we must enforce forwarding at the ASBR to the eBGP peer. This could be done by :

- implementing policies on ASBR to prefer eBGP path and install it in FIB.

- implementing tunneling of traffic until the outside interface (ASBR action to switch to outside interface).

The exact choice of encapsulation and techniques to prevent transport loops (including potential loops at gateways) is left to the operator choice and its specification is outside of the scope of this document.

6. Deployment considerations

The solutions are primarily intended for end-to-end tunneled environments, i.e. where traffic is label switched or IP tunneled across the core. If unencapsulated hop-by-hop forwarding is used, either misconfigurations or conflicts between these optimizations and classical BGP path selection rules could lead to intra-domain forwarding loops. Under certain circumstances the solutions can also be deployable without end-to-end tunneling. In particular the best path selection based on the client's IGP best-path selection is guaranteed not to cause any forwarding loops (other than micro loops associated with reconvergence) when deployed in a flat IGP area provided that no distance tolerance value is used so that the path choice is truly made on a per-client basis.

Regarding potential intra-domain forwarding loops at ASBR level, this could be solved by enforcing external route preference or by performing tunnel to external interface switching action on ASBRs.

Regarding client's IGP best-path selection, it should be self evident that this solution does not interfere with policies enforced above IGP tie breaking in the BGP best path algorithm.

The solution applies to NLRIs of all address families which can be route reflected.

It should be noted that customized per-client or group of clients best path selection is already in use today in the context of Internet Exchange Point (IXP) route servers. In an IXP route server the client best path is selected as a result of different policies

rather than IGP metric distance to BGP next hop.

A possible scalability impact of optimizing path selection to take account of the RR client position or operator's policy based preference is that different RR clients receive different paths, and therefore update/peer group efficiency diminishes. This cost is imposed by the requirement to optimize the egress path from the client's perspective. It is also likely that groups of clients will end up receiving the same best path/s, in which case, inefficiency of update generation will be minimized. It should be noted that in the cases described under flexible router placement where placement is determined on a per update/peer group basis or per route reflector, the scale benefits of peer groupings are retained.

7. Security considerations

No new security issues are introduced to the BGP protocol by this specification.

8. IANA Considerations

IANA is requested to allocate a type code for the Standard BGP Community to be used for inter cluster propagation of angular position of the clients.

IANA is requested to allocate a new type code from BGP OPEN Optional Parameter Types registry to be used for Group_ID propagation.

9. Acknowledgments

Authors would like to thank Eric Rosen, Clarence Filsfils, Uli Bornhauser Russ White, Jakob Heitz and Mike Shand for their valuable input.

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