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Influencing BGP Path Selection Using Weight and Local Preference

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ABSTRACT: Routing protocols determine the best routes to transfer data from one node to another and specify how routers communicate between each other in order to complete this task. There are different classes of routing protocols, two of which are Exterior Gateway Protocol (EGP) and Interior Gateway Routing (IGR). Border Gateway Protocol (BGP) is a standardized exterior gateway protocol designed to exchange routing and reachability information among autonomous systems (AS) on the Internet. As the internet evolves to become a vital resource for many organizations, configuring The Border Gateway protocol (BGP) as an exterior gateway protocol in order to connect to the Internet Service Providers (ISP) is crucial. BGP implements routing policies based on a set of attributes accompanying each route used to choose the “shortest” path across multiple ASs. It also controlled by one or more routing policies. This paper describes implementation of BGP and BGP attributes using GNS3 and Cisco router Image. We include on this paper the comparative results for different BGP attributes implementation, in addition how these attributes affect routing path.

KEYWORDS: BGP, BGP Attributes, weight and Local Preference Attributes Implementation, GNS3

I. INTRODUCTION

On the network layer, achieving routing convergence, the process in which routing tables are updated, is a crucial and complex process. At every topology change, including a link failure or recovery, the routing tables need to be updated at which time the convergence process takes place. The task of updating these tables is accomplished by routers that communicate according to a set of rules set by routing protocols. The main goals of any routing protocol are to achieve fast convergence, while remaining simple, flexible, accurate and robust. The Border Gateway Protocol (BGP) is responsible for finding the best route for data transmission between two endpoints connected across the internet. In this paper, we dive deep into its inner workings to answer a common network engineering question: How do BGP attributes work.

The Internet has grown significantly over the past several decades. Border Gateway Protocol (BGP) is a standardized exterior gateway protocol that enables the internet to exchange routing and reachability information between autonomous systems (AS). BGP is treated as a useful tool in designing and implementing complex networks. The protocol is often classified as a path vector protocol. Border Gateway Protocol (BGP) is one of the most widely deployed protocols to exchange network layer reachability information between routing domains. A routing domain is often called an autonomous system (AS). The current Internet is a network of interconnected autonomous systems, where BGP version 4 is the de facto routing protocol

The Border Gateway Protocol makes routing decisions based on paths, network policies, or rule-sets configured by a network administrator and is involved in making core routing decisions. BGP routers typically receive multiple paths to the same destination. The BGP best path algorithm decides which is the best path to install in the IP routing table and to use it for traffic forwarding. There are many ways to manipulate BGP paths, known as BGP attributes or in some cases BGP parameters and is used to determine the best path to a destination.

1.2 Border Gateway Protocol

BGP is a standardized exterior gateway protocol (EGP), as opposed to RIP, OSPF, and EIGRP which are interior gateway protocols (IGP's). BGP Version 4 (BGPv4) is the current standard deployment. BGP is considered a



“Path Vector” routing protocol. BGP was not built to route within an Autonomous System (AS), but rather to route between AS’s. BGP maintains a separate routing table based on shortest AS Path and various other attributes, as opposed to IGP metrics like distance or cost. BGP is the routing protocol of choice on the Internet.

BGP Feature:

- Exterior gateway protocol, designed for inter-AS Domain Routing.
- Ability to hold huge routing table//Designed to scale huge inter network link internet.
- Support Classless routing //Support FLSM. VLSM. CIDR.
- Updates are incremental and Trigger
- It Send updates to manually defined neighbor as unicast. Neighbors in BGP should be manually configured (Neighbors are discovered using Hello packets in OSPF and EIGRP.)
- BGP utilizes TCP for reliable transfer of its packets, on port 179.
- TCP does not support multicasting that’s why need to form Neighbors manually.
- AD
 - 20 External updates (EBGP)
 - 200 internal updates (IBGP)

A router that advertises BGP messages is called a BGP speaker. The BGP speaker establishes peer relationships with other BGP speakers to exchange routing information. When a BGP speaker receives a new route or a route better than the current one from another AS, it advertises the route to all the other BGP peers in the local AS.

BGP can be configured to run on a router in the following two modes:

- iBGP (internal BGP)
- eBGP (external BGP)

When a BGP speaker peers with another BGP speaker that resides in the same autonomous system, the session is referred to as an iBGP session. When a BGP speaker peers with a BGP speaker that resides in a different autonomous system, the session is referred to as an eBGP session.

1.3BGP Path Attributes

There are four categories of path attributes:

Well-known mandatory	Must be recognized by all BGP routers and must be included in every update message. Routing information errors occur without this attribute.
Well-known discretionary	Can be recognized by all BGP routers; can be included in every update message as needed.
Optional transitive	Transitive attribute between ASs. A BGP router not supporting this attribute can still receive routes with this attribute and advertise them to other peers.
Optional non-transitive	If a BGP router does not support this attribute, it will not advertise routes with this attribute.

BGP path attributes are a set of parameters describing the characteristics of a BGP prefix. Because BGP is foremost a routing policy tool, BGP makes extensive use of these attributes in influencing the path section. Effective use of these attributes is critical in designing an effective BGP routing architecture. The following attributes currently are supported in Cisco IOS software:

- AS-Path (well-known mandatory) – Identifies the list (or path) of traversed AS’s to reach a particular destination.
- Next-Hop (well-known mandatory) – Identifies the next hop IP address to reach a particular destination.
- Origin (well-known mandatory) – Identifies the originator of the route.
- Local Preference (well-known, discretionary) – Provides a preference to determine the best path for outbound traffic.
- Atomic Aggregate (well-known discretionary) – Identifies routes that have been summarized, or aggregated.
- Aggregator (optional transitive) – Identifies the BGP router that performed an address aggregation.
- Community (optional transitive) – Tags routes that share common characteristics into communities.



- Multi-Exit-Discriminator (MED) (optional non-transitive) – Provides a preference to eBGP peers to a specific inbound router.
- Weight (Cisco Proprietary) – Similar to Local Preference, provides a local weight to determine the best path for outbound traffic.

1.4 BGP Path Selection Algorithm

If BGP contains multiple routes to the same destination, it compares the routes in pairs, starting with the newest entries (listed higher in the routing table), and working towards the oldest entries (listed lower in the table). BGP determines the best path by successively comparing the attributes of each “route pair.” The attributes are compared in a specific order:

- Weight – Which route has the highest weight
- Local Preference – Which route has the highest local preference
- Locally Originated – Did the local router originate this route. Or in other words we can say/check, is the next hop to the destination 0.0.0.0
- AS-Path – Which route has the shortest AS-Path.
- Origin Code – Where did the route originate. The following origin codes are listed in order of preference: o IGP (originated from an interior gateway protocol) o EGP (originated from an exterior gateway protocol) o”?” (Unknown origin)
- MED – Which path has the lowest MED.
- BGP Route Type – Is this an eBGP or iBGP route. (eBGP routes are preferred)
- Age – Which route is the oldest. (oldest is preferred)
- Router ID – Which route originated from the router with the lowest BGP router ID.
- Peer IP Address – Which route originated from the router with the lowest IP. When applying attributes, Weight and Local Preference are applied to inbound routes, dictating the best outbound path. AS-Path and MED are applied to outbound routes, dictating the best inbound path.

II. LITERATURE SURVEY

This section briefly describes published work related to the topic. This is to provide an overview of already researched areas and to show the source of inspiration. Deeper, more explanatory details and critical analysis regarding related work and methods are presented in the section, Literature Review.

Below are certain papers for the BGP technology. Based on the literature review we can say that the enforcement of routing policies is very important for any network administration of AS. The present BGP simulation study is rather simple one, but its operation in real-world is extremely complex. There are number of open and interesting research problems in this area for enforcing routing policies using BGP. The Internet is composed of Autonomous System (ASs) that uses BGP to implement inter-AS or intra-AS IP routing policies. BGP implements routing policies based a set of attributes accompanying each route used to pick the “shortest” path across multiple ASs, along with one or more routing policies. Paper [20] “Implementation of Border Gateway Protocol (BGP) Attributes” by Nael A. Zidan, Mohammad M. N. Hamarsheh describes implementation of BGP and BGP attributes using GNS3 and Cisco router Image. We include on this paper the comparative results for different BGP attributes implementation, in addition how these attributes affect routing path. BGP design accomplish its goal, with AS owner administration and enforcing policies. This paper explains that this simulation of BGP is mostly operation in real world is extremely complex. In this paper they discussed four route attributes, which are AS Path, Local Preference, Multi-Exit discriminator (Metric) and AS Path Prepend.

Referring “Optimal Configuration for BGP Route Selection” by Thomas C. Rajeev Rastogi and Mark A. This paper[14], precisely define and formulate the problem of BGP router selection, including the two problem variants of Single Egress Selection and Multiple Egress Selection. This paper examines the problem of determining an optimal set of border routers for the advertisement of network prefixes so as to minimize the cost of traffic across a transit service provider’s network while maintaining egress bandwidth constraints at the border routers. Further developing and proposing heuristic solutions for both problem variants and show the results of an implementation embodying those heuristics on simulated network topologies and traffic for a varying set of border router capacities, they concluded conclude that the problem formulation is sound and that our heuristic solutions show marked improvement over alternatives. Both the formulation and the solutions should be of great value to providers as they migrate away from ad-hoc methods of configuration and look to optimize their network utilization and balance traffic across the capacities of their border routers.



“Border Gateway Protocol (BGP): A Simulation Based Overview” by P. R. Gundalwar¹, Dr. V. N. Chavan². This paper [10] describes the BGP in different perspective from routing aspects, message and packets formats, route path attributes to its implementations in different network simulation scenarios. They used OPNET Academic IT Guru Edition 9.1 for network simulation study of BGP as routing protocol. Further discussing two route attributes: AS path and Local preference in this simulation study, they studied router configuration setups of router for route map and neighbor information used for enforcing routing policy. In this paper, they discussed the comparative results for BGP simple routing policy needed in any network administration for effective network utilization.

1. System Development

For system development we used Graphical Network Simulator-3 (GNS3) software, which offers an easy way to design and build networks of any size without the need of hardware. Here we used Cisco 7200 series routers IOS image. We needed to download the IOS image of the required router.

For implementation we used seven Cisco 7200 series routers connected with gig eth link as shown in below Figure 1. And configured as shown in Figure 2.

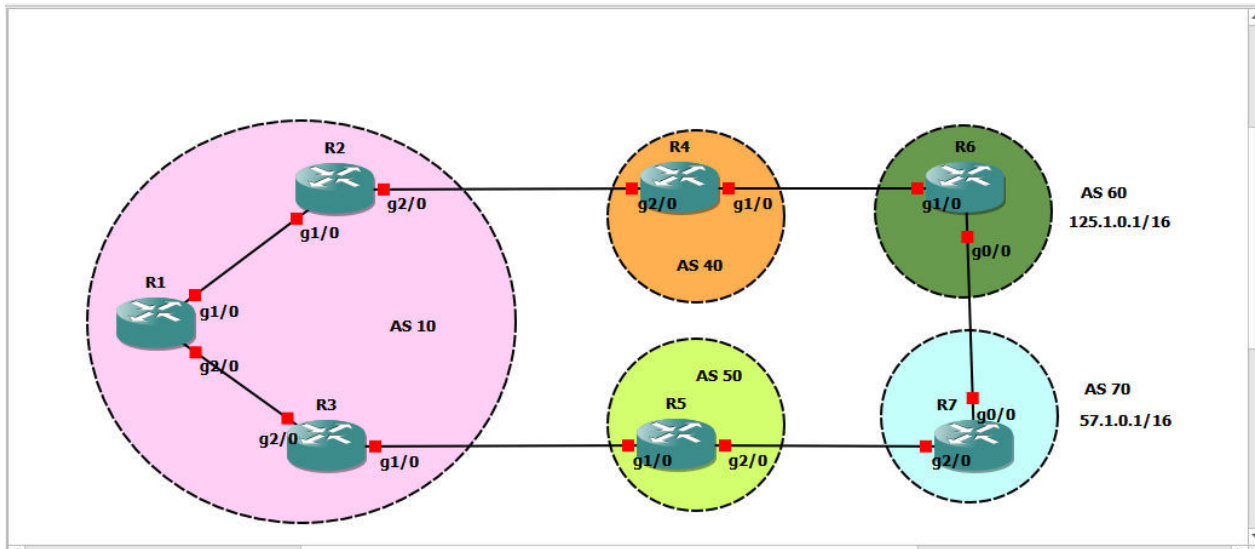


Figure 1: Network Dig

As per below table we have configured all routers R1, R2, R3, R4, R5, R6 and R7. The interface address of the routers and their subnets are specified in Table 1

Router	AS	Interface	Ip add
R1	10	GE1/0	21.0.0.1
		GE2/0	31.0.0.1
R2	10	GE1/0	21.0.0.2
		GE2/0	42.0.0.2
R3	10	GE2/0	31.0.0.3
		GE1/0	53.0.0.3
R4	40	GE2/0	42.0.0.4
		GE1/0	64.0.0.4
R5	50	GE1/0	53.0.0.5
		GE2/0	75.0.0.5
R6	60	GE1/0	64.0.0.6
		GE0/0	76.0.0.6
		Loopback0	125.1.0.1/16
R7	70	GE2/0	75.0.0.7
		GE0/0	76.0.0.7
		Loopback 1	75.1.0.1/16

Table 1 : The interface address And AS of the routers



```
R1#config t
Enter configuration commands, one per line. End with CNTL/Z.
R1(config)#int gig 2/0
R1(config-if)#ip add 31.0.0.1 255.0.0.0
R1(config-if)#no shut
R1(config-if)#
R1(config-if)#int gig 1/0
R1(config-if)#ip add 21.0.0.1 255.0.0.0
R1(config-if)#no shut
R1(config-if)#
R1(config-if)#end
R1#wr me
```

Figure 2: Interface configuration on R1

3.1 Basic BGP configuration:

In this section we are implementing BGP attributes and monitoring how it affects path selection hence we are using simple topology consisting of BGP protocol only. We have to enable BGP on each router including AS setting. As discussed earlier BGP cannot discover neighbors automatically so we have to explicitly declare them.

```
R2#
R2#config t
Enter configuration commands, one per line. End with CNTL/Z.
R2(config)#router bgp 10
R2(config-router)#neighbor 42.0.0.4 remote-as 40
R2(config-router)#neighbor 21.0.0.1 remote-as 10
R2(config-router)#^Z
R2#wr me
*Dec 23 01:23:09.907: %SYS-5-CONFIG_I: Configured from console by console
R2#wr me
```

Figure 3: Basic BGP configuration on R2

```
21.0.0.1 4 10 4 4 1 0 0 00:00:35 0
42.0.0.4 4 40 3 4 1 0 0 00:01:31 0
R2#
R2#show ip bgp summ
BGP router identifier 42.0.0.2, local AS number 10
BGP table version is 1, main routing table version 1

Neighbor V AS MsgRcvd MsgSent TblVer InQ OutQ Up/Down State/PfxRcd
21.0.0.1 4 10 4 4 1 0 0 00:00:36 0
42.0.0.4 4 40 3 4 1 0 0 00:01:32 0
R2#
```

Figure 4: This Fig shows status of all BGP neighbor connected to R2.

Similarly we have defined BGP neighbor for each router. Here We are studying how paths are selected based on attributes. Hence for testing routing path we are advertising network on R6 and R7 using the network statement and redistribution.

Further, the network statement must exactly match a mask that we have given on the interface. If no mask is specified, a classful mask will be assumed.

R7(config-router)#network 57.1.0.0 mask 255.255.0.0. Refer Figure 5 for basic configuration for advertising network in bgp. Similarly we have advertised network 125.1.0.1/16 onto R6



```
R7#
R7#
R7#config t
Enter configuration commands, one per line. End with CNTL/Z.
R7(config)#router bgp 70
R7(config-router)#network 57.1.0.0 mask 255.255.0.0
R7(config-router)#^Z
R7#
R7#
*Dec 23 01:45:48.211: %SYS-5-CONFIG_I: Configured from console by console
R7#
```

Figure 5: Configuration to advertised network in BGP

3.2The BGP Routing Table :

As stated earlier BGP maintains its own separate routing table. This table contains a list of routes that can be advertised to BGP peers.

```
R1#
R1#sho ip bgp
BGP table version is 3, local router ID is 31.0.0.1
Status codes: s suppressed, d damped, h history, * valid, > best, i - internal,
               r RIB-failure, S Stale, m multipath, b backup-path, f RT-Filter,
               x best-external, a additional-path, c RIB-compressed,
Origin codes: i - IGP, e - EGP, ? - incomplete
RPKI validation codes: V valid, I invalid, N Not found

   Network          Next Hop        Metric LocPrf Weight Path
* i 57.1.0.0/16     42.0.0.4         0      100      0 40 60 70 i
> i 57.1.0.0/16     31.0.0.3         0      100      0 50 70 i
* i 125.1.0.0/16    31.0.0.3         0      100      0 50 70 60 i
* i 125.1.0.0/16    42.0.0.4         0      100      0 40 60 i
R1#
R1#
```

Figure 6: R1 routing table without Policy

For network 75.1.0.0/16, the ‘i’ is the origin code and indicates that this network was advertised into BGP using the network command, the table says it refers to IGP but it doesn’t have anything to do with “interior gateway protocols”. When you redistribute something into BGP it will show up with the “?” symbol. You will never see the ‘e’ symbol, this refers to EGP (Exterior Gateway Protocol) which is the predecessor of BGP. The Next Hop of 0.0.0.0 indicates that the route was locally originated into BGP. And The Path is empty, as the route originated in the Autonomous Systems.

Also Notice the Status Codes of “*>”.

- The * means that this is a valid route and that BGP is able to use it.
- The > means that this entry has been selected as the best path.

Further to the right we see metric, local preference and weight. These are the BGP attributes that are used to select the best path. Path will show the AS path, there’s nothing there since this network was advertised in BGP on this router. For 125.1.0.0/16 network AS 60 has been added to path. and that the Next Hop is now router 6..

IV. RESULT BASED ON ROUTE-MANIPULATION

Consider the network as shown in Figure 1. All of the routers are configured with necessary BGP configuration. Route-manipulation techniques are described as follows

1. When there is a tie in weight, local preference and Origin of the route and path is selected based on shortest AS-Path.
2. Use weight so that R1 will give more weightage/preference to R2 than R3 and all the traffic will flow via R2
3. Configure R3 with higher local preference so that R1 will prefer R3 to reach all the prefixes.



1.1 BGP path Selection on basis of AS path/without any additional policy.

This result show in Fig 7 is routing table for router R1 with earlier configurations, it chooses the best path routing from router R2 for 125.1.0.0 network and from router R3 to reach 57.1.0.0 network. As we discussed earlier If BGP contains multiple routes to the same destination, BGP determines the best path by successively comparing the attributes of each “route pair.” The attributes are compared in a specific order as describes in 1.4.

For this case by default, there is a tie in weight, local preference and Origin of the route. Now going further BGP will choose path with shortest AS-Path and decides different valid and best route to reach 125 and 57 network

```
R1#
R1#sho ip bgp
BGP table version is 4, local router ID is 31.0.0.1
Status codes: s suppressed, d damped, h history, * valid, > best, i - internal,
               r RIB-failure, S Stale, m multipath, b backup-path, f RT-Filter,
               x best-external, a additional-path, c RIB-compressed,
Origin codes: i - IGP, e - EGP, ? - incomplete
RPKI validation codes: V valid, I invalid, N Not found

   Network          Next Hop          Metric LocPrf Weight Path
* i 57.1.0.0/16     21.0.0.2           0     100     0 40 60 70 i
*>i                 31.0.0.3           0     100     0 50 70 i
* i 125.1.0.0/16   31.0.0.3           0     100     0 50 70 60 i
*>i                 21.0.0.2           0     100     0 40 60 i
R1#
R1#
```

Figure 7: R1 routing table without any changes in Policy

1.2 BGP with Weight attributes.

Here we use same configuration as in scenario 1 with modification in BGP configuration by Changing Weight on R1 for neighbor R2. It is a Cisco-proprietary attribute, and is only locally significant (and thus, is never passed on to BGP neighbors). By default, a route originated on the local router will be assigned a weight of 32768. All other routes will be assigned a weight of 0, by default. For this we can say that we are having aim that, all traffic should go via R2 including 57.1.0.0 network

Now changing weight value to 100 (from default 0,) for router R2 on router R1 we are giving more weightage to R2 than R3 and all the traffic will flow via R2.

```
R1(config)#
R1(config)#
R1(config)#
R1(config)#
R1(config)#router bgp 10
R1(config-router)#neig
R1(config-router)#neighbor 21.0.0.2 weig
R1(config-router)#neighbor 21.0.0.2 weight 200
R1(config-router)#
R1(config-router)#
R1(config-router)#
R1(config-router)#
```

Figure 8: BGP configuration for changing weight of R2

R1 routing table: Notice that earlier for 75 network best and valid route was via R3, but after changing weight the best valid path is via R2 only (even though the R2 path is longer,)and also included in routers routing table.



```
R1#
R1#show ip bgp
BGP table version is 6, local router ID is 31.0.0.1
Status codes: s suppressed, d damped, h history, * valid, > best, i - internal,
               r RIB-failure, S Stale, m multipath, b backup-path, f RT-Filter,
               x best-external, a additional-path, c RIB-compressed,
Origin codes: i - IGP, e - EGP, ? - incomplete
RPKI validation codes: V valid, I invalid, N Not found

   Network          Next Hop           Metric LocPrf Weight Path
* >i 57.1.0.0/16    21.0.0.2           0     100    200 40 60 70 i
* i 125.1.0.0/16   31.0.0.3           0     100      0 50 70 i
* >i 125.1.0.0/16   31.0.0.3           0     100      0 50 70 60 i
* >i 21.0.0.0/24    21.0.0.2           0     100    200 40 60 i
R1#
R1#
```

Figure 9: R1 routing table with showing best and valid path with higher Weight attributes

1.3 BGP with Local Preference :

Again for influencing path selection using Local Preference, we use same configuration in scenario 1 with modification in BGP configuration for Local Preference only. We can achieve this either by decrementing LocPrf on R2 or by incrementing LocPrf on R3 as compared to default LocPrf. The highest Local Preference is preferred, and the default preference is 100.

For this case also we can say that we are having aim that, all traffic should go via R3 including 57.1.0.0 and 125.1.0.0 network. Now going to R3 we are setting LocPrf value to 400, higher than default.

```
R3(config-router)#
R3(config-router)#
R3(config-router)#
R3(config-router)#
R3(config-router)#bgp defa
R3(config-router)#bgp default loc
R3(config-router)#bgp default local-preference 400
R3(config-router)#
R3(config-router)#
```

Figure 10: BGP configuration for changing Local Preference

R1 routing table : Now we can go to R1 and observed that R1 will now prefer the route through router R3 to reach any destination outside the local AS irrespective of AS path value.

```
R1#
R1#show ip bgp
BGP table version is 12, local router ID is 31.0.0.1
Status codes: s suppressed, d damped, h history, * valid, > best, i - internal,
               r RIB-failure, S Stale, m multipath, b backup-path, f RT-Filter,
               x best-external, a additional-path, c RIB-compressed,
Origin codes: i - IGP, e - EGP, ? - incomplete
RPKI validation codes: V valid, I invalid, N Not found

   Network          Next Hop           Metric LocPrf Weight Path
* i 57.1.0.0/16    21.0.0.2           0     200      0 40 60 70 i
* >i 125.1.0.0/16   31.0.0.3           0     400      0 50 70 i
* >i 125.1.0.0/16   31.0.0.3           0     400      0 50 70 60 i
* i 21.0.0.0/24    21.0.0.2           0     200      0 40 60 i
R1#
R1#
```

Figure 11: R1 routing table selecting path on basis of LocPrf



V. CONCLUSION

BGP makes routing decision based on paths, rules or network policies configured by a network administrator. BGP Offers network stability that guarantees routers can quickly adapt to send packets through another reconnection if one internet path goes down or any changes in routing policy. Here we discussed about BGP path selection process based on AS path, weight and Local Preference. In this paper we studied BGP attributes and BGP path selection process and using GNS 3 simulation we described how to configure BGP, configure BGP neighbors, reading BGP routing table and how to configure BGP attributes and apply them to influence path selection process.

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