GROW Working Group
Internet-Draft
Intended status: Informational
Expires: March 18, 2012

R. Raszuk, Ed.
NTT MCL
R. Fernando
K. Patel
Cisco Systems
D. McPherson
Verisign
K. Kumaki
KDDI Corporation

September 15, 2011

# Distribution of diverse BGP paths. draft-ietf-grow-diverse-bgp-path-dist-05

Abstract

The BGP4 protocol specifies the selection and propagation of a single best path for each prefix. As defined today BGP has no mechanisms to distribute paths other then best path between its speakers. This behaviour results in number of disadvantages for new applications and services.

This document presents an alternative mechanism for solving the problem based on the concept of parallel route reflector planes. Such planes can be build in parallel or they can co-exit on the current route reflection platforms. Document also compares existing solutions and proposed ideas that enable distribution of more paths than just the best path.

This proposal does not specify any changes to the BGP protocol definition. It does not require upgrades to provider edge or core routers nor does it need network wide upgrades. The authors believe that the GROW WG would be the best place for this work.

material or to cite them other than as "work in progress."

This Internet-Draft will expire on March 18, 2012.

Copyright Notice

Table of Contents

## 1. Introduction

Current BGP4 [RFC4271] protocol specification allows for the selection and propagation of only one best path for each prefix. The BGP protocol as defined today has no mechanism to distribute other then best path between its speakers. This behaviour results in a number of problems in the deployment of new applications and services.

This document presents an alternative mechanism for solving the problem based on the concept of parallel route reflector planes. It also compares existing solutions and proposed ideas that enable distribution of more paths than just the best path. The parallel route reflector planes solution brings very significant benefits at a negligible capex and opex deployment price as compared to the alternative techniques and is being considered by a number of network operators for deployment in their networks.

This proposal does not specify any changes to the BGP protocol definition. It does not require upgrades to provider edge or core routers nor does it need network wide upgrades. The only upgrade required is the new functionality on the new or current route reflectors. The authors believe that the GROW WG would be the best place for this work.

## 2. History

The need to disseminate more paths than just the best path is primarily driven by three requirements. First is the problem of BGP oscillations [I-D.ietf-idr-route-oscillation]. The second is the desire for reduction of time of reachability restoration in the event of network or network element's failure. Third requirement is to enhance BGP load balancing capabilities. Those reasons have lead to the proposal of BGP add-paths [I-D.ietf-idr-add-paths].

### 2.1. BGP Add-Paths Proposal

As it has been proven that distribution of only the best path of a route is not sufficient to meet the needs of continuously growing number of services carried over BGP the add-paths proposal was submitted in 2002 to enable BGP to distribute more then one path. This is achieved by including as a part of the NLRI an additional four octet value called the Path Identifier.

The implication of this change on a BGP implementation is that it must now maintain per path, instead of per prefix, peer advertisement state to track which of the peers each path was advertised to. This

new requirement has its own memory and processing cost. Suffice to say that by the end of 2009 none of the commercial BGP implementation could claimed to support the new add-path behaviour in production code, in major part due to this resource overhead.

An important observation is that distribution of more than one best path by Autonomous System Border Routers (ASBRs) with multiple EBGP peers attached to it where no "next hop self" is set may result in bestpath selection inconsistency within the autonomous system. Therefore it is also required to attach in the form of a new attribute the possible tie breakers and propagate those within the domain. The example of such attribute for the purpose of fast connectivity restoration to address that very case of ASBR injecting multiple external paths into the IBGP mesh has been presented and discussed in Fast Connectivity Restoration Using BGP Add-paths [I-D.ietf-idr-add-paths] document. Based on the additionally propagated information also best path selection is recommended to be modified to make sure that best and backup path selection within the domain stays consistent. More discussion on this particular point will be contained in the deployment considerations section below. In the proposed solution in this document we observe that in order to address most of the applications just use of best external advertisement is required. For ASBRs which are peering to multiple upstream ASs setting "next hop self" is recommended.

The add paths protocol extensions have to be implemented by all the routers within an AS in order for the system to work correctly. It remains quite a research topic to analyze benefits or risk associated with partial add-paths deployments. The risk becomes even greater in networks not using some form of edge to edge encapsulation.

The required code modifications include enhancements such as the Fast Connectivity Restoration Using BGP Add-path [I-D.pmohapat-idr-fast-conn-restore]. The deployment of such technology in an entire service provider network requires software and perhaps sometimes in the cases of End-of-Engineering or End-of-Life equipment even hardware upgrades. Such operation may or may not be economically feasible. Even if add-path functionality was available today on all commercial routing equipment and across all vendors, experience indicates that to achieve 100% deployment coverage within any medium or large global network may easily take years.

While it needs to be clearly acknowledged that the add-path mechanism provides the most general way to address the problem of distributing many paths between BGP speakers, this document provides a much easier to deploy solution that requires no modification to the BGP protocol where only a few additional paths may be required. The alternative

method presented is capable of addressing critical service provider requirements for disseminating more than a single path across an AS with a significantly lower deployment cost.

## 3. Goals

The proposal described in this document is not intended to compete with add-paths. Instead if deployed it is to be used as a very easy method to accommodate the majority of applications which may require presence of alternative BGP exit points.

It is presented to network operators as a possible choice and provides those operators who need additional paths today an alternative from the need to transition to a full mesh.

It is intended as a way to buy more time allowing for a smoother and gradual migration where router upgrades will be required for perhaps different reasons. It will also allow the time required where standard RP/RE memory size can easily accommodate the associated overhead with other techniques without any compromises.

## 4. Multi plane route reflection

The idea contained in the proposal assumes the use of route reflection within the network. Other techniques as described in the following sections already provide means for distribution of alternate paths today.

Let's observe today's picture of simple route reflected domain:

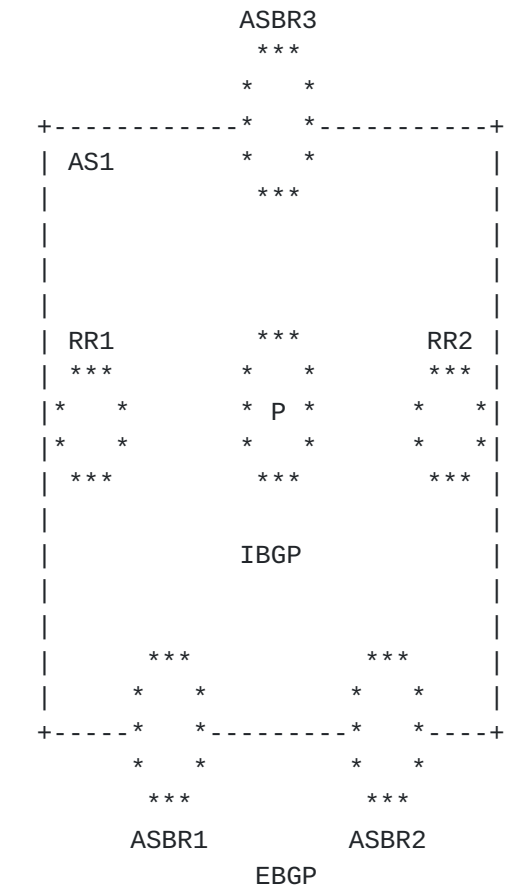


Figure1: Simple route reflection

Figure 1 shows an AS that is connected via EBGP peering at ASBR1 and ASBR2 to an upstream AS or set of ASes. For a given destination "D" ASBR1 and ASBR2 will each have an external path P1 and P2 respectively. The AS network uses two route reflectors RR1 and RR2 for redundancy reasons. The route reflectors propagate the single BGP best path for each route to all clients. All ASBRs are clients of RR1 and RR2.

Below are the possible cases of the path information that ASBR3 may receive from route reflectors RR1 and RR2:

1. When best path tie breaker is the IGP distance: When paths P1 and P2 are considered to be equally good best path candidates the selection will depend on the distance of the path next-hops from the route reflector making the decision. Depending on the positioning of the route reflectors in the IGP topology they may choose the same best path or a different one. In such a case

ASBR3 may receive either the same path or different paths from each of the route reflectors.

2. When best path tie breaker is Multi-Exit-Discriminator or Local Preference: In this case only one path from preferred exit point ASBR will be available to RRs since the other peering ASBR will consider the IBGP path as best and will not announce (or if already announced will withdraw) its own external path. The exception here is the use of BGP Best-External proposal which will allow stated ASBR to still propagate to the RRs its own external path. Unfortunately RRs will not be able to distribute it any further to other clients as only the overall best path will be reflected.

The proposed solution is based on the use of additional route reflectors or new functionality enabled on the existing route reflectors that instead of distributing the best path for each route will distribute an alternative path other then best. The best path (main) reflector plane distributes the best path for each route as it does today. The second plane distributes the second best path for each route and so on. Distribution of N paths for each route can be achieved by using N reflector planes.

As diverse-path functionality may be enabled on a per peer basis one of the deployment model can be realized to continue advertisement of overall best path from both route reflectors while in addition new session can be provisioned to get additional path. That will allow the non interupted use of best path even if one of the RRs goes down provided that the overall best path is still a valid one.

Each plane of route reflectors is a logical entity and may or may not be co-located with the existing best path route reflectors. Adding a route reflector plane to a network may be as easy as enabling a logical router partition, new BGP process or just a new configuration knob on an existing route reflector and configuring an additional IBGP session from the current clients if required. There are no code changes required on the route reflector clients for this mechanism to work. It is easy to observe that the installation of one or more additional route reflector control planes is much cheaper and an easier than the need of upgrading 100s of route reflector clients in the entire network to support different bgp protocol encoding.

Diverse path route reflectors need the new ability to calculate and propagate the Nth best path instead of the overall best path. An implementation is encouraged to enable this new functionality on a per neighbor basis.

While this is an implementation detail, the code to calculate Nth

best path is also required by other BGP solutions. For example in the application of fast connectivity restoration BGP must calculate a backup path for installation into the RIB and FIB ahead of the actual failure.

To address the problem of external paths not being available to route reflectors due to local preference or MED factors it is recommended that ASBRs enable the best-external functionality in order to always inject their external paths to the route reflectors.

## 4.1. Co-located best and backup path RRs

To simplify the description let's assume that we only use two route reflector planes (N=2). When co-located the additional 2nd best path reflectors are connected to the network at the same points from the perspective of the IGP as the existing best path RRs. Let's also assume that best-external is enabled on all ASBRs.

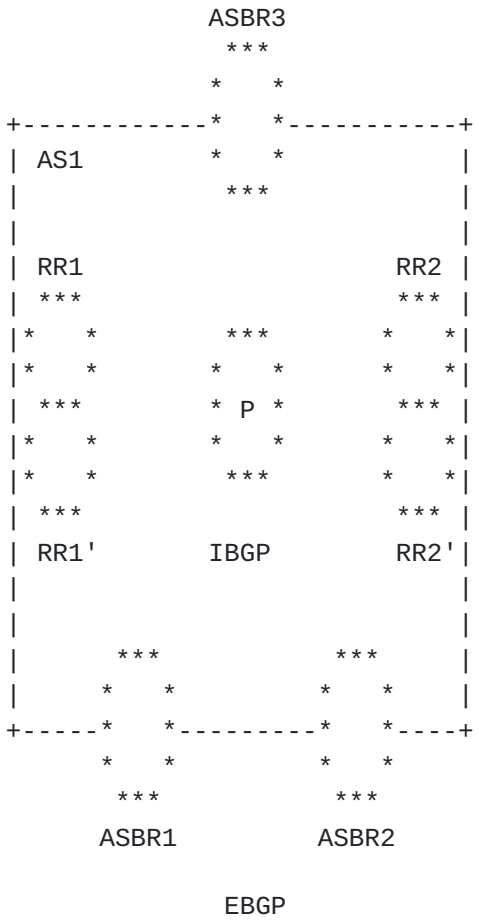


Figure2: Co-located 2nd best RR plane

The following is a list of configuration changes required to enable the 2nd best path route reflector plane:

1. Unless same RR1/RR2 platform is being used adding RR1' and RR2' either as logical or physical new control plane RRs in the same IGP points as RR1 and RR2 respectively.

2. Enabling best-external on ASBRs

3. Enabling RR1' and RR2' for 2nd plane route reflection. Alternatively instructing existing RR1 and RR2 to calculate also 2nd best path.

4. Unless one of the existing RRs is turned to advertise only diverse path to it's current clients configuring new ASBRs-RR' IBGP sessions

The expected behaviour is that under any BGP condition the ASBR3 and P routers will receive both paths P1 and P2 for destination D. The availability of both paths will allow them to implement a number of new services as listed in the applications section below.

As an alternative to fully meshing all RRs and RRs' an operator who has a large number of reflectors deployed today may choose to peer newly introduced RRs' to a hierarchical RR' which would be an IBGP interconnect point within the 2nd plane as well as between planes.

One of the deployment model of this scenario can be achieved by simple upgrade of the existing route reflectors without the need to deploy any new logical or physical platforms. Such upgrade would allow route reflectors to service both upgraded to add-paths peers as well as those peers which can not be immediately upgraded while in the same time allowing to distribute more then single best path. The obvious protocol benefit of using existing RRs to distribute towards their clients best and diverse bgp paths over different IBGP session is the automatic assurance that such client would always get different paths with their next hop being different.

The way to accomplish this would be to create a separate IBGP session for each N-th BGP path. Such session should be preferably terminated at a different loopback address of the route reflector. At the BGP OPEN stage of each such session a different bgp_router_id may be used. Correspondingly route reflector should also allow its clients to use the same bgp_router_id on each such session.

### 4.2. Randomly located best and backup path RRs

Now let's consider a deployment case where an operator wishes to enable a 2nd RR' plane using only a single additional router in a different network location to his current route reflectors. This model would be of particular use in networks where some form of end-to-end encapsulation (IP or MPLS) is enabled between provider edge routers.

Note that this model of operation assumes that the present best path route reflectors are only control plane devices. If the route reflector is in the data forwarding path then the implementation must be able to clearly separate the Nth best-path selection from the selection of the paths to be used for data forwarding. The basic premise of this mode of deployment assumes that all reflector planes have the same information to choose from which includes the same set of BGP paths. It also requires the ability to ignore the step of comparison of the IGP metric to reach the bgp next hop during best-path calculation.

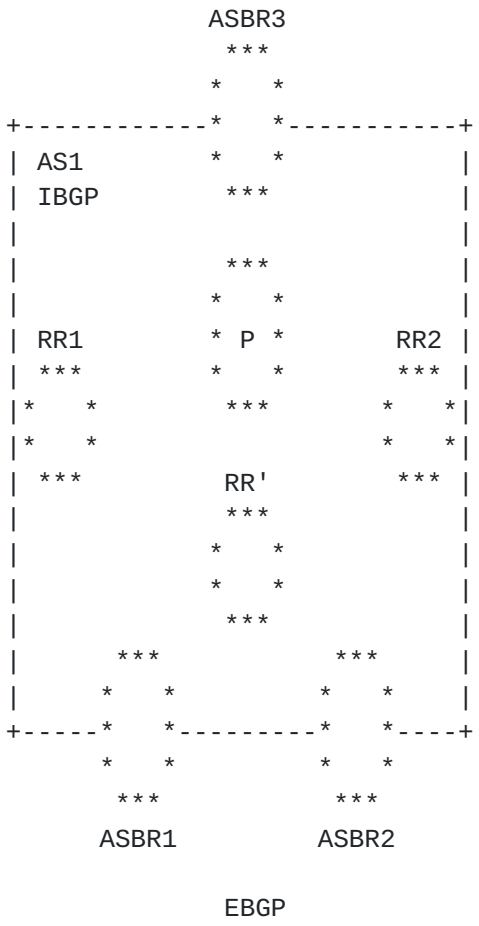


Figure3: Experimental deployment of 2nd best RR

The following is a list of configuration changes required to enable the 2nd best path route reflector RR' as a single platform or to enable one of the existing control plane RRs for diverse-path functionality:

1. If needed adding RR' logical or physical as new route reflector anywhere in the network

2. Enabling best-external on ASBRs

3. Disabling IGP metric check in BGP best path on all route reflectors.

4. Enabling RR' or any of the existing RR for 2nd plane path calculation

5. If required fully meshing newly added RRs' with the all other reflectors in both planes. That condition does not apply if the

newly added RR'(s) already have peering to all ASBRs/PEs.

6. Unless one of the existing RRs is turned to advertise only diverse path to it's current clients configuring new ASBRs-RR' IBGP sessions

In this scenario the operator has the flexibility to introduce the new additional route reflector functionality on any existing or new hardware in the network. Any of the existing routers that are not already members of the best path route reflector plane can be easily configured to serve the 2nd plane either via using a logical / virtual router partition or by having their bgp implementation compliant to this specification.

Even if the IGP metric is not taken into consideration when comparing paths during the bestpath calculation, an implementation still has to consider paths with unreachable nexthops as invalid. It is worth pointing out that some implementations today already allow for configuration which results in no IGP metric comparison during the best path calculation.

The additional planes of route reflectors do not need to be fully redundant as the primary one does. If we are preparing for a single network failure event, a failure of a non backed up N-th best-path route reflector would not result in an connectivity outage of the actual data plane. The reason is that this would at most affect the presence of a backup path (not an active one) on same parts of the network. If the operator chooses to build the N-th best path plane redundantly by installing not one, but two or more route reflectors serving each additional plane the additional robustness will be achieved.

As a result of this solution ASBR3 and other ASBRs peering to RR' will be receiving the 2nd best path.

Similarly to section 4.1 as an alternative to fully meshing all RRs & RRs' an operator who may have a large number of reflectors already deployed today may choose to peer newly introduced RRs' to a hierarchical RR' which would be an IBGP interconnect point between planes.

## 4.3. Multi plane route servers for Internet Exchanges

Another group of devices where the proposed multi-plane architecture may be of particular applicability are EBGP route servers used at many of internet exchange points.

In such cases 100s of ISPs are interconnected on a common LAN.

Instead of having 100s of direct EBGP sessions on each exchange client, a single peering is created to the transparent route server. The route server can only propagate a single best path. Mandating the upgrade for 100s of different service providers in order to implement add-path may be much more difficult as compared to asking them for provisioning one new EBGP session to an Nth best-path route server plane. That will allow to distribute more then single best BGP path from a given route server to such IX peer.

The solution proposed in this document fits very well with the requirement of having broader EBGP path diversity among the members of any Internet Exchange Point.

## 5. Discussion on current models of IBGP route distribution

In today's networks BGP4 operates as specified in [RFC4271]

There are a number of technology choices for intra-AS BGP route distribution:

1. Full mesh

2. Confederations

3. Route reflectors

### 5.1. Full Mesh

A full mesh, the most basic iBGP architecture, exists when all the BGP speaking routers within the AS peer directly with all other BGP speaking routers within the AS, irrespective of where a given router resides within the AS (e.g., P router, PE router, etc..).

While this is the simplest intra-domain path distribution method, historically there have been a number of challenges in realizing such an IBGP full mesh in a large scale network. While some of these challenges are no longer applicable today some may still apply, to include the following:

1. Number of TCP sessions: The number of IBGP sessions on a single router in a full mesh topology of a large scale service provider can easily reach 100s. While on hardware and software used in the late 70s, 80s and 90s such numbers could be of concern, today customer requirements for the number of BGP sessions per box are reaching 1000s. This is already an order of magnitude more then the potential number of IBGP sessions. Advancement in hardware and software used in production routers mean that running a full

mesh of IBGP sessions should not be dismissed due to the resulting number of TCP sessions alone.

2. Provisioning: When operating and troubleshooting large networks one of the top-most requirements is to keep the design as simple as possible. When the autonomous systems network is composed of hundreds of nodes it becomes very difficult to manually provision a full mesh of IBGP sessions. Adding or removing a router requires reconfiguration of all the other routers in the AS. While this is a real concern today there is already work in progress in the IETF to define IBGP peering automation through an IBGP Auto Discovery [I-D.raszuk-idr-ibgp-auto-mesh] mechanism.

3. Number of paths: Another concern when deploying a full IBGP mesh is the number of BGP paths for each route that have to be stored at every node. This number is very tightly related to the number of external peerings of an AS, the use of local preference or multi-exit-discriminator techniques and the presence of best-external [I-D.ietf-idr-best-external] advertisement configuration. If we make a rough assumption that the BGP4 path data structure consumes about 80-100 bytes the resulting control plane memory requirement for 500,000 IPv4 routes with one additional external path is 38-48 MB while for 1 million IPv4 routes it grows linearly to 76-95 MB. It is not possible to reach a general conclusion if this condition is negligible or if it is a show stopper for a full mesh deployment without direct reference to a given network.

To summarize, a full mesh IBGP peering can offer natural dissemination of multiple external paths among BGP speakers. When realized with the help of IBGP Auto Discovery peering automation this seems like a viable deployment especially in medium and small scale networks.

## 5.2. Confederations

For the purpose of this document let's observe that confederations [RFC5065] can be viewed as a hierarchical full mesh model.

Within each sub-AS BGP speakers are fully meshed and as discussed in section 2.1 all full mesh characteristics (number of TCP sessions, provisioning and potential concern over number of paths still apply in the sub-AS scale).

In addition to the direct peering of all BGP speakers within each sub-AS, all sub-AS border routers must also be fully meshed with each other. Sub-AS border routers configured with best-external functionality can inject additional exit paths within a sub-AS.

To summarize, it is technically sound to use confederations with the combination of best-external to achieve distribution of more than a single best path per route in a large autonomous systems.

In topologies where route reflectors are deployed within the confederation sub-ASes the technique describe here does apply.

### 5.3. Route reflectors

The main motivation behind the use of route reflectors [RFC4456] is the avoidance of the full mesh session management problem described above. Route reflectors, for good or for bad, are the most common solution today for interconnecting BGP speakers within an internal routing domain.

Route reflector peerings follow the advertisement rules defined by the BGP4 protocol. As a result only a single best path per prefix is sent to client BGP peers. That is the main reason why many current networks are exposed to a phenomenon called BGP path starvation which essentially results in inability to deliver a number of applications discussed later.

The route reflection equivalent when interconnecting BGP speakers between domains is popularly called the Route Server and is globally deployed today in many internet exchange points.

## 6. Deployment considerations

The diverse BGP path dissemination proposal allows the distribution of more paths than just the best-path to route reflector or route server clients of today's BGP4 implementations.

From the client's point of view receiving additional paths via separate IBGP sessions terminated at the new router reflector plane is functionally equivalent to constructing a full mesh peering without the problems that such a full mesh would come with set of problems as discussed in earlier section.

By precisely defining the number of reflector planes, network operators have full control over the number of redundant paths in the network. This number can be defined to address the needs of the service(s) being deployed.

The Nth plane route reflectors should be acting as control plane network entities. While they can be provisioned on the current production routers selected Nth best BGP paths should not be used directly in the date plane with the exception of such paths being BGP

multipath eligible and such functionality is enabled. On RRs being in the data plane unless multipath is enabled 2nd best path is expected to be a backup path and should be installed as such into local RIB/FIB.

The proposed architecture deployed along with the BGP best-external functionality covers all three cases where the classic BGP route reflection paradigm would fail to distribute alternate exit points paths.

1. ASBRs advertising their single best external paths with no local-preference or multi-exit-discriminator present.

2. ASBRs advertising their single best external paths with local-preference or multi-exit-discriminator present and with BGP best-external functionality enabled.

3. ASBRs with multiple external paths.

Let's discuss the 3rd above case in more detail. This describes the scenario of a single ASBR connected to multiple EBGP peers. In practice this peering scenario is quite common. It is mostly due to the geographic location of EBGP peers and the diversity of those peers (for example peering to multiple tier 1 ISPs etc...). It is not designed for failure recovery scenarios as single failure of the ASBR would simultaneously result in loss of connectivity to all of the peers. In most medium and large geographically distributed networks there is always another ASBR or multiple ASBRs providing peering backups, typically in other geographically diverse locations in the network.

When an operator uses ASBRs with multiple peerings setting next hop self will effectively allow to locally repair the atomic failure of any external peer without any compromise to the data plane. The most common reason for not setting next hop self is traditionally the associated drawback of loosing ability to signal the external failures of peering ASBRs or links to those ASBRs by fast IGP flooding. Such potential drawback can be easily avoided by using different peering address from the address used for next hop mapping as well as removing such next hop from IGP at the last possible BGP path failure.

Herein one may correctly observe that in the case of setting next hop self on an ASBR, attributes of other external paths such ASBR is peering with may be different from the attributes of its best external path. Therefore, not injecting all of those external paths with their corresponding attribute can not be compared to equivalent paths for the same prefix coming from different ASBRs.

While such observation in principle is correct one should put things in perspective of the overall goal which is to provide data plane connectivity upon a single failure with minimal interruption/packet loss. During such transient conditions, using even potentially suboptimal exit points is reasonable, so long as forwarding information loops are not introduced. In the mean time BGP control plane will on its own re-advertise newly elected best external path, route reflector planes will calculate their Nth best paths and propagate to its clients. The result is that after seconds even if potential sub-optimality were encountered it will be quickly and naturally healed.

## 7. Summary of benefits

The diverse BGP path dissemination proposal provides the following benefits when compared to the alternatives:

1. No modifications to BGP4 protocol.

2. No requirement for upgrades to edge and core routers. Backward compatible with the existing BGP deployments.

3. Can be easily enabled by introduction of a new route reflector, route server plane dedicated to the selection and distribution of Nth best-path or just by new configuration of the upgraded current route reflector(s).

4. Does not require major modification to BGP implementations in the entire network which will result in an unnecessary increase of memory and CPU consumption due to the shift from today's per prefix to a per path advertisement state tracking.

5. Can be safely deployed gradually on a RR cluster basis.

6. The proposed solution is equally applicable to any BGP address family as described in Multiprotocol Extensions for BGP-4 RFC4760 [RFC4760]. In particular it can be used "as is" without any modifications to both IPv4 and IPv6 address families.

## 8. Applications

This section lists the most common applications which require presence of redundant BGP paths:

1. Fast connectivity restoration where backup paths with alternate exit points would be pre-installed as well as pre-resolved in the FIB of routers. That would allow for a local action upon reception of a critical event notification of network / node failure. This failure recovery mechaism based on the presence of backup paths is also suitable for gracefully addressing scheduled maintenane requirements as described in [I-D.decraene-bgp-graceful-shutdown-requirements].

2. Multi-path load balancing for both IBGP and EBGP.

3. BGP control plane churn reduction both intra-domain and inter-domain.

An important point to observe is that all of the above intra-domain applications based on the use of reflector planes but are also applicable in the inter-domain Internet exchange point examples. As discussed in section 4.3 an internet exchange can conceptually deploy shadow route server planes each responsible for distribution of an Nth best path to its EBGP peers. In practice it may just equal to new short configuration and establishment of new BGP sessions to IX peers.

## 9. Security considerations

The new mechanism for diverse BGP path dissemination proposed in this document does not introduce any new security concerns as compared to base BGP4 specification [RFC4271].

## 10. IANA Considerations

The new mechanism for diverse BGP path dissemination does not require any new allocations from IANA.

## 11. Contributors

The following people contributed significantly to the content of the document:

Selma Yilmaz
Cisco Systems
170 West Tasman Drive
San Jose, CA 95134
US
Email: seyilmaz@cisco.com

Satish Mynam
Cisco Systems
170 West Tasman Drive
San Jose, CA 95134
US
Email: mynam@cisco.com

Isidor Kouvelas
Cisco Systems
170 West Tasman Drive
San Jose, CA 95134
US
Email: kouvelas@cisco.com

## 12. Acknowledgments

The authors would like to thank Bruno Decraene, Bart Peirens, Eric Rosen, Jim Uttaro, Renwei Li and George Wes for their valuable input.

The authors would also like to express special thank you to number of operators who helped to optimize the provided solution to be as close as possible to their daily operational practices. Especially many thx goes to Ted Seely, Shan Amante, Benson Schliesser and Seiichi Kawamura.

## 13. References

### 13.1. Normative References

[RFC2119] Bradner, S., "Key words for use in RFCs to Indicate Requirement Levels", BCP 14, RFC 2119, March 1997.

[RFC4271] Rekhter, Y., Li, T., and S. Hares, "A Border Gateway Protocol 4 (BGP-4)", RFC 4271, January 2006.

[RFC4760] Bates, T., Chandra, R., Katz, D., and Y. Rekhter, "Multiprotocol Extensions for BGP-4", RFC 4760,

January 2007.

[RFC5226] Narten, T. and H. Alvestrand, "Guidelines for Writing an IANA Considerations Section in RFCs", BCP 26, RFC 5226, May 2008.

## 13.2. Informative References

[I-D.decraene-bgp-graceful-shutdown-requirements]
Decraene, B., Francois, P., pelsser, c., Ahmad, Z., and A. Armengol, "Requirements for the graceful shutdown of BGP sessions", draft-decraene-bgp-graceful-shutdown-requirements-01 (work in progress), March 2009.

[I-D.ietf-idr-add-paths]
Walton, D., Chen, E., Retana, A., and J. Scudder, "Advertisement of Multiple Paths in BGP", draft-ietf-idr-add-paths-05 (work in progress), July 2011.

[I-D.ietf-idr-best-external]
Marques, P., Fernando, R., Chen, E., Mohapatra, P., and H. Gredler, "Advertisement of the best external route in BGP", draft-ietf-idr-best-external-04 (work in progress), April 2011.

[I-D.ietf-idr-route-oscillation]
McPherson, D., "BGP Persistent Route Oscillation Condition", draft-ietf-idr-route-oscillation-01 (work in progress), February 2002.

[I-D.pmohapat-idr-fast-conn-restore]
Mohapatra, P., Fernando, R., Filsfils, C., and R. Raszuk, "Fast Connectivity Restoration Using BGP Add-path", draft-pmohapat-idr-fast-conn-restore-01 (work in progress), March 2011.

[I-D.raszuk-idr-ibgp-auto-mesh]
Raszuk, R., "IBGP Auto Mesh", draft-raszuk-idr-ibgp-auto-mesh-00 (work in progress), June 2003.

[RFC4456] Bates, T., Chen, E., and R. Chandra, "BGP Route Reflection: An Alternative to Full Mesh Internal BGP (IBGP)", RFC 4456, April 2006.

[RFC5065] Traina, P., McPherson, D., and J. Scudder, "Autonomous System Confederations for BGP", RFC 5065, August 2007.

Authors' Addresses

Robert Raszuk (editor)
NTT MCL
101 S Ellsworth Avenue Suite 350
San Mateo, CA 94401
US

Email: robert@raszuk.net

Rex Fernando
Cisco Systems
170 West Tasman Drive
San Jose, CA 95134
US

Email: rex@cisco.com

Keyur Patel
Cisco Systems
170 West Tasman Drive
San Jose, CA 95134
US

Email: keyupate@cisco.com

Danny McPherson
Verisign
21345 Ridgetop Circle
Dulles, VA 20166
US

Email: dmcpherson@verisign.com

Kenji Kumaki
KDDI Corporation
Garden Air Tower
Iidabashi, Chiyoda-ku, Tokyo 102-8460
Japan

Email: ke-kumaki@kddi.com