BGP Attributes and Policy Control

ISP/IXP Workshops

Agenda

- BGP Attributes
- BGP Path Selection
- Applying Policy

BGP Attributes

The “tools” available for the job

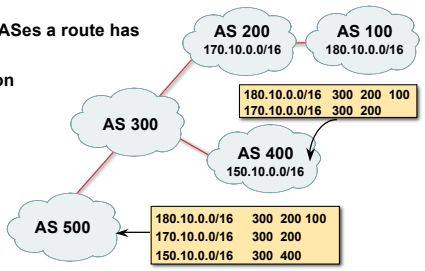
What Is an Attribute?

...	Next Hop	AS Path	MED	...	...

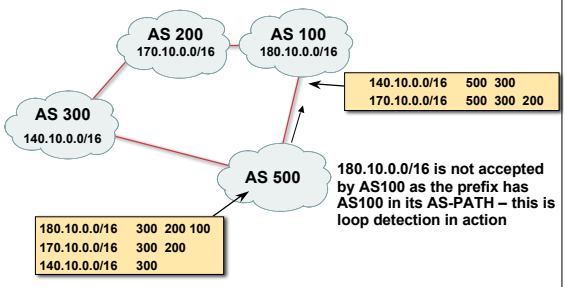
- Describes the characteristics of prefix
- Transitive or non-transitive
- Some are mandatory

AS-Path

- Sequence of ASes a route has traversed
- Loop detection
- Apply policy

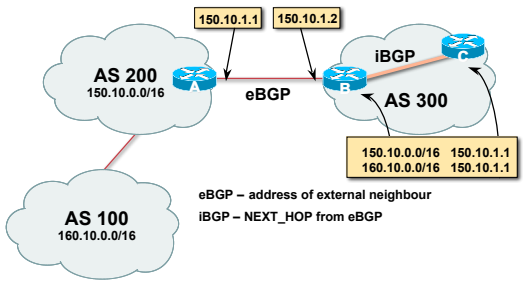


AS-Path loop detection

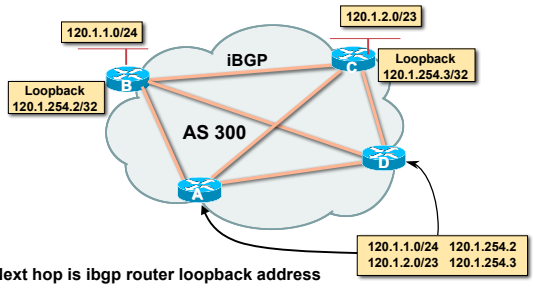


180.10.0.0/16 is not accepted by AS100 as the prefix has AS100 in its AS-PATH – this is loop detection in action

Next Hop



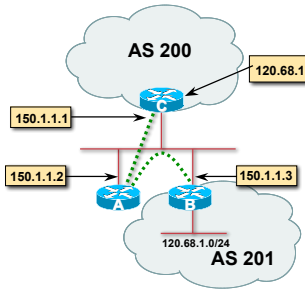
iBGP Next Hop



Next hop is ibgp router loopback address

Recursive route look-up

Third Party Next Hop



- eBGP between Router A and Router C
- eBGP between RouterA and RouterB
- 120.68.1/24 prefix has next hop address of 150.1.1.3 – this is passed on to RouterC instead of 150.1.1.2
- More efficient
- No extra config needed

Next Hop (summary)

- IGP should carry route to next hops
- Recursive route look-up
- Unlinks BGP from actual physical topology
- Allows IGP to make intelligent forwarding decision

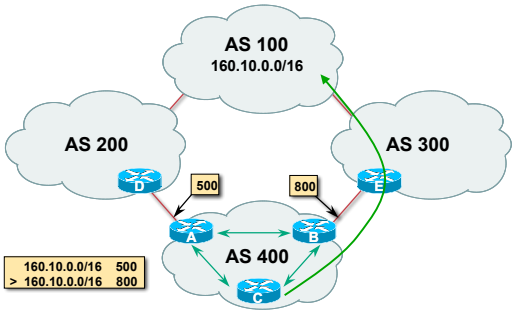
Origin

- Conveys the origin of the prefix
- "Historical" attribute
- Influences best path selection
- Three values: IGP, EGP, incomplete
  - IGP – generated by BGP network statement
  - EGP – generated by EGP
  - incomplete – redistributed from another routing protocol

Aggregator

- Useful for debugging purposes
- Conveys the IP address of the router/BGP speaker generating the aggregate route
- Does not influence path selection

Local Preference



Local Preference

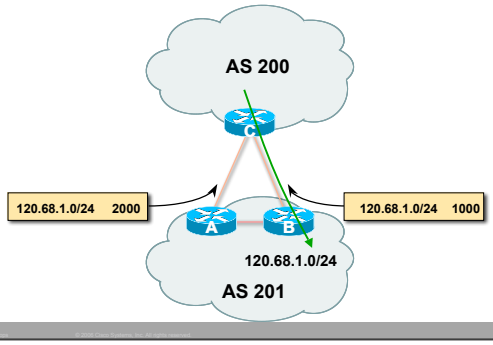
- Local to an AS – non-transitive
  - local preference set to 100 when heard from neighbouring AS
- Used to influence BGP path selection
  - determines best path for *outbound* traffic
- Path with highest local preference wins

Local Preference

- Configuration of Router B:

```
router bgp 400
 neighbor 120.5.1.1 remote-as 300
 neighbor 120.5.1.1 route-map local-pref in
!
route-map local-pref permit 10
 match ip address prefix-list MATCH
 set local-preference 800
!
ip prefix-list MATCH permit 160.10.0.0/16
```

Multi-Exit Discriminator (MED)



Multi-Exit Discriminator

- Inter-AS – non-transitive & optional attribute
- Used to convey the relative preference of entry points
  - determines best path for *inbound* traffic
- Comparable if paths are from same AS
  - bgp always-compared-med allows comparisons of MEDs from different ASes
- Path with lowest MED wins
- Absence of MED attribute implies MED value of zero (RFC4271)

MED & IGP Metric

- IGP metric can be conveyed as MED
  - set metric-type internal in route-map
    - enables BGP to advertise a MED which corresponds to the IGP metric values
    - changes are monitored (and re-advertised if needed) every 600s
    - bgp dynamic-med-interval <secs>

Multi-Exit Discriminator

- Configuration of Router B:

```
router bgp 400
 neighbor 120.5.1.1 remote-as 200
 neighbor 120.5.1.1 route-map set-med out
!
route-map set-med permit 10
 match ip address prefix-list MATCH
 set metric 1000
!
ip prefix-list MATCH permit 120.68.1.0/24
```

Weight

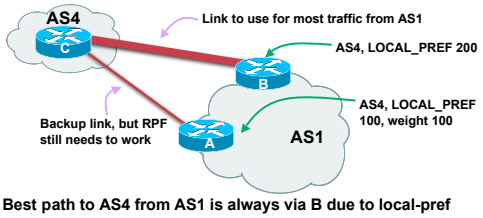
- Not really an attribute – local to router
- Highest weight wins
- Applied to all routes from a neighbour

```
neighbor 120.5.7.1 weight 100
```

- Weight assigned to routes based on filter

```
neighbor 120.5.7.3 filter-list 3 weight 50
```

Weight – Used to help Deploy RPF

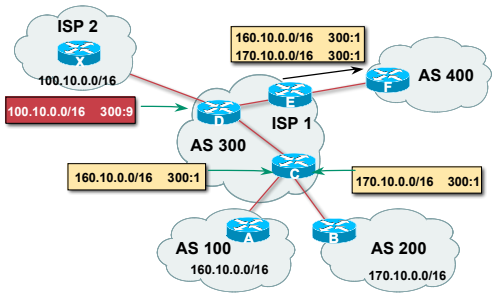


- Best path to AS4 from AS1 is always via B due to local-pref
- But packets arriving at A from AS4 over the direct C to A link will pass the RPF check as that path has a priority due to the weight being set
  - If weight was not set, best path back to AS4 would be via B, and the RPF check would fail

Community

- Communities are described in RFC1997
  - Transitive & Optional attribute
- 32 bit integer
  - Represented as two 16 bit integers (RFC1997/8)
  - Common format is *<local-ASN>:xx*
  - 0:0 to 0:65535 and 65535:0 to 65535:65535 are reserved
- Used to group destinations
  - Each destination could be member of multiple communities
- Very useful for applying policies within and between ASes

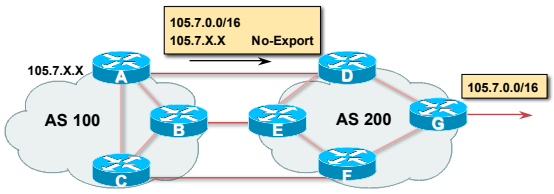
Community



Well-Known Communities

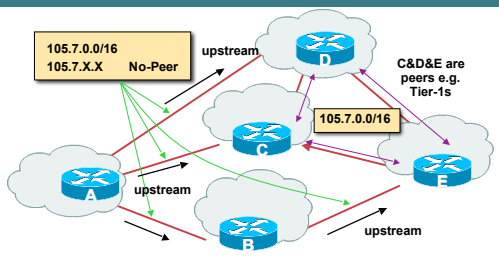
- Several well known communities
  - www.iana.org/assignments/bgp-well-known-communities
- no-export 65535:65281
  - do not advertise to any eBGP peers
- no-advertise 65535:65282
  - do not advertise to any BGP peer
- no-export-subconfed 65535:65283
  - do not advertise outside local AS (only used with confederations)
- no-peer 65535:65284
  - do not advertise to bi-lateral peers (RFC3765)

No-Export Community



- AS100 announces aggregate and subprefixes
  - aim is to improve loadsharing by leaking subprefixes
- Subprefixes marked with no-export community
- Router G in AS200 does not announce prefixes with no-export community set

No-Peer Community



- Sub-prefixes marked with no-peer community are not sent to bi-lateral peers
  - They are only sent to upstream providers

Summary Attributes in Action

```
Router1>sh ip bgp
BGP table version is 28, local router ID is 100.1.15.224
Status codes: s suppressed, d damped, h history,
       * valid, > best,i - internal, r RIB-failure, S Stale
Origin codes: i - IGP, e - EGP, ? - incomplete

   Network          Next Hop            Metric LocPrf Weight Path
*> 100.1.0.0/20     0.0.0.0                  0         32768 i
*>i100.1.16.0/20    100.1.31.224             0    100      0 i
*>i100.1.32.0/19    100.1.63.224             0    100      0 i
...
```

BGP Path Selection Algorithm

Why is this the best path?

BGP Path Selection Algorithm

- Do not consider path if no route to next hop
- Do not consider iBGP path if not synchronised
- Highest weight (local to router)
- Highest local preference (global within AS)
- Prefer locally originated route
- Shortest AS path

BGP Path Selection Algorithm (continued)

- Lowest origin code
  - IGP < EGP < incomplete
- Lowest Multi-Exit Discriminator (MED)
  - If bgp deterministic-med, order the paths before comparing
  - If bgp always-compare-med, then compare for all paths
  - otherwise MED only considered if paths are from the same AS (default)

BGP Path Selection Algorithm (continued)

- Prefer eBGP path over iBGP path
- Path with lowest IGP metric to next-hop
- For eBGP paths:
  - If multipath is enabled, install N parallel paths in forwarding table
  - If router-id is the same, go to next step
  - If router-id is not the same, select the oldest path

BGP Path Selection Algorithm (continued)

- Lowest router-id (originator-id for reflected routes)
- Shortest cluster-list
  - Client must be aware of Route Reflector attributes!
- Lowest neighbour address

Applying Policy with BGP

How to use the “tools”

Applying Policy with BGP

- Policy-based on AS path, community or the prefix
- Rejecting/accepting selected routes
- Set attributes to influence path selection
- Tools:
  - Prefix-list (filters prefixes)
  - Filter-list (filters ASes)
  - Route-maps and communities

Policy Control – Prefix List

- Per neighbour prefix filter
  - incremental configuration
- Inbound or Outbound
- Based upon network numbers (using familiar IPv4 address/mask format)
- Using access-lists for filtering prefixes was deprecated long ago
  - Strongly discouraged!

Prefix-list Command

- Syntax:

  [no] ip prefix-list <*list-name*> **[seq** <*seq-value*>**] permit|deny** <*network*>/<*len*> **[ge** <*ge-value*>**] [le** <*le-value*>**]**

  <*network*>/<*len*>: The prefix and its length

  ge <*ge-value*>: "greater than or equal to”

  le <*le-value*>: "less than or equal to”

  Both "ge" and "le" are optional. Used to specify the range of the prefix length to be matched for prefixes that are more specific than <*network*>/<*len*>

Prefix Lists – Examples

- Deny default route

```
ip prefix-list EG deny 0.0.0.0/0
```

- Permit the prefix 35.0.0.0/8

```
ip prefix-list EG permit 35.0.0.0/8
```

- Deny the prefix 172.16.0.0/12

```
ip prefix-list EG deny 172.16.0.0/12
```

- In 192/8 allow up to /24

```
ip prefix-list EG permit 192.0.0.0/8 le 24
```

This allows all prefix sizes in the 192.0.0.0/8 address block, apart from /25, /26, /27, /28, /29, /30, /31 and /32.

Prefix Lists – Examples

- In 192/8 deny /25 and above

```
ip prefix-list EG deny 192.0.0.0/8 ge 25
```

This denies all prefix sizes /25, /26, /27, /28, /29, /30, /31 and /32 in the address block 192.0.0.0/8.

It has the same effect as the previous example

- In 193/8 permit prefixes between /12 and /20

```
ip prefix-list EG permit 193.0.0.0/8 ge 12 le 20
```

This denies all prefix sizes /8, /9, /10, /11, /21, /22, … and higher in the address block 193.0.0.0/8.

- Permit all prefixes

```
ip prefix-list EG permit 0.0.0.0/0 le 32
```

0.0.0.0 matches all possible addresses, "0 le 32" matches all possible prefix lengths

Policy Control – Prefix List

- Example Configuration

```
router bgp 100
 network 105.7.0.0 mask 255.255.0.0
 neighbor 102.10.1.1 remote-as 110
 neighbor 102.10.1.1 prefix-list PEER-IN in
 neighbor 102.10.1.1 prefix-list PEER-OUT out
!
ip prefix-list PEER-IN deny 218.10.0.0/16
ip prefix-list PEER-IN permit 0.0.0.0/0 le 32
ip prefix-list PEER-OUT permit 105.7.0.0/16
ip prefix-list PEER-OUT deny 0.0.0.0/0 le 32
```

Policy Control – Filter List

- Filter routes based on AS path
- Inbound or Outbound
- Example Configuration:

```
router bgp 100
 network 105.7.0.0 mask 255.255.0.0
 neighbor 102.10.1.1 filter-list 5 out
 neighbor 102.10.1.1 filter-list 6 in
!
ip as-path access-list 5 permit ^200$
ip as-path access-list 6 permit ^150$
```

Policy Control – Regular Expressions

- Like Unix regular expressions

.	Match one character
*	Match any number of preceding expression
+	Match at least one of preceding expression
^	Beginning of line
$	End of line
_	Beginning, end, white-space, brace
|	Or
()	brackets to contain expression

Policy Control – Regular Expressions

- Simple Examples

.*	match anything
.+	match at least one character
^$	match routes local to this AS
_1800$	originated by AS1800
^1800_	received from AS1800
_1800_	via AS1800
_790_1800_	via AS1800 and AS790
_(1800_)+	multiple AS1800 in sequence (used to match AS-PATH prepends)
_\(65530\)_	via AS65530 (confederations)

Policy Control – Regular Expressions

- Not so simple Examples

^[0-9]+$	Match AS_PATH length of one
^[0-9]+_[0-9]+$	Match AS_PATH length of two
^[0-9]*_[0-9]+$	Match AS_PATH length of one or two
^[0-9]*_[0-9]*$	Match AS_PATH length of one or two (will also match zero)
^[0-9]+_[0-9]+_[0-9]+$	Match AS_PATH length of three
_(701|1800)_	Match anything which has gone through AS701 or AS1800
_1849(_.+_)12163$	Match anything of origin AS12163 and passed through AS1849

Policy Control – Route Maps

- A route-map is like a "programme" for IOS
- Has "line" numbers, like programmes
- Each line is a separate condition/action
- Concept is basically:

  if *match* then do *expression* and *exit*

  else

  if *match* then do *expression* and *exit*

  else *etc*

Route Maps – Caveats

- Lines can have multiple set statements but only one match statement
- Line with only a set statement

  all prefixes are matched and set

  any following lines are ignored
- Line with a match/set statement and no following lines

  only prefixes matching go through

  the rest are dropped

Route Maps – Caveats

- Example

  omitting the third line below means that prefixes not matching list-one or list-two are dropped

```
route-map sample permit 10
 match ip address prefix-list list-one
 set local-preference 120
!
route-map sample permit 20
 match ip address prefix-list list-two
 set local-preference 80
!
route-map sample permit 30      ! Don't forget this
```

Policy Control – Route Maps

- Example Configuration – route map and prefix-lists

```
router bgp 100
 neighbor 1.1.1.1 route-map infilter in
!
route-map infilter permit 10
 match ip address prefix-list HIGH-PREF
 set local-preference 120
!
route-map infilter permit 20
 match ip address prefix-list LOW-PREF
 set local-preference 80
!
ip prefix-list HIGH-PREF permit 10.0.0.0/8
ip prefix-list LOW-PREF permit 20.0.0.0/8
```

Policy Control – Route Maps

- Example Configuration – route map and filter lists

```
router bgp 100
 neighbor 102.10.1.2 remote-as 200
 neighbor 102.10.1.2 route-map filter-on-as-path in
!
route-map filter-on-as-path permit 10
 match as-path 1
 set local-preference 80
!
route-map filter-on-as-path permit 20
 match as-path 2
 set local-preference 200
!
ip as-path access-list 1 permit _150$
ip as-path access-list 2 permit _210_
```

Policy Control – Route Maps

- Example configuration of AS-PATH prepend

```
router bgp 300
 network 105.7.0.0 mask 255.255.0.0
 neighbor 2.2.2.2 remote-as 100
 neighbor 2.2.2.2 route-map SETPATH out
!
route-map SETPATH permit 10
 set as-path prepend 300 300
```

- Use your own AS number when prepending
  - Otherwise BGP loop detection may cause disconnects

Policy Control – Route Maps

- Route Map MATCH Articles
  - as-path
  - clns address
  - clns next-hop
  - clns route-source
  - community
  - interface
  - ip address
  - ip next-hop
  - ip route-source
  - length
  - metric
  - nlri
  - route-type
  - tag

Policy Control – Route Maps

- Route map SET Articles
  - as-path
  - automatic-tag
  - clns
  - comm-list
  - community
  - dampening
  - default interface
  - interface
  - ip default next-hop
  - ip next-hop

Policy Control – Route Maps

- Route map SET Articles
  - ip precedence
  - ip qos-group
  - ip tos
  - level
  - local preference
  - metric
  - metric-type
  - next-hop
  - nlri multicast
  - nlri unicast
  - origin
  - tag
  - traffic-index
  - weight

Policy Control – Matching Communities

- Example Configuration

```
router bgp 100
 neighbor 102.10.1.2 remote-as 200
 neighbor 102.10.1.2 route-map filter-on-community in
!
route-map filter-on-community permit 10
 match community 1
 set local-preference 50
!
route-map filter-on-community permit 20
 match community 2 exact-match
 set local-preference 200
!
ip community-list 1 permit 150:3 200:5
ip community-list 2 permit 88:6
```

Policy Control – Setting Communities

- Example Configuration

```
router bgp 100
 network 105.7.0.0 mask 255.255.0.0
 neighbor 102.10.1.1 remote-as 200
 neighbor 102.10.1.1 send-community
 neighbor 102.10.1.1 route-map set-community out
!
route-map set-community permit 10
 match ip address prefix-list NO-ANNOUNCE
 set community no-export
!
route-map set-community permit 20
 match ip address prefix-list AGGREGATE
!
ip prefix-list NO-ANNOUNCE permit 105.7.0.0/16 ge 17
ip prefix-list AGGREGATE permit 105.7.0.0/16
```

Aggregation Policies

- **Suppress Map**

  Used to suppress selected more-specific prefixes (e.g. defined through a route-map) in the absence of the summary-only keyword.

- **Unsuppress Map**

  Used to unsuppress selected more-specific prefixes per BGP peering when the summary-only keyword is in use.

Aggregation Policies – Suppress Map

- **Example**

```
router bgp 100
 network 102.10.10.0
 network 102.10.11.0
 network 102.10.12.0
 network 102.10.33.0
 network 102.10.34.0
 aggregate-address 102.10.0.0 255.255.0.0 suppress-map block-net
 neighbor 102.5.7.2 remote-as 200
!
route-map block-net permit 10
 match ip address prefix-list SUPPRESS
!
ip prefix-list SUPPRESS permit 102.10.8.0/21 le 32
ip prefix-list SUPPRESS deny 0.0.0.0/0 le 32
!
```

Aggregation Policies – Suppress Map

- **show ip bgp on the local router**

```
router1#sh ip bgp
BGP table version is 11, local router ID is 102.5.7.1
Status codes: s suppressed, d damped, h history, * valid, > best, i - internal
Origin codes: i - IGP, e - EGP, ? - incomplete
Network          Next Hop            Metric LocPrf Weight Path
*> 102.10.0.0/16  0.0.0.0                              32768 i
s> 102.10.10.0    0.0.0.0                0           32768 i
s> 102.10.11.0    0.0.0.0                0           32768 i
s> 102.10.12.0    0.0.0.0                0           32768 i
*> 102.10.33.0    0.0.0.0                0           32768 i
*> 102.10.34.0    0.0.0.0                0           32768 i
```

Aggregation Policies – Suppress Map

- **show ip bgp on the remote router**

```
router2#sh ip bgp
BGP table version is 90, local router ID is 102.5.7.2
Status codes: s suppressed, d damped, h history, * valid, > best, i - internal
Origin codes: i - IGP, e - EGP, ? - incomplete
Network          Next Hop            Metric LocPrf Weight Path
*> 102.10.0.0/16  102.5.7.1                            0  100 i
*> 102.10.33.0    102.5.7.1              0             0  100 i
*> 102.10.34.0    102.5.7.1              0             0  100 i
```

Aggregation Policies – Unsuppress Map

- **Example**

```
router bgp 100
 network 102.10.10.0
 network 102.10.11.0
 network 102.10.12.0
 network 102.10.33.0
 network 102.10.34.0
 aggregate-address 102.10.0.0 255.255.0.0 summary-only
 neighbor 102.5.7.2 remote-as 200
 neighbor 102.5.7.2 unsuppress-map leak-net
!
route-map leak-net permit 10
 match ip address prefix-list LEAK
!
ip prefix-list LEAK permit 102.10.8.0/21 le 32
ip prefix-list LEAK deny 0.0.0.0/0 le 32
!
```

Aggregation Policies – Unsuppress Map

- **show ip bgp on the local router**

```
router1#sh ip bgp
BGP table version is 11, local router ID is 102.5.7.1
Status codes: s suppressed, d damped, h history, * valid, > best, i -internal
Origin codes: i - IGP, e - EGP, ? - incomplete
Network          Next Hop            Metric LocPrf Weight Path
*> 102.10.0.0/16  0.0.0.0                              32768 i
s> 102.10.10.0    0.0.0.0                0           32768 i
s> 102.10.11.0    0.0.0.0                0           32768 i
s> 102.10.12.0    0.0.0.0                0           32768 i
s> 102.10.33.0    0.0.0.0                0           32768 i
s> 102.10.34.0    0.0.0.0                0           32768 i
```

Aggregation Policies – Unsuppress Map

- show ip bgp on the remote router

```
router2#sh ip bgp
BGP table version is 90, local router ID is 102.5.7.2
Status codes: s suppressed, d damped, h history, * valid, > best, i - internal
Origin codes: i - IGP, e - EGP, ? - incomplete
Network          Next Hop       Metric LocPrf Weight Path
*> 102.10.0.0/16    102.5.7.1                        0  100 i
*> 102.10.10.0      102.5.7.1         0              0  100 i
*> 102.10.11.0      102.5.7.1         0              0  100 i
*> 102.10.12.0      102.5.7.1         0              0  100 i
```


Aggregation Policies – Aggregate Address

- Summary-only used
  - all subprefixes suppressed
  - unsuppress-map to selectively leak subprefixes
  - bgp per neighbour configuration
- Absence of summary-only
  - no subprefixes suppressed
  - suppress-map to selectively suppress subprefixes
  - bgp global configuration

Cisco Systems

BGP Attributes and Policy Control

ISP/IXP Workshops