



# BGP Attributes and Policy Control

ISP/IXP Workshops

# Agenda

- BGP Attributes
- BGP Path Selection
- Applying Policy



# BGP Attributes

The “tools” available for the job

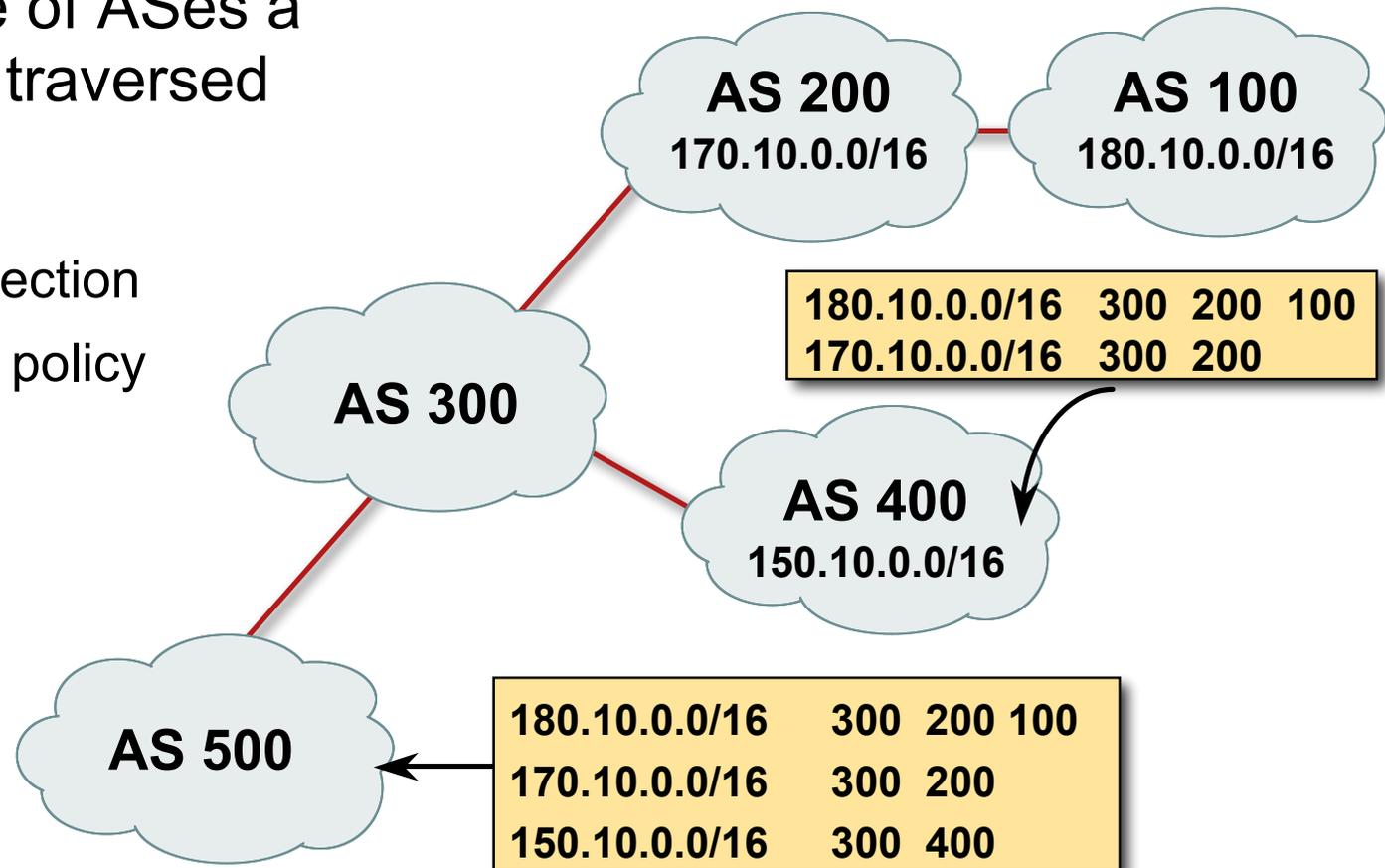
# What Is an Attribute?



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

# AS-Path

- Sequence of ASes a route has traversed
- Used for:
  - Loop detection
  - Applying policy

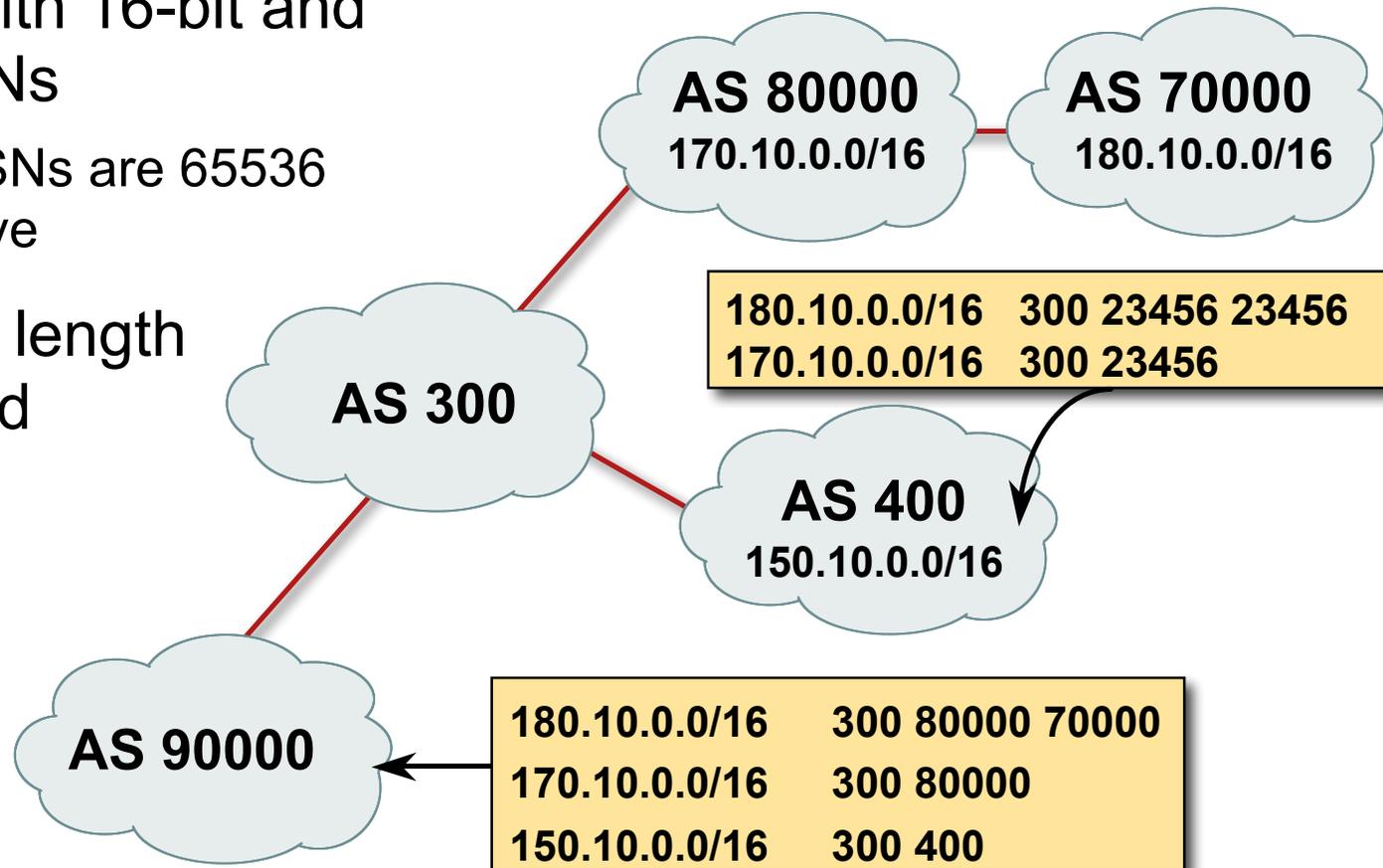


# AS-Path (with 16 and 32-bit ASNs)

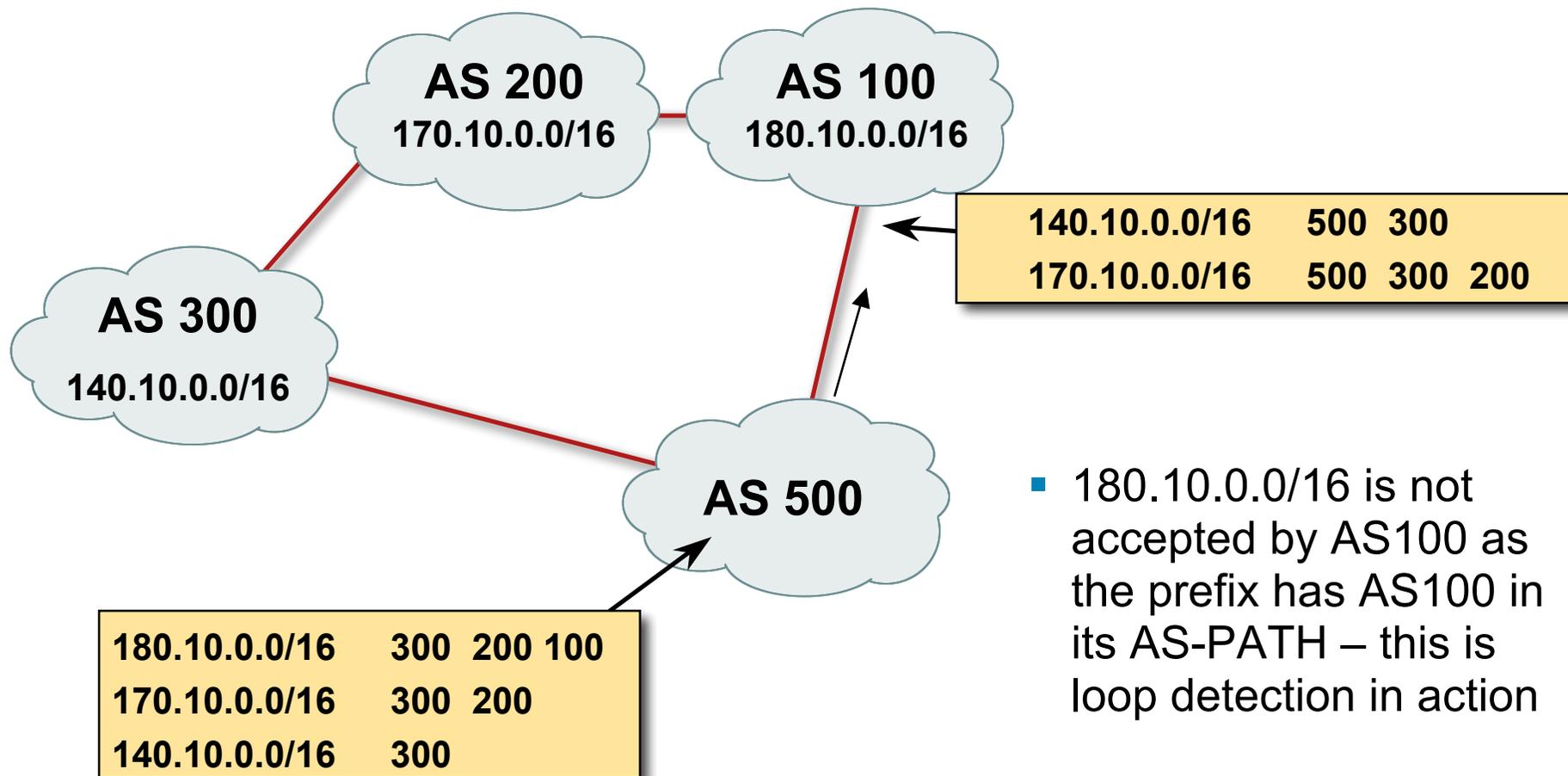
- Internet with 16-bit and 32-bit ASNs

32-bit ASNs are 65536 and above

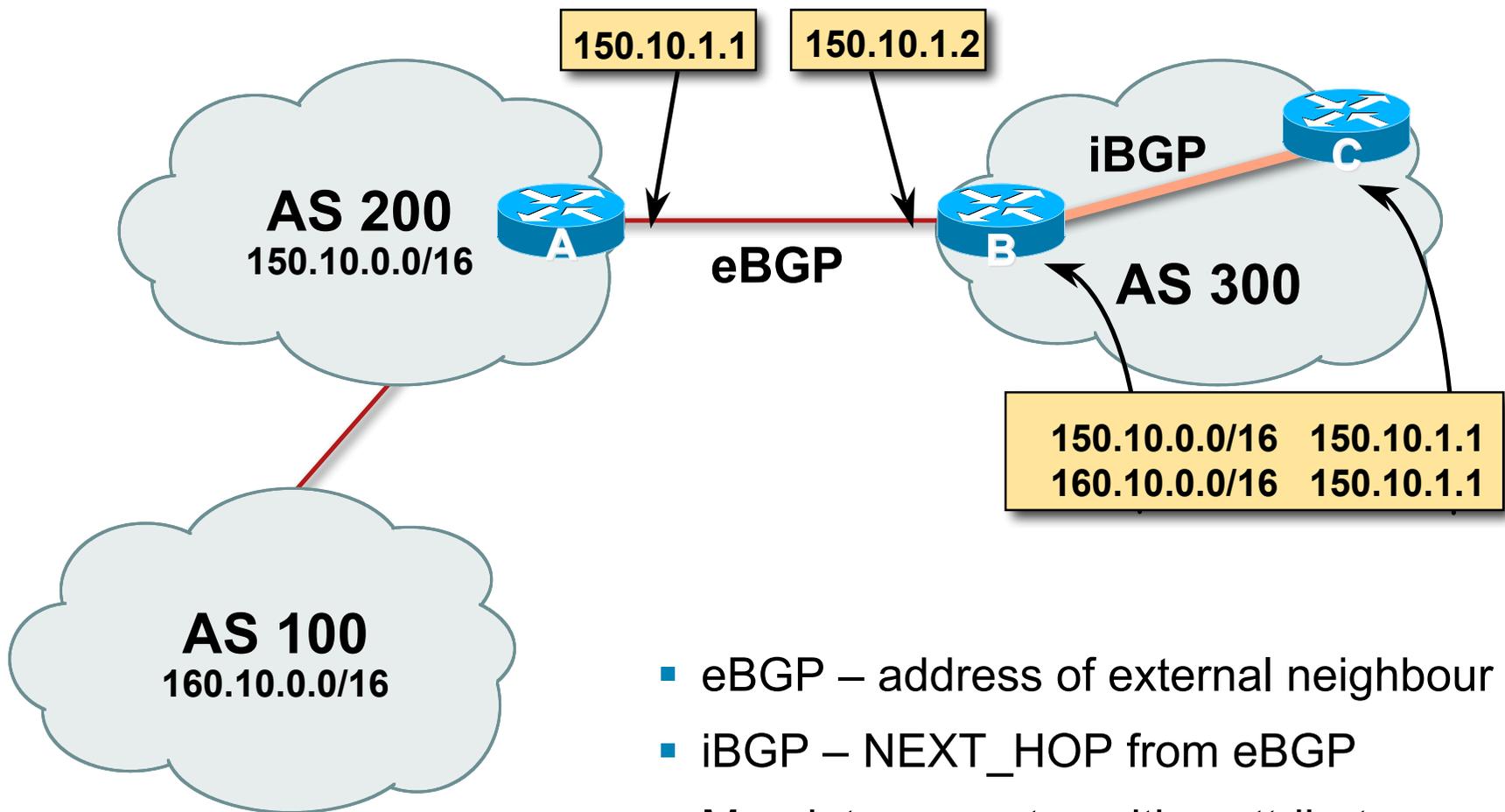
- AS-PATH length maintained



# AS-Path loop detection

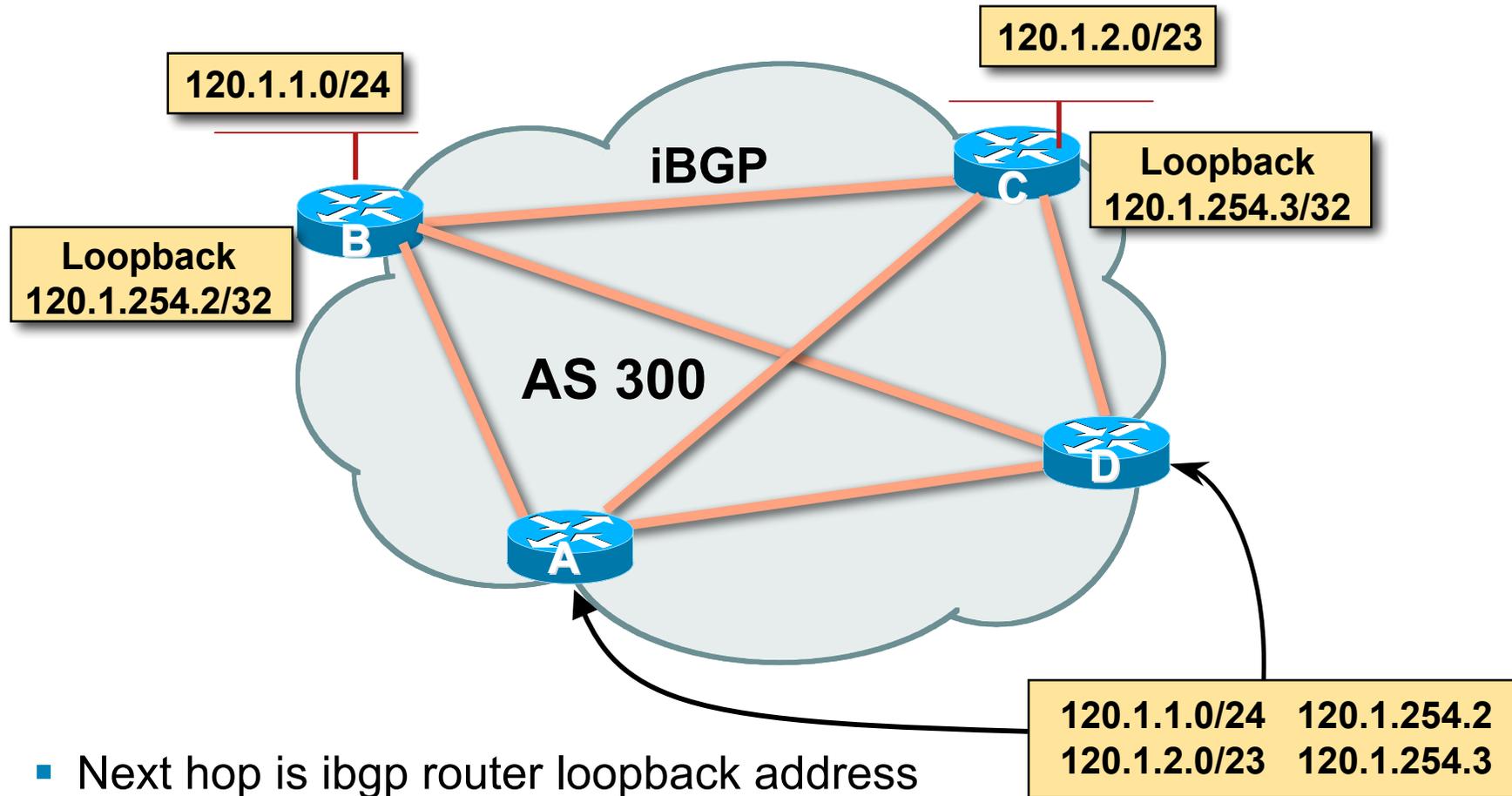


# Next Hop



- eBGP – address of external neighbour
- iBGP – NEXT\_HOP from eBGP
- Mandatory non-transitive attribute

# iBGP Next Hop





# Next Hop Best Practice

- IOS default is for external next-hop to be propagated unchanged to iBGP peers

This means that IGP has to carry external next-hops

Forgetting means external network is invisible

With many eBGP peers, it is unnecessary extra load on IGP

- ISP Best Practice is to change external next-hop to be that of the local router

```
neighbor x.x.x.x next-hop-self
```

## Next Hop (Summary)

- IGP should carry route to next hops
- Recursive route look-up
- Unlinks BGP from actual physical topology
- Use “next-hop-self” for external next hops
- Allows IGP to make intelligent forwarding decision

# Origin

- Conveys the origin of the prefix
- **Historical** attribute
  - Used in transition from EGP to BGP
- Transitive and Mandatory 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

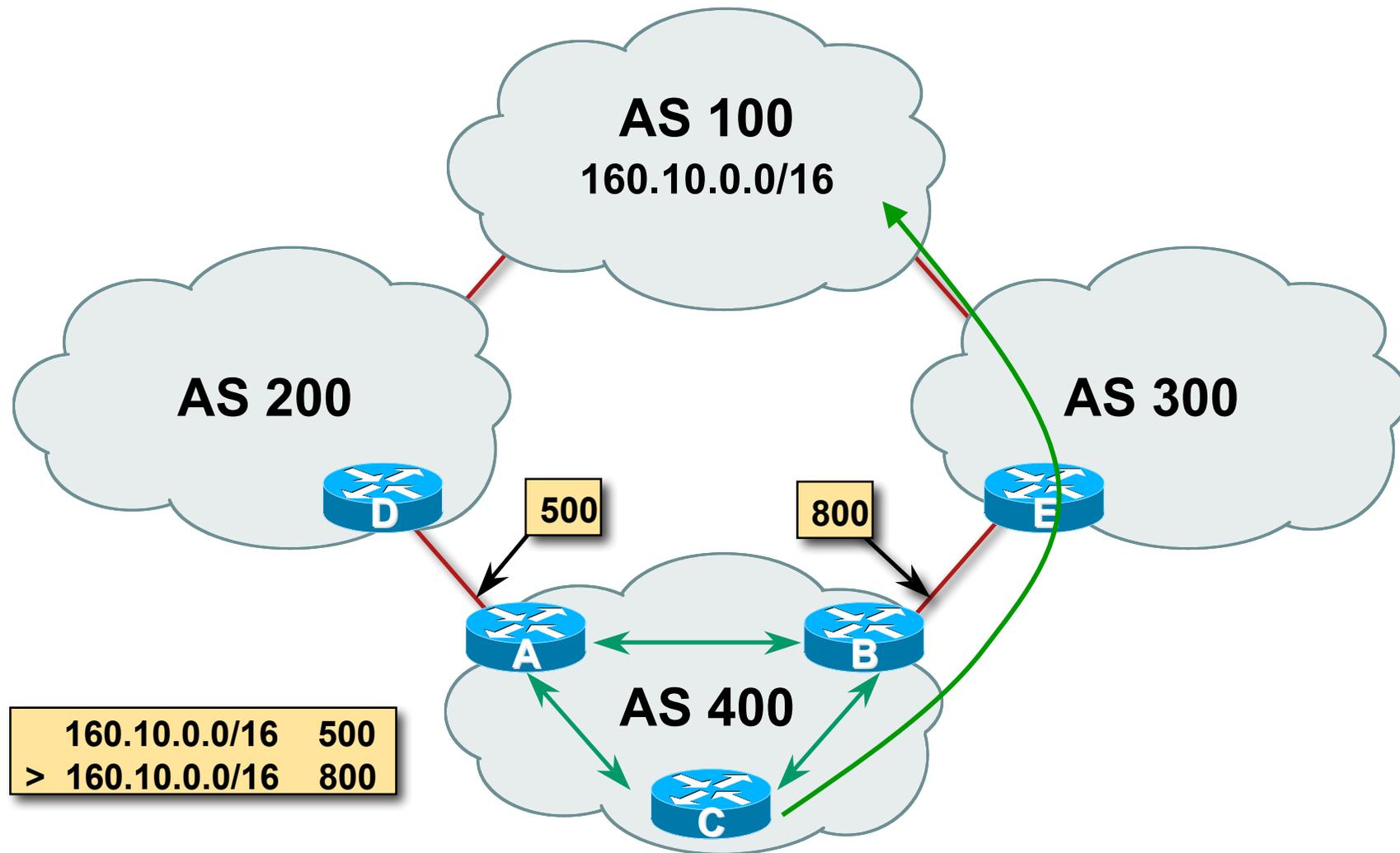
# Aggregator

- Conveys the IP address of the router or BGP speaker generating the aggregate route
- Optional & transitive attribute
- Useful for debugging purposes
- Does not influence best path selection
- Creating aggregate using “aggregate-address” sets the aggregator attribute:

```
router bgp 100
```

```
aggregate-address 100.1.0.0 255.255.0.0
```

# Local Preference



# Local Preference

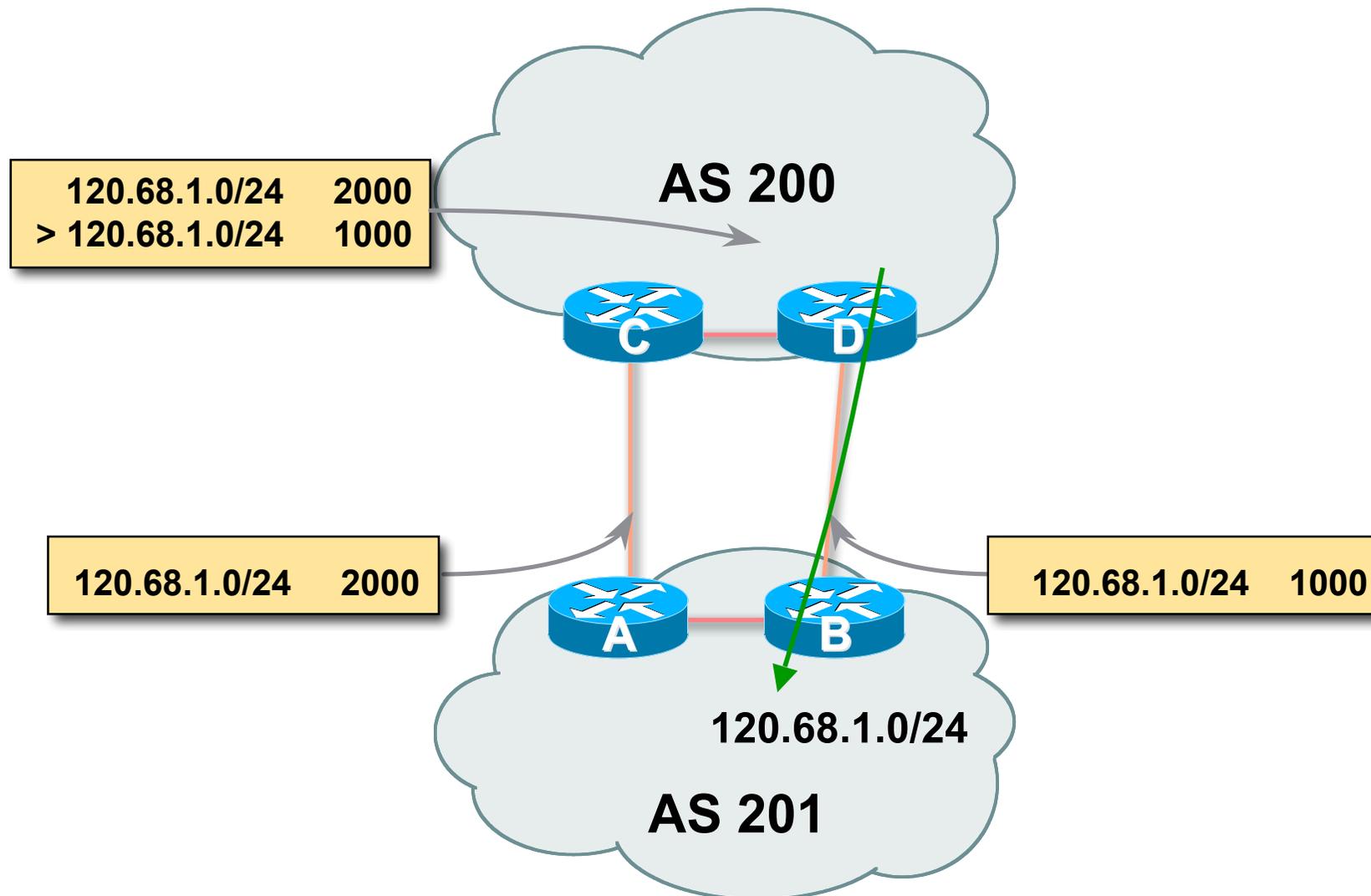
- Non-transitive and optional attribute
- Local to an AS only
  - Default local preference is 100 (IOS)
- Used to influence BGP path selection
  - determines best path for *outbound* traffic
- Path with highest local preference wins

# 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-compare-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

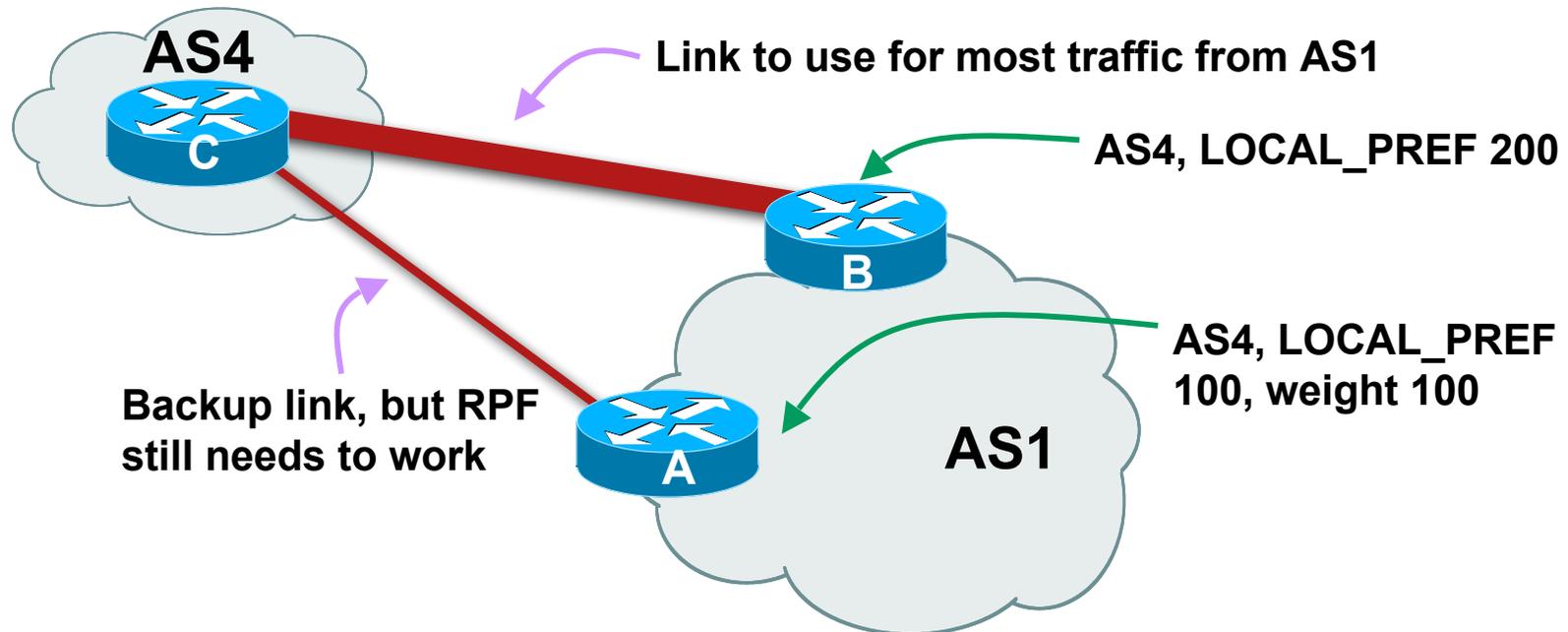
- Not really an attribute – local to router
- Highest weight wins
- Applied to all routes from a neighbour

```
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



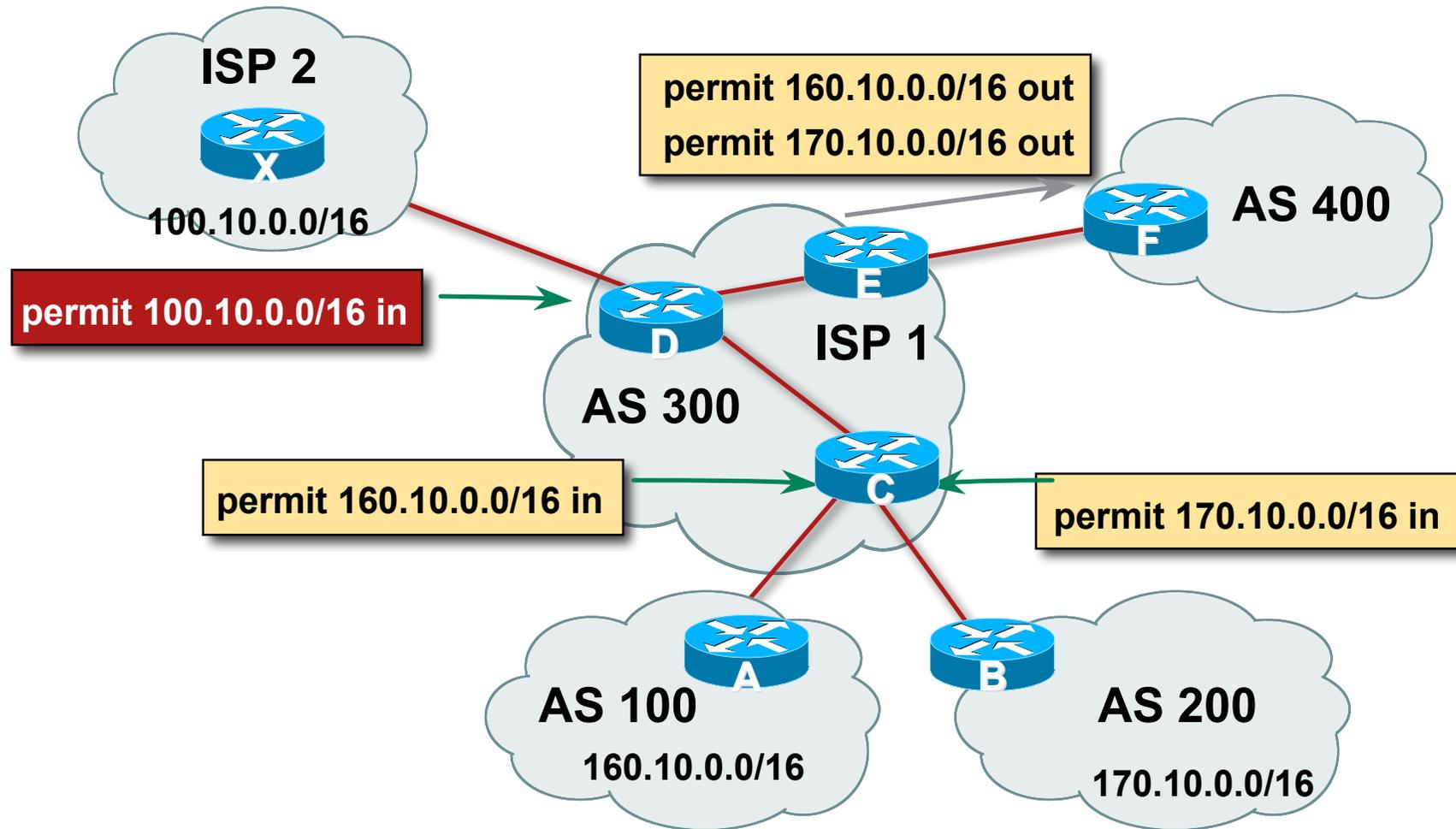
- Best path to AS4 from AS1 is always via B due to local-pref
- But packets arriving at A from AS4 over the direct C to A link will pass the RPF check as that path has a priority due to the weight being set

If weight was not set, best path back to AS4 would be via B, and the RPF check would fail

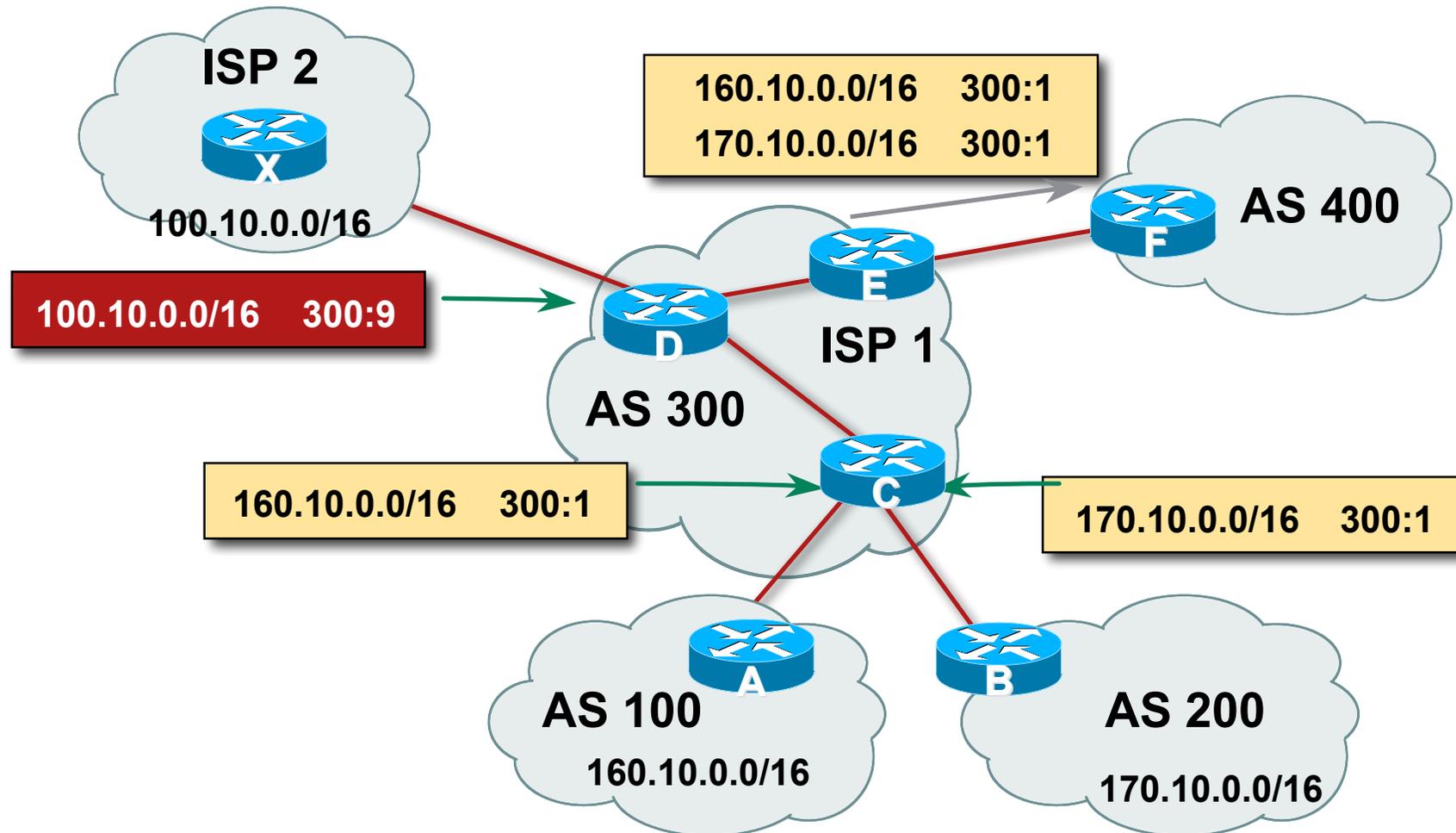
# Community

- Communities are described in RFC1997  
Transitive and Optional Attribute
- 32 bit integer  
Represented as two 16 bit integers (RFC1998)  
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 in applying policies within and between ASes

# Community Example (before)



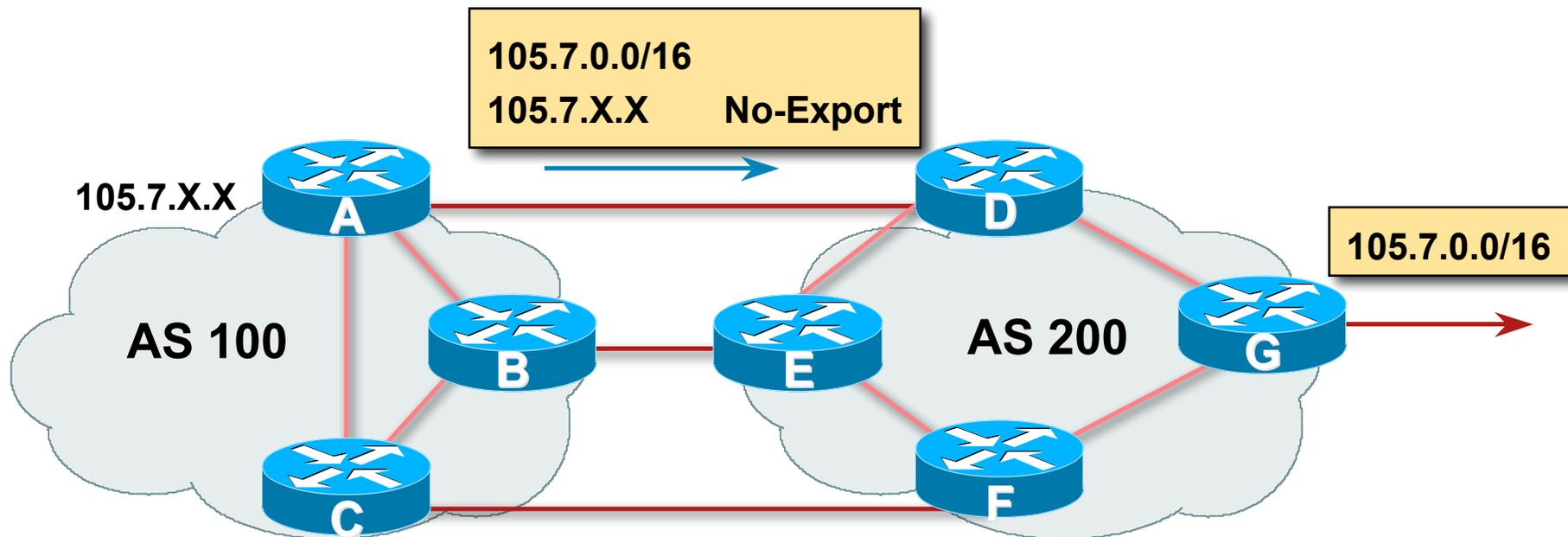
# Community Example (after)



# Well-Known Communities

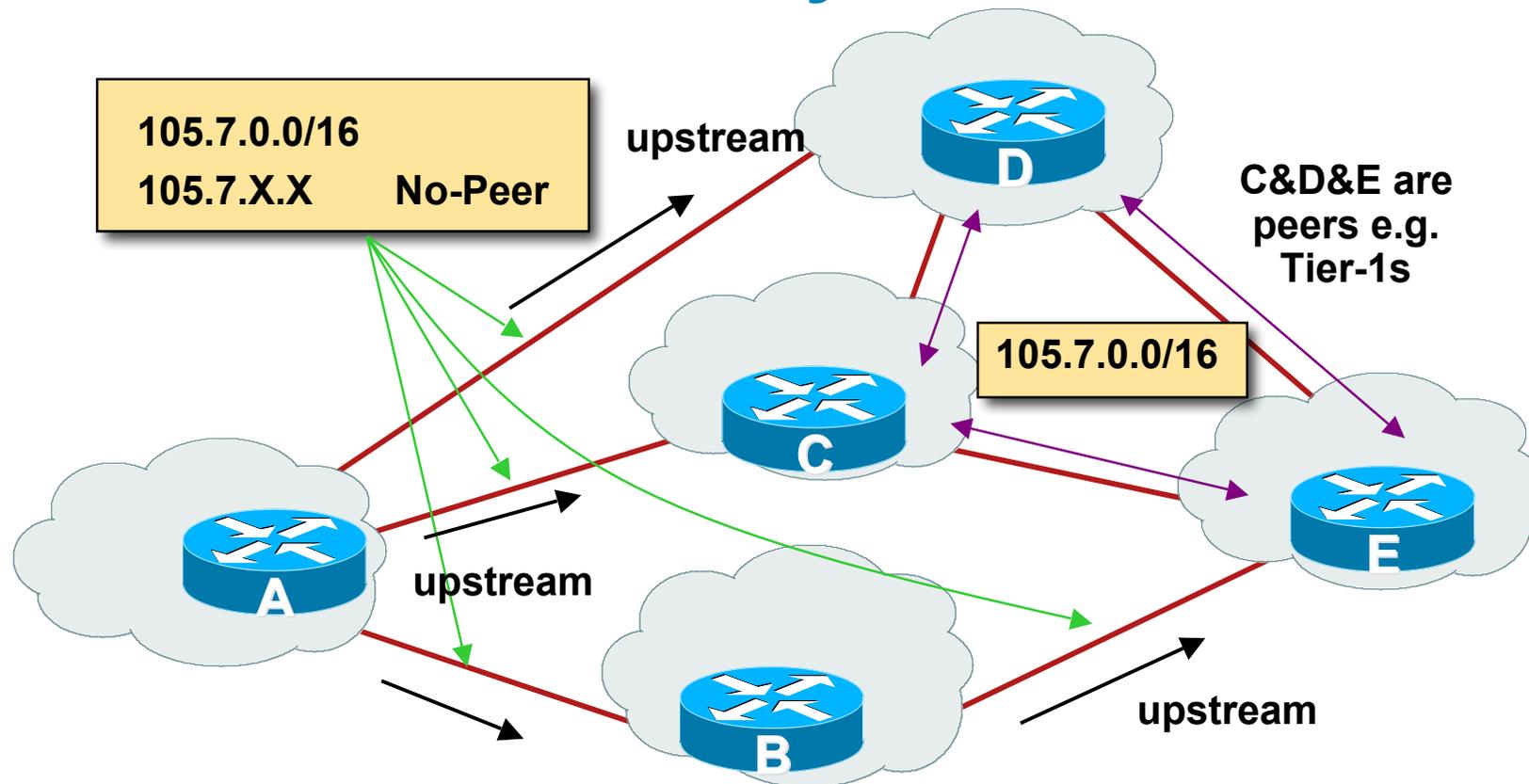
- Several well known communities  
[www.iana.org/assignments/bgp-well-known-communities](http://www.iana.org/assignments/bgp-well-known-communities)
- no-export **65535:65281**  
do not advertise to any eBGP peers
- no-advertise **65535:65282**  
do not advertise to any BGP peer
- no-export-subconfed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

# No-Export Community



- AS100 announces aggregate and subprefixes  
Intention 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

```
Router6>sh ip bgp
```

```
BGP table version is 30, local router ID is 10.0.15.246
```

```
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
*>i10.0.0.0/26	10.0.15.241	0	100	0	i
*>i10.0.0.64/26	10.0.15.242	0	100	0	i
*>i10.0.0.128/26	10.0.15.243	0	100	0	i
*>i10.0.0.192/26	10.0.15.244	0	100	0	i
*>i10.0.1.0/26	10.0.15.245	0	100	0	i
*> 10.0.1.64/26	0.0.0.0	0		32768	i
...					



# BGP Path Selection Algorithm

Why is this the best path?

# BGP Path Selection Algorithm for IOS

## Part One

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

# BGP Path Selection Algorithm for IOS

## Part Two

- 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 for IOS

## Part Three

- 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 for IOS

## Part Four

- 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

- 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*

- Sequence number is also optional

```
no ip prefix-list sequence-number to disable display of  
sequence numbers
```

# 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 AS110-IN in
  neighbor 102.10.1.1 prefix-list AS110-OUT out
!
ip prefix-list AS110-IN deny 218.10.0.0/16
ip prefix-list AS110-IN permit 0.0.0.0/0 le 32
ip prefix-list AS110-OUT permit 105.7.0.0/16
ip prefix-list AS110-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
\	Escape a regular expression character
_	Beginning, end, white-space, brace
	Or
()	brackets to contain expression
[]	brackets to contain number ranges

# 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

<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

# 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-map “continue” lets ISPs apply multiple conditions and actions in one route-map

# Route Maps – Caveats

- Lines can have multiple set statements
- Lines can have multiple match statements
- Line with only a match statement
  - Only prefixes matching go through, the rest are dropped
- 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 are set, 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
```

# Route Maps – Matching prefixes

- Example Configuration

```
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
```

# Route Maps – AS-PATH filtering

- Example Configuration

```
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_
```

# Route Maps – AS-PATH prepends

- 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

# Route Maps – 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
```

# Route Maps – Setting Communities

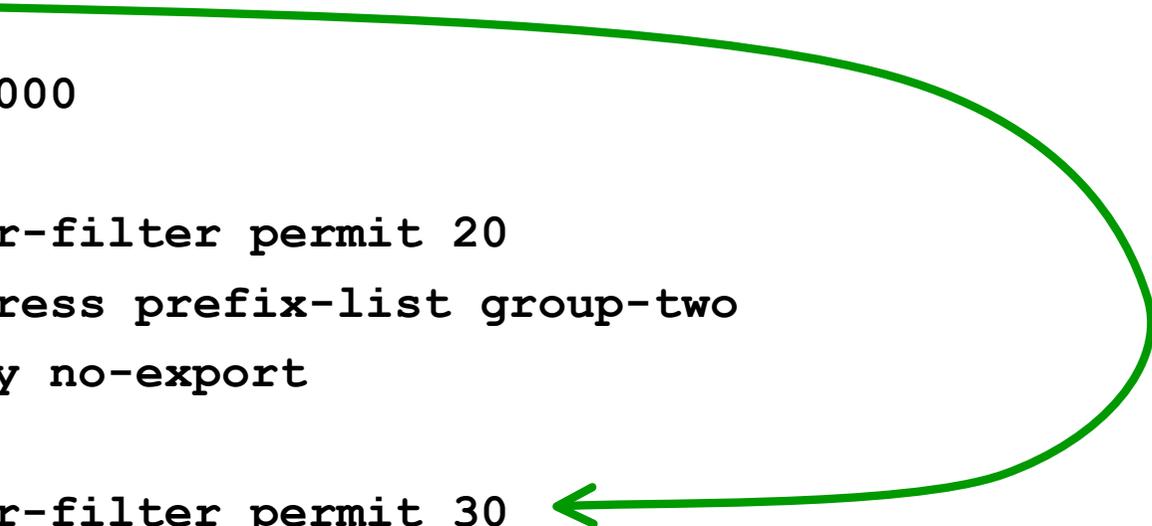
- Example Configuration

```
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
```

# Route Map Continue

- Handling multiple conditions and actions in one route-map (for BGP neighbour relationships only)

```
route-map peer-filter permit 10
  match ip address prefix-list group-one
  continue 30
  set metric 2000
!
route-map peer-filter permit 20
  match ip address prefix-list group-two
  set community no-export
!
route-map peer-filter permit 30
  match ip address prefix-list group-three
  set as-path prepend 100 100
!
```



# Managing Policy Changes

- New policies only apply to the updates going through the router **AFTER** the policy has been introduced or changed
- To facilitate policy changes on the entire BGP table the router handles the BGP peerings need to be “refreshed”
  - This is done by clearing the BGP session either in or out, for example:

```
clear ip bgp <neighbour-addr> in|out
```
- Do NOT forget **in** or **out** — doing so results in a hard reset of the BGP session

# Managing Policy Changes

- Ability to clear the BGP sessions of groups of neighbours configured according to several criteria

- **clear ip bgp <addr> [in|out]**

**<addr>** may be any of the following

**x.x.x.x**

IP address of a peer

**\***

all peers

**ASN**

all peers in an AS

**external**

all external peers

**peer-group <name>**

all peers in a peer-group



# BGP Attributes and Policy Control

ISP/IXP Workshops



# Supplementary Materials

# 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

# 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