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Autonomous System (AS) Migration Features and Their Effects on the BGP AS_PATH Attribute
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Abstract

This draft discusses common methods of managing an ASN migration using some BGP feaures that while commonly-used are not formally part of the BGP4 protocol specification and may be vendor-specific in exact implementation. It is necessary to document these de facto standards to ensure that they are properly supported in BGPSec.

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1. Introduction

This draft discusses common methods of managing an ASN migration using some BGP features that while commonly-used are not formally part of the BGP4 [RFC4271] protocol specification and may be vendor-specific in exact implementation. This draft does not attempt to standardize these features, because they are local to given implementation and do not require negotiation with or cooperation of BGP neighbors. The deployment of these features do not need to interwork with one another to accomplish the desired results. However, it is necessary to document these de facto standards to ensure that any future protocol enhancements to BGP that propose to read, copy, manipulate or compare the AS_PATH attribute can do so without inhibiting the use of these very widely used ASN migration features.

It is important to understand the business need for these features, as well, to illustrate why they are critical, particularly for ISP's operations. (It should be noted that these features are not limited to ISP's and that organizations of all sizes use these features for similar reasons to ISP's). During a merger, acquisition or diverstiture involving two organizations it is necessary to seamlessly migrate BGP speakers from one ASN to a second ASN. The overall goal in doing so, particularly in the case of a merger or acquisition, is to achieve a uniform operational model through consistent configurations across all BGP speakers in the combined network. In addition, and perhaps more imporantly, it is common practice in the industry for ISPs to bill customers based on utilization. ISPs bill customers based on the 95th percentile of the greater of the traffic sent or received, over the course of a 1-month period, on the customer's PE-CE access circuit. Given that the BGP Path Selection algorithm selects routes with the shortest AS_PATH attribute, it is critical for the ISP to not increase AS_PATH length during or after ASN migration, toward both downstream transit customers as well as settlement-free peers, who are likely sending or receiving traffic from those transit customers. This would not only result in sudden changes in traffic patterns in the network, but also (substantially) decrease utilization driven revenue at the ISP.

Lastly, it is important to note that, by default, the BGP protocol requires an operator to configure a single remote ASN for the eBGP neighbor inside a router, in order to successfully negotiate and establish an eBGP session. Prior to the existence of these features, it would have required an ISP to work with, in some cases, tens of thousands of customers. In particular, the ISP would have to encourage those customers to change their CE router configs to use the new ASN, in a very short period of time, when the customer has no business incentive to do so. Thus, it because critical to allow the

ISP to seamlessly migrate the ASN within its network(s), not disturb existing customers and allow the customer's to gradually migrate to the ISP's new ASN at their leisure.

1.1. Requirements Language

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in RFC 2119 [RFC2119].

2. ASN Migration Scenario Overview

The use case being discussed here is an ISP merging two or more ASNs, where eventually one ASN subsumes the other(s). In this use case, we will assume the most common case where there are two ISPs, A and B, that use AS 200 and 300, respectively, before the ASN migration is to occur. AS 200 will be the permanently retained ASN used going forward across the consolidated set of both ISPs network equipment and AS 300 will be retired. Thus, at the conclusion of the ASN migration, there will be a single ISP A' with all internal BGP speakers configured to use AS 200. To all external BGP speakers, the AS_PATH length will not be increased.

In this same scenario, AS 100 and AS 400 represent two, separate customer networks: C and D, respectively. Originally, customer C (AS 100) is attached to ISP B, which will undergo ASN migration from AS 300 to AS 200. Furthermore, customer D (AS 100) is attached to ISP A, which does not undergo ASN migration since ISP A's ASN will remain constant, (AS 200). Although this example refers to AS 100 and 400 as customer networks, either or both may be settlement-free or other types of peers. In this use case they are referred to as "customers" merely for convenience.

The general order of operations, typically carried out in a single maintenance window by the network undergoing ASN migration, ISP B, are as follows. First, ISP B, will change the global BGP ASN used by a PE router, from ASN 300 to 200. At this point, the router will no longer be able to establish eBGP sessions toward the existing CE devices that are attached to it and still using AS 300. Second, ISP B will configure two separate, but related ASN migration features discussed in this document on all eBGP sessions toward all CE devices. These features modify the AS_PATH attribute received from and transmitted toward CE devices to acheive the desired effect of not increasing the length of the AS_PATH.

At the conclusion of the ASN migration, the CE devices at the edge of the network are not aware of and do not observe any change in the

length of the AS_PATH attribute. However, after the changes discussed in this document are put in place by ISP A', there is a change to the contents of the AS_PATH attribute to ensure the AS_PATH is not artifically lengthened for the duration of time that these AS migration parameters are used.

In this use case, neither ISP is using BGP Confederations RFC 5065 [RFC5065] internally.

Additional information about this scenario, including vendor-specific implementation details can be found here: Cisco [CISCO] and here: Juniper [JUNIPER]. Equivalent features do exist in several implementations, however publicly available documentation is not available. Finally, the examples cited below use Cisco IOS CLI for ease of illustration purposes only.

3. External BGP Autonomous System Migration Features

The following section addresses features that are specific to modifying the AS_PATH attribute at the Autonomous System Border Routers (ASBRs) of an organization, (typically a single Service Provider). This ensures that external BGP customers/peers are not forced to make any configuration changes on their CE routers before or during the exact time the Service Provider wishes to migrate to a new, permanently retained ASN. Furthermore, these features eliminate the artificial lengthening of the AS_PATH both transmitted from and received by the Service Provider that is undergoing AS Migration, which would have negative implications on path selection by external networks.

3.1. Local AS: Modify Inbound BGP AS_PATH Attribute

ISP B needs to reconfigure its router(s) to participate as an internal BGP speaker in AS 200, to realize the business goal of becoming a single Service Provider: ISP A'. ISP B needs to do this without coordinating the change of its ASN with all of its eBGP peers, simultaneously. The first step is for ISP B to change the global AS in its router configuration, used by the local BGP process as the system-wide Autonomous System ID, from AS 300 to AS 200. The next step is for ISP B to establish iBGP sessions with ISP A's existing routers, thus consolidating ISP B into ISP A resulting in operating under a single AS: ISP A', (AS 200).

The next step is for ISP B to reconfigure its PE router(s) so that each of its eBGP sessions toward all eBGP speakers with a feature called "Local AS". This feature allows ISP B's PE router to re-establish a eBGP session toward the existing CE devices using the

legacy AS, AS 300, in the eBGP session establishment. Ultimately, the CE devices, (i.e.: customer C), are completely unaware that ISP B has reconfigured its router to participate as a member of a new AS. Within the context of ISP B's PE router, the second effect this feature has is that, by default, it prepends all received BGP UPDATE's with the legacy AS of ISP B: AS 300. Thus, within ISP A' the AS_PATH toward customer C would appear as: 300 100, which is an increase in AS_PATH length from previously. Therefore, a secondary feature "No Prepend" is required to be added to the "Local AS" configuration toward every eBGP neighbor on ISP B's PE router. The "No Prepend" feature causes ISP B's PE router to not prepend the legacy AS, AS 300, on all received eBGP UPDATE's from customer C. This restores the AS_PATH within ISP A' toward customer C so that it is just one ASN in length: 100.

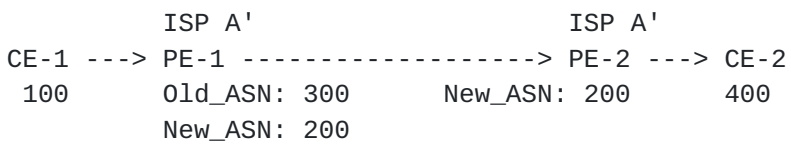
In the direction of CE -> PE (inbound):

1. 'local-as <old_ASN>': appends the <old_ASN> value to the AS_PATH of routes received from the CE

2. 'local-as <old_ASN> no-prepend': does not prepend <old_ASN> value to the AS_PATH of routes received from the CE

As stated previously, local-as <old_ASN> no-prepend, (configuration #2), is critical because it does not increase the AS_PATH length. Ultimately, this ensures that routes learned from ISP B's legacy customers will be transmitted through legacy eBGP sessions of ISP A, toward both customers and peers, will contain only two AS'es in the AS_PATH: 200 100. Thus, the legacy customers and peers of ISP A will not see an increase in the AS_PATH length to reach ISP B's legacy customers. Ultimately, it is considered mandatory by operators that both the "Local AS" and "No Prepend" configuration parameters always be used in conjunction with each other in order to ensure the AS_PATH length is not increased.

PE-1 is a PE that was originally in ISP B. PE-1 has had its global configuration ASN changed from AS 300 to AS 200 to make it part of the permanently retained ASN. This now makes PE-1 a member of ISP A'. PE-2 is a PE that was originally in ISP A. Although its global configuration ASN remains AS 200, throughout this exercise we also consider PE-2 a member of ISP A'.



Note: Direction of BGP UPDATE as per the arrows.

Figure 1: Local AS BGP UPDATE Diagram

The final configuration on PE-1 after completing the "Local AS" portion of the AS migration is as follows:

```
router bgp 200
 neighbor <CE-1_IP> remote-as 100
 neighbor <CE-1_IP> local-as 300 no-prepend
```

As a result of the "Local AS No Prepend" configuration, on PE-1, CE-2 will see an AS_PATH of: 200 100. CE-2 will not receive a BGP UPDATE containing AS 300 in the AS_PATH. (If only the "local-as 300" feature was configured without the keyword "no-prepend" on PE-1, then CE-2 would see an AS_PATH of: 100 300 200, which is unacceptable).

3.2. Replace AS: Modify Outbound BGP AS_PATH Attribute

The previous feature, "Local AS No Prepend", was only designed to modify the AS_PATH Attribute received from CE devices by the ISP, when CE devices still have an eBGP session established with the ISPs legacy AS, (AS300). Use of "Local AS No Prepend" has an unfortunate side effect where its use does not concurrently modify the AS_PATH Attribute for BGP UPDATEs that are transmitted by the ISP to CE devices. Specifically, with "Local AS No Prepend" enabled on ISP A's PE-1, it automatically causes a lengthening of the AS_PATH in outbound BGP UPDATEs from ISP A' toward directly attached eBGP speakers, (Customer C in AS 100). This is the result of the "Local AS No Prepend" feature automatically appending the new global configuration ASN, AS200, after the legacy ASN, AS300, on ISP A' PE-1 in BGP UPDATEs that are transmitted by PE-1 to CE-1. The end result is that customer C, in AS 100, will receive the following AS_PATH: 300 200 400. Therefore, if ISP A' takes no further action, it will cause an increase in AS_PATH length within customer's networks directly attached to ISP A', which is unacceptable.

A second feature, called "Replace AS", was designed to resolve this problem. This feature allows ISP A' to not append the global configured AS in outbound BGP UPDATEs toward its customer's networks configured with the "Local AS" feature. Instead, only the historical (or, legacy) AS will be prepended in the outbound BGP UPDATE toward customer's network, restoring the AS_PATH length to what it what was

before AS Migration occurred.

To re-use the above diagram, but in the opposite direction, we have:

```
               ISP A'                     ISP A'
     CE-1 <--- PE-1 <------------------- PE-2 <--- CE-2
      100      Old_ASN: 300      New_ASN: 200      400
               New_ASN: 200
```

Note: Direction of BGP UPDATE as per the arrows.

Figure 2: Replace AS BGP UPDATE Diagram

The final configuration on PE-1 after completing the "Replace AS" portion of the AS migration is as follows:

```
router bgp 200
 neighbor <CE-1_IP> remote-as 100
 neighbor <CE-1_IP> local-as 300 no-prepend replace-as
```

By default, without "Replace AS" enabled, CE-1 would see an AS_PATH of: 300 200 400, which is artificially lengthened by the ASN Migration. After ISP A' changes PE-1 to include the "Replace AS" feature, CE-1 would receive an AS_PATH of: 300 400, which is the same AS_PATH length pre-AS migration.

4. Internal BGP Autonomous System Migration Features

The following section describes features that are specific to performing an ASN migration within medium to large networks in order to realize the business and operational benefits of a single network using one, globally unique Autonomous System. These features assist with a gradual and least service impacting migration of Internal BGP sessions from a legacy ASN to the permanently retained ASN. It should be noted that the following feature is very valuable to networks undergoing AS migration, but its use does not cause changes to the AS_PATH attribute.

4.1. Internal BGP Alias

In this case, all of the routers to be consolidated into a single, permanently retained ASN are under the administrative control of a single entity. Unfortunately, though, the traditional method of migrating all Internal BGP speakers, particularly within larger networks, is both time consuming and widely service impacting.

The traditional method to migrate Internal BGP sessions was strictly

limited to reconfiguration of the global configuration ASN and, concurrently, changing of iBGP neighbor's remote ASN from the legacy ASN to the new, permanently retained ASN on each router within the legacy AS. These changes can be challenging to swiftly execute in networks with with more than a few dozen internal BGP speakers. There is also the concomitant service interruptions as these changes are made to routers within the network, resulting in a reset of iBGP sessions and subsequent reconvergence times to reestablish optimal routing paths. Operators do not and, in some cases, cannot make such changes given the associated risks and highly visible service interruption; rather, they require a more gradual method to migrate Internal BGP sessions, from one ASN to a second, permanently retained ASN, that is not visibly service-impacting to its customers.

With the "Internal BGP Alias" [JUNIPER] feature, it allows an Internal BGP speaker to form a single iBGP session using either the old, legacy ASN or the new, permanently retained ASN. The benefits of using this feature are several fold. First, it allows for a more gradual and less service-impacting migration away from the legacy ASN to the permanently retained ASN. Second, it (temporarily) permits the coexistence of the legacy and permanently retained ASN within a single network, allowing for uniform BGP path selection among all routers within the consolidated network.

When the "Internal BGP Alias" feature is enabled, typically just on one-side of a iBGP session, it allows that iBGP speaker to establish a single iBGP session with either the legacy ASN or the new, permanently retained ASN, depending on which one it receives in the "My Autonomous System" field of the BGP OPEN message from its iBGP session neighbor. It is important to recognize that enablement of the "Internal BGP Alias" feature preserves the semantics of a regular iBGP session, (using identical ASNs). Thus, the BGP attributes transmitted by and the acceptable methods of operation on BGP attributes received from iBGP sessions configured with "Internal BGP Alias" are no different than those exchanged across an iBGP session without "Internal BGP Alias" configured, as defined by [RFC4271] and [RFC4456].

Typically, in medium to large networks, BGP Route Reflectors [RFC4456] (RRs) are used to aid in reduction of configuration of iBGP sessions and scalability with respect to overall TCP (and, BGP) session maintenance between adjacent iBGP speakers. Furthermore, BGP Route Reflectors are typically deployed in pairs within a single Route Reflection cluster to ensure high reliability of the BGP Control Plane. As such, the following example will use Route Reflectors to aid in understanding the use of the "Internal BGP Alias" feature. It should be noted that Route Reflectors are not a prerequisite to enable "Internal BGP Alias" and this feature can be

enabled independent of the use of Route Reflectors.

The general order of operations is as follows.

1. Within the legacy network, (the routers comprising the set of devices that still have a globally configured legacy ASN), take one member of a redundant pair of RRs and change its global configuration ASN to the permanently retained ASN. Concurrently, enable use of "Internal BGP Alias" on all iBGP sessions. This will comprise Non-Client iBGP sessions to other RRs as well as Client iBGP sessions, typically to PE devices, both still utilizing the legacy ASN. Note that during this step there will be a reset and reconvergence event on all iBGP sessions on the RRs whose configuration was modified; however, this should not be service impacting due to the use of redundant RRs in each RR Cluster.

2. Repeat the above step for the other side of the redundant pair of RRs. The one alteration to the above procedure is to disable use of "Internal BGP Alias" on the Non-Client iBGP sessions toward the other (previously reconfigured) RRs, since it is no longer needed. "Internal BGP Alias" is still required on all RRs for all RR Client iBGP sessions. Also during this step, there will be a reset and reconvergence event on all iBGP sessions whose configuration was modified, but this should not be service impacting. At the conclusion of this step, all RRs should now have their globally configured ASN set to the permanently retained ASN and "Internal BGP Alias" enabled and in use toward RR Clients.

3. At this point, the network administrators would then be able to establish iBGP sessions between all Route Reflectors in both the legacy and permanently retained networks. This would allow the network to appear to function, both internally and externally, as a single, consolidated network using the permanently retained network.

4. The next steps to complete the AS migration are to gradually modify each RR Client, (PE), in the legacy network still utilizing the legacy ASN. Specifically, each legacy PE would have its globally configured ASN changed to use the permanently retained ASN. The ASN used by the PE for the iBGP sessions, toward each RR, would be changed to use the permanently retained ASN. (It is unnecessary to enable "Internal BGP Alias" on the migrated iBGP sessions). During the same maintenance window, External BGP sessions would be modified to include the above "Local AS No Prepend" and "Replace-AS" features, since all of the changes are service interrupting to the eBGP sessions of the PE.

At this point, all PE's will have been migrated to the permanently retained ASN.

5. The final step is to excise the "Internal BGP Alias" configuration from the first half of the legacy RR Client pair -- this will expunge "Internal BGP Alias" configuration from all devices in the network. After this is complete, all routers in the network will be using the new, permanently retained ASN for all iBGP sessions with no vestiges of the legacy ASN on any iBGP sessions.

The benefit of using "Internal BGP Alias" is a more gradual and less, externally visible, service-impacting change to accomplish an AS migration. Previously, without "Internal BGP Alias", such an AS migration change would carry a high risk and need to be successfully accomplished in a very short timeframe, (e.g.: at most several hours). In addition, it would cause substantial routing churn and, likely, rapid fluctuations in traffic carried -- potentially causing periods of congestion and resultant packet loss -- during the period the configuration changes are underway to complete the AS Migration. On the other hand, with "Internal BGP Alias", the migration from the legacy ASN to the permanently retained ASN can occur over a period of days or weeks with little disruption experienced by customers of the network undergoing AS migration. (The only observable service disruption should be when each PE undergoes the changes discussed in step 4 above.)

5. Additional Operational Considerations

This document describes several implementation-specific features to support ISP's and other organizations that need to perform ASN migrations. Other variations of these features may exist, for example, in legacy router software that has not been upgraded or reached End of Life, but continues to operate in the network. Such variations are beyond the scope of this document.

Companies routinely go through periods of mergers, acquisitions and divestitures, which in the case of the former cause them to accumulate several legacy ASN's over time. ISPs often do not have control over the configuration of customer's devices, (i.e.: the ISPs are often not providing a managed CE router service, particularly to medium and large customers that require eBGP). Furthermore, ISPs are using methods to perform ASN migration that do not require coordination with customers. Ultimately, this means there is not a finite period of time after which legacy ASN's will be completely expunged from the ISP's network. In fact, it is common that legacy ASN's and the associated External BGP AS Migration features discussed

in this document can and do persist for several years, if not longer. Thus, it is prudent to plan that legacy ASN's and associated External BGP AS Migration features will persist in a operational network indefinitely.

With respect to the Internal BGP AS Migration Features, all of the routers to be consolidated into a single, permanently retained ASN are under the administrative control of a single entity. Thus, completing the migration from iBGP sessions using the legacy ASN to the permanently retained ASN is more straightforward and could be accomplished in a matter of days to months. Finally, good operational hygiene would dictate that it is good practice to avoid using "Internal BGP Alias" over a long period of time for reasons of not only operational simplicity of the network, but also reduced reliance on that feature during the ongoing lifecycle management of software, features and configurations that are maintained on the network.

6. Conclusion

Although the features discussed in this document are not formally recognized as part of the BGP4 specification, they have been in existence in commercial implementations for well over a decade. These features are widely known by the operational community and will continue to be a critical necessity in the support of network integration activities going forward. Therefore, these features are extremely unlikely to be deprecated by vendors. As a result, these features must be acknowledged by protocol designers, particularly when there are proposals to modify BGP's behavior with respect to handling or manipulation of the AS_PATH Attribute. More specifically, assumptions should not be made with respect to the preservation or consistency of the AS_PATH Attribute as it is transmitted along a sequence of ASN's. In addition, proposals to manipulate the AS_PATH that would gratuitously increase AS_PATH length or remove the capability to use these features described in this document will not be accepted by the operational community.

7. Acknowledgements

Thanks to Kotikalapudi Sriram for his comments.

8. IANA Considerations

This memo includes no request to IANA.

9. Security Considerations

This draft discusses a process by which one ASN is migrated into and subsumed by another. This involves manipulating the AS_PATH Attribute with the intent of not increasing the AS_PATH length, which would typically cause the BGP route to no longer be selected by BGP's Path Selection Algorithm in other's networks. This could result in a loss of revenue if the ISP is billing based on measured utilization of traffic sent to/from entities attached to its network. This could also result in sudden, and unexpected shifts in traffic patterns in the network, potentially resulting in congestion, in the most extreme cases.

Given that these features can only be enabled through configuration of router's within a single network, standard security measures should be taken to restrict access to the management interface(s) of routers that implement these features.

10. References

10.1. Normative References

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