



# BGP Attributes and Policy Control

ISP/IXP Workshops

## Agenda

- BGP Attributes
- BGP Path Selection
- Applying Policy



## BGP Attributes

The "tools" available for the job

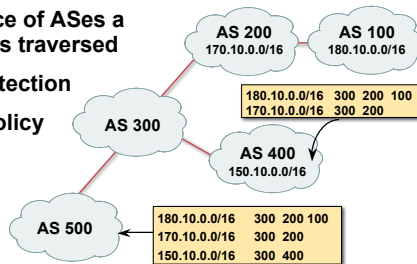
## What Is an Attribute?



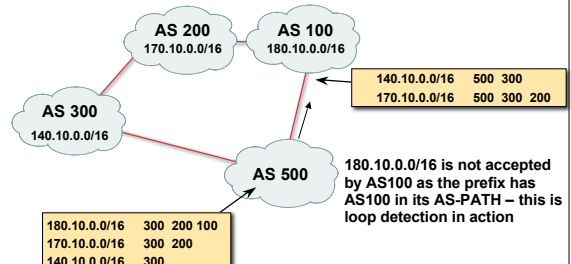
- Describes the characteristics of prefix
- Transitive or non-transitive
- Some are mandatory

## AS-Path

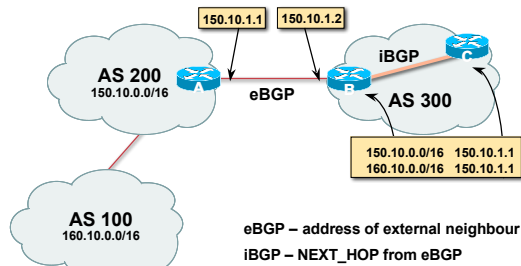
- Sequence of ASes a route has traversed
- Loop detection
- Apply policy



## AS-Path loop detection

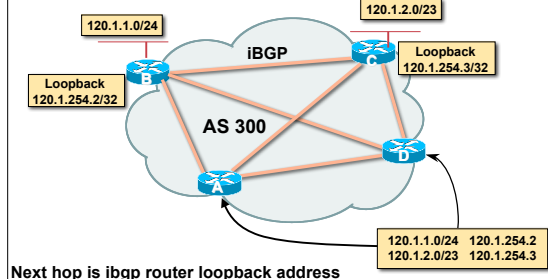


## Next Hop



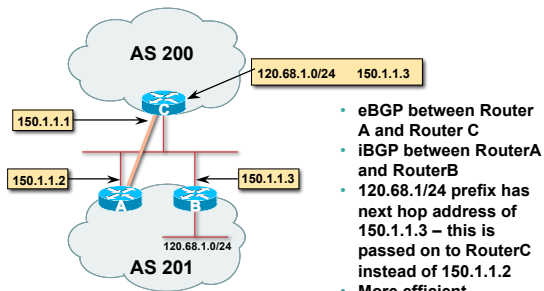
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## iBGP Next Hop



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## Third Party Next Hop



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## 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

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## 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

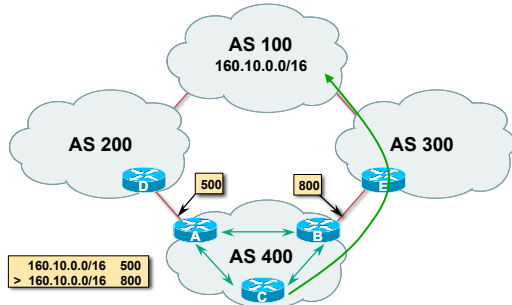
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## Aggregator

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

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## Local Preference



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## 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

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## Local Preference

- Configuration of Router B:

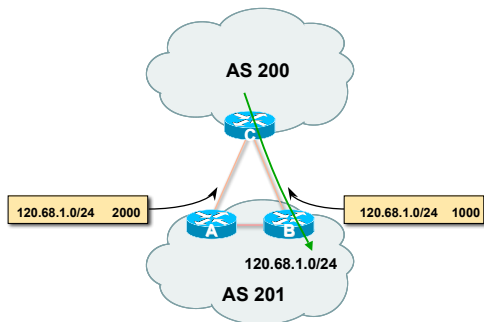
```
router bgp 400
 neighbor 120.5.1.1 remote-as 300
 neighbor 120.5.1.1 route-map local-pref in
 !
 route-map local-pref permit 10
 match ip address prefix-list MATCH
 set local-preference 800
 !
 ip prefix-list MATCH permit 160.10.0.0/16
```

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## Multi-Exit Discriminator (MED)



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## 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** (draft-ietf-idr-bgp4-26.txt)

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## 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>**

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## 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
```

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## 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
 

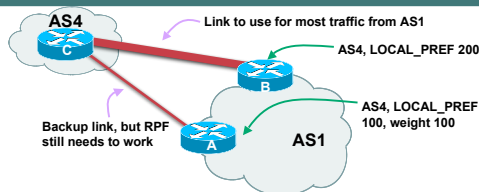
```
neighbor 120.5.7.3 filter-list 3 weight 50
```

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## 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

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## Community

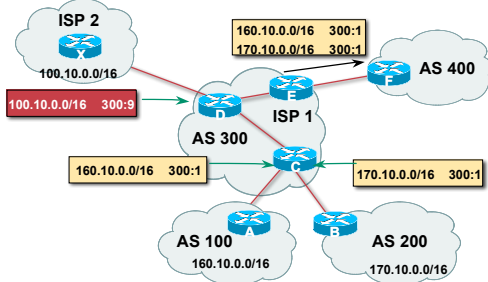
- Communities are described in RFC1997
  - Transitive & Optional attribute
- 32 bit integer
  - Represented as two 16 bit integers (RFC1997/8)
  - Common format is <local-ASN>:xx
  - 0:0 to 0:65535 and 65535:0 to 65535:65535 are reserved
- Used to group destinations
  - Each destination could be member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

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## Community



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## Well-Known Communities

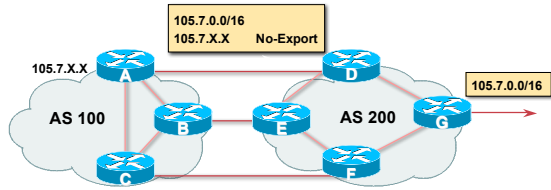
- Several well known communities
  - [www.iana.org/assignments/bgp-well-known-communities](http://www.iana.org/assignments/bgp-well-known-communities)
- no-export **65535:65281**
  - do not advertise to any eBGP peers
- no-advertise **65535:65282**
  - do not advertise to any BGP peer
- no-export-subconfed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

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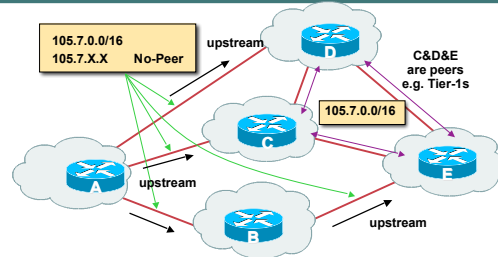
## No-Export Community



- 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

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## No-Peer Community



- Sub-prefixes marked with **no-peer** community are not sent to bi-lateral peers

They are only sent to upstream providers

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## 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
*> 100.1.16.0/20	100.1.31.224	0	100	0	i
*> 100.1.32.0/19	100.1.63.224	0	100	0	i
...					

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## BGP Path Selection Algorithm

Why is this the best path?

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## 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

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## 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)

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## 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

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## 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

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## Applying Policy with BGP

How to use the "tools"

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## 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

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## 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!**

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## 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>
```

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## 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.

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## 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

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## 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
```

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## 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$
```

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## 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

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## Policy Control – Regular Expressions

- Simple Examples
  - match anything
  - match at least one character
  - match routes local to this AS
  - originated by AS1800
  - received from AS1800
  - via AS1800
  - via AS1800 and AS790
  - multiple AS1800 in sequence (used to match AS-PATH prepends)
  - via AS65530 (confederations)

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## Policy Control – Regular Expressions

- Not so simple Examples

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

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## 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

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## 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

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## 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
```

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## 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
```

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## 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_
```

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## 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

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## Policy Control – Route Maps

- Route Map MATCH Articles

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

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## Policy Control – Route Maps

- Route map SET Articles

as-path	dampening
automatic-tag	default interface
clns	interface
comm-list	ip default next-hop
community	ip next-hop

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## Policy Control – Route Maps

- Route map SET Articles

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

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## 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
```

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## 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
```

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## 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.

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## 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
!
```

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## 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          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
```

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## 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          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
```

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## 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
!
```

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## 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          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
```

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## 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         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
```

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## 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

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## BGP Attributes and Policy Control

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