BGP Attributes and Policy Control

AfNOG 2011 AR-E Workshop

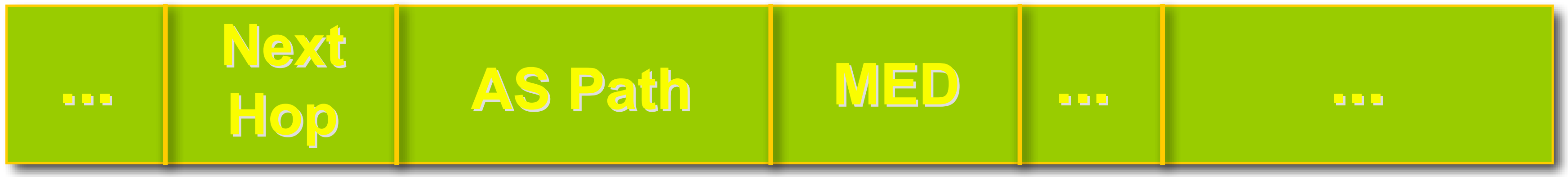
Agenda

- BGP Attributes
- BGP Path Selection
- Applying Policy

BGP Attributes

The “tools” available for the job

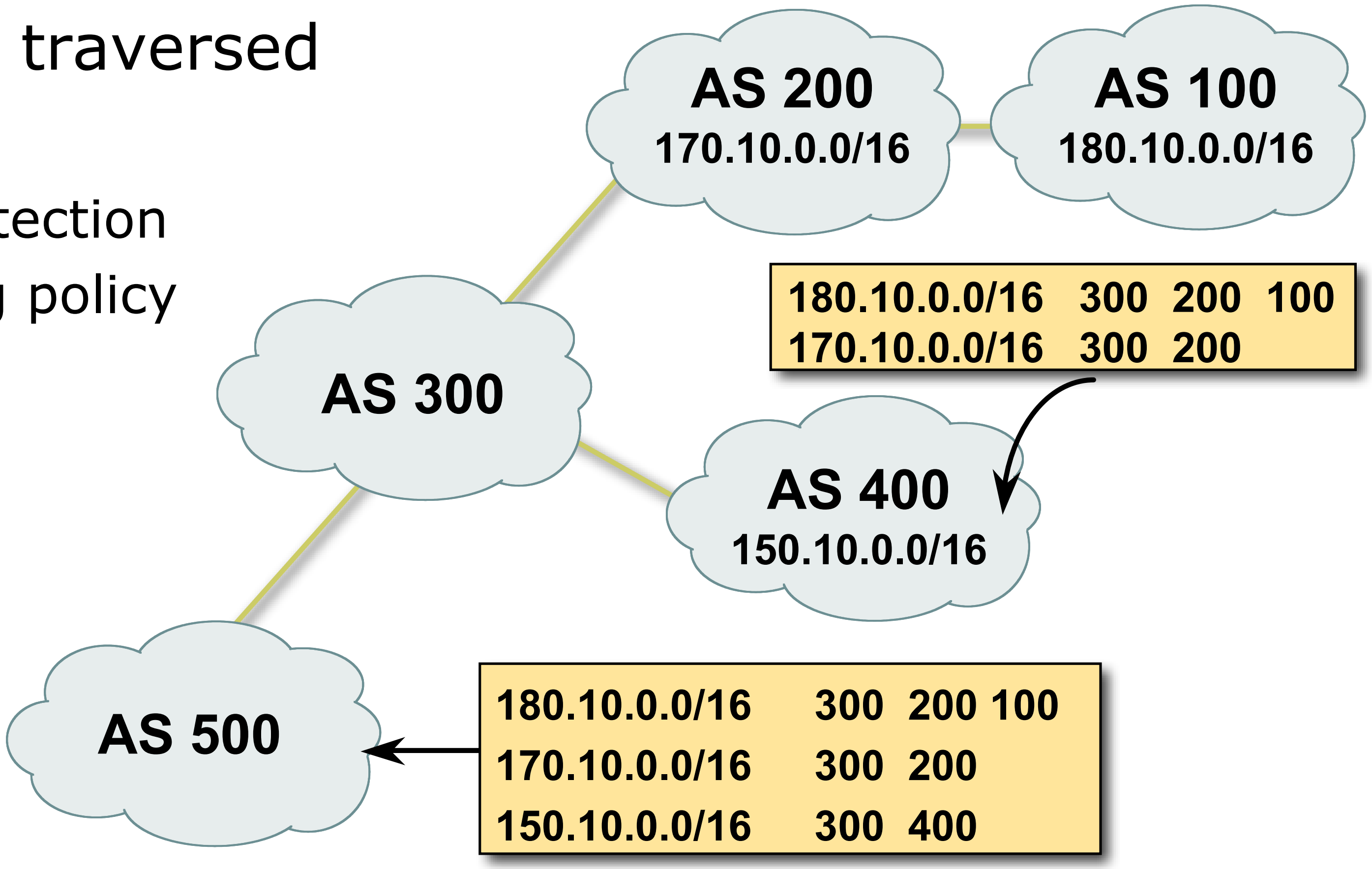
What Is an Attribute?



- 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

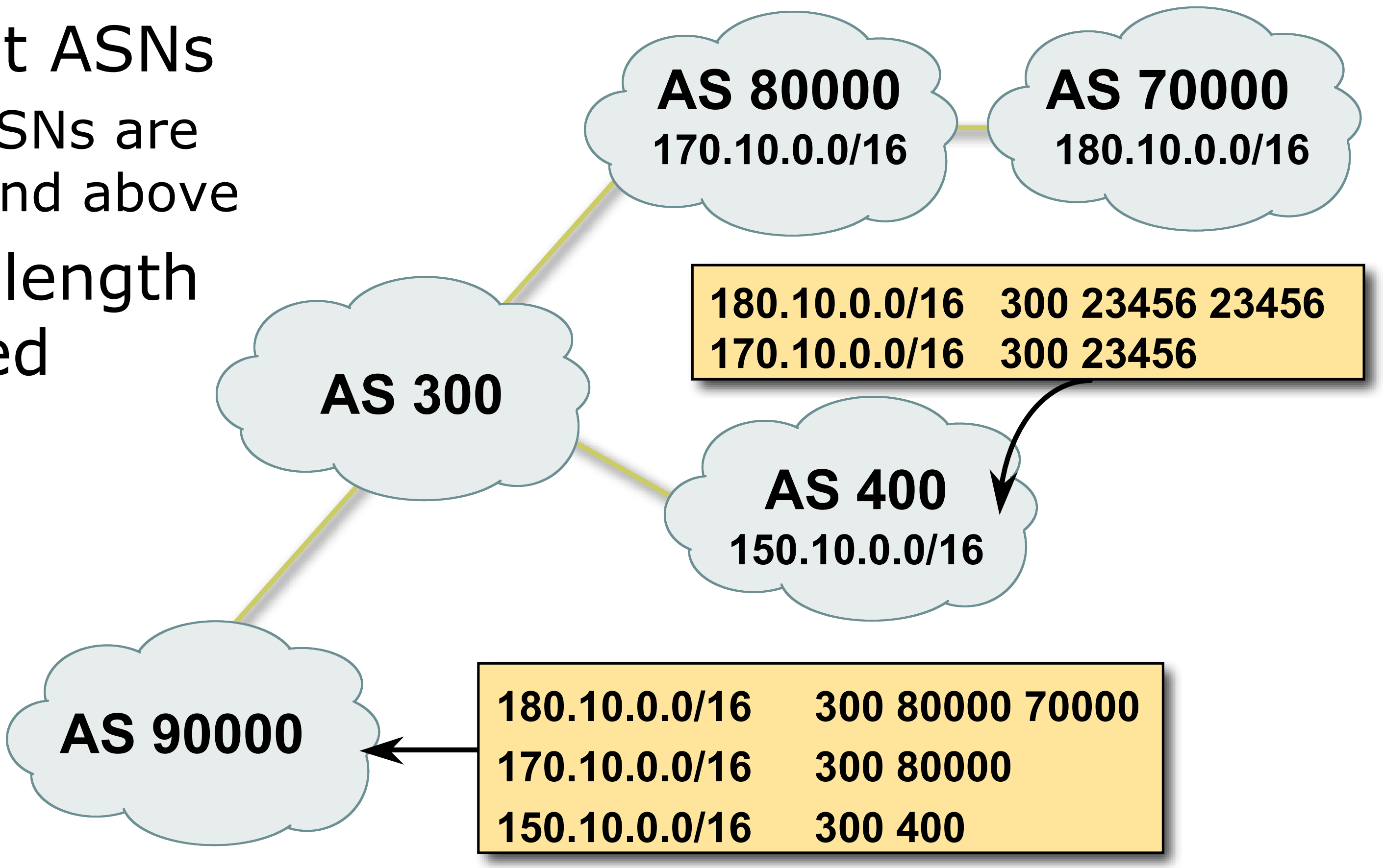


180.10.0.0/16	300 200 100
170.10.0.0/16	300 200

180.10.0.0/16	300 200 100
170.10.0.0/16	300 200
150.10.0.0/16	300 400

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

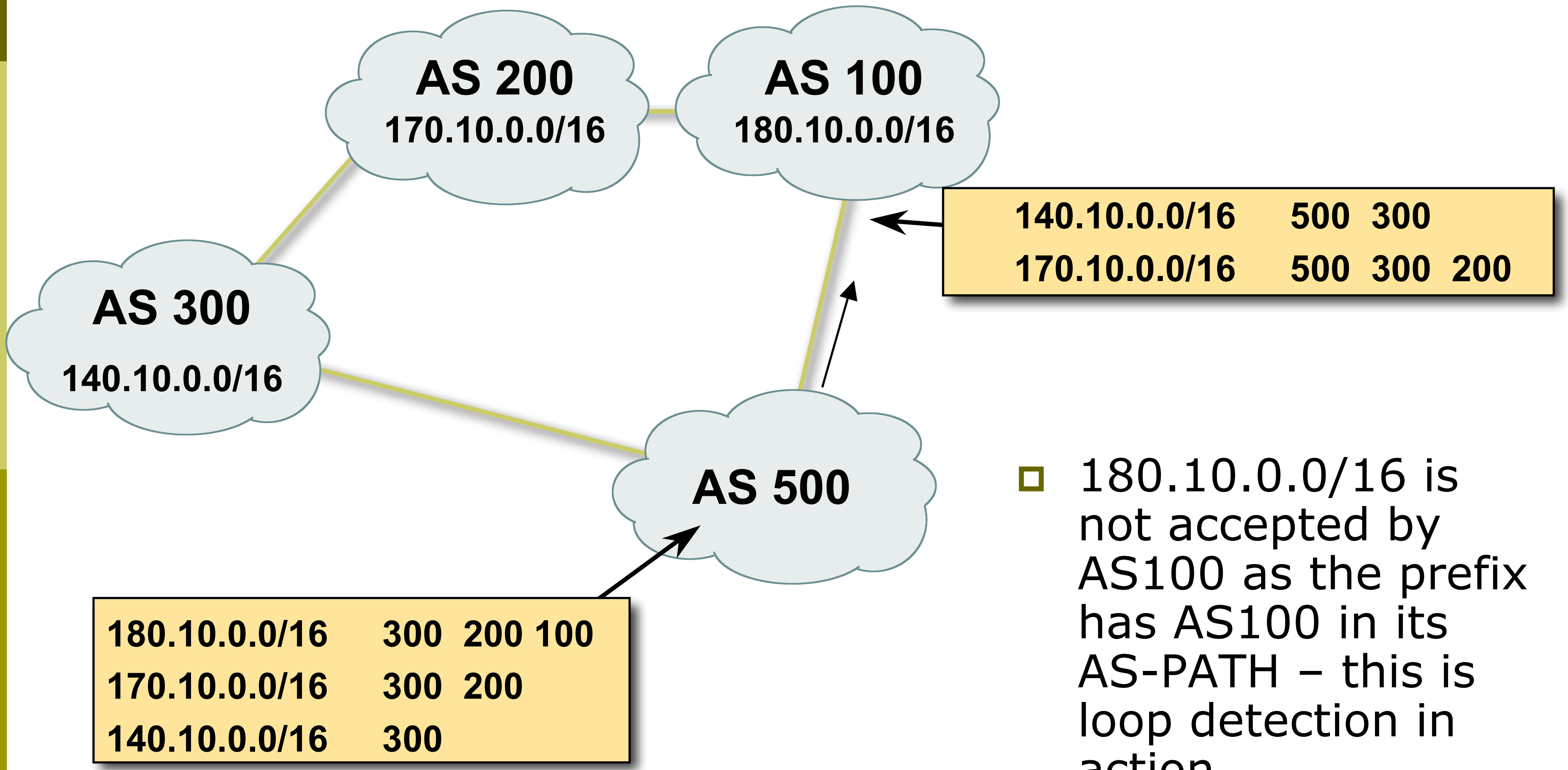
- Internet with 16-bit and 32-bit ASNs
  - 32-bit ASNs are 65536 and above
- AS-PATH length maintained



180.10.0.0/16	300 23456 23456
170.10.0.0/16	300 23456

180.10.0.0/16	300 80000 70000
170.10.0.0/16	300 80000
150.10.0.0/16	300 400

AS-Path loop detection

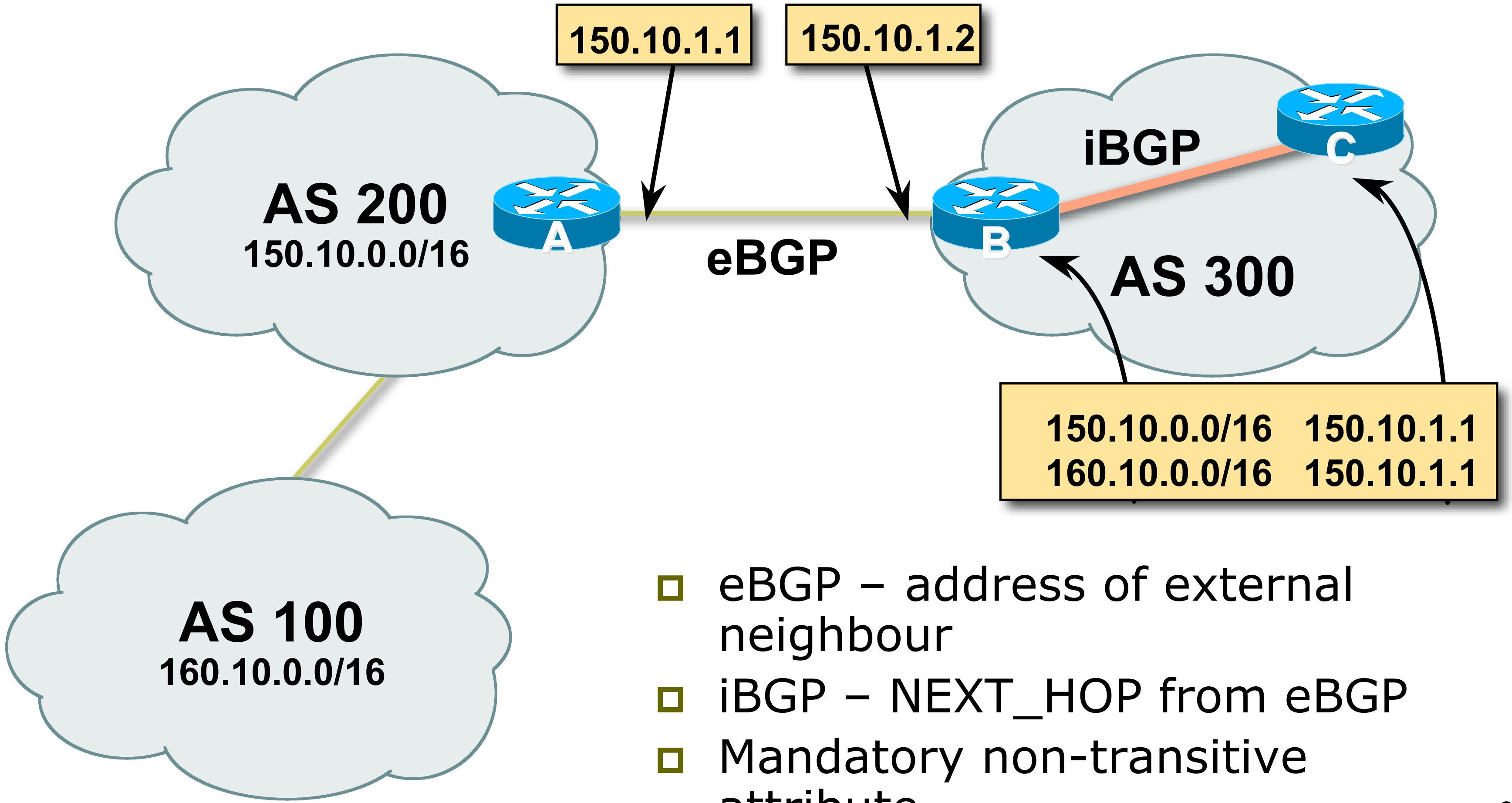


140.10.0.0/16	500 300
170.10.0.0/16	500 300 200

180.10.0.0/16	300 200 100
170.10.0.0/16	300 200
140.10.0.0/16	300

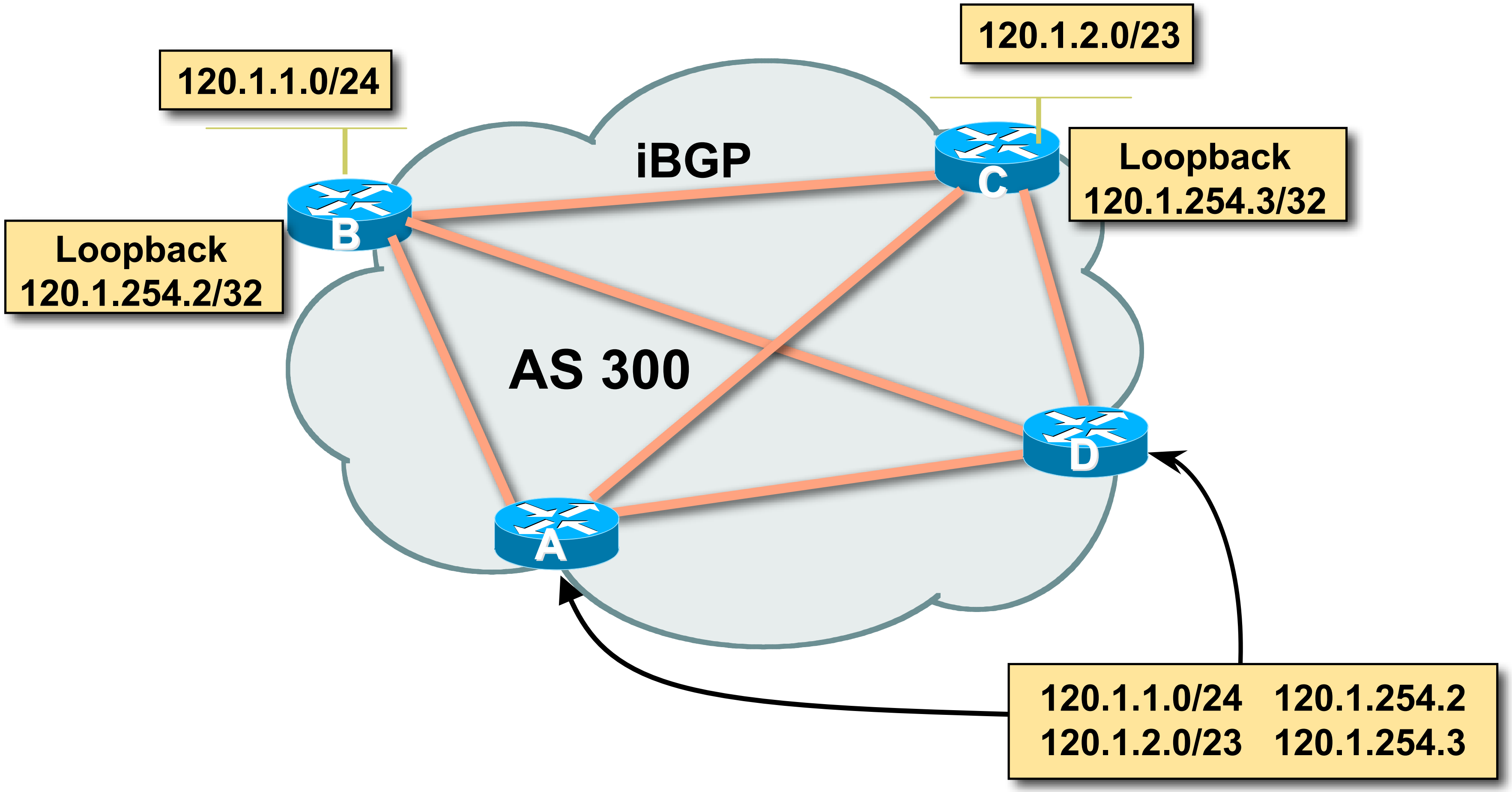
- 180.10.0.0/16 is not accepted by AS100 as the prefix has AS100 in its AS-PATH – this is loop detection in action

Next Hop



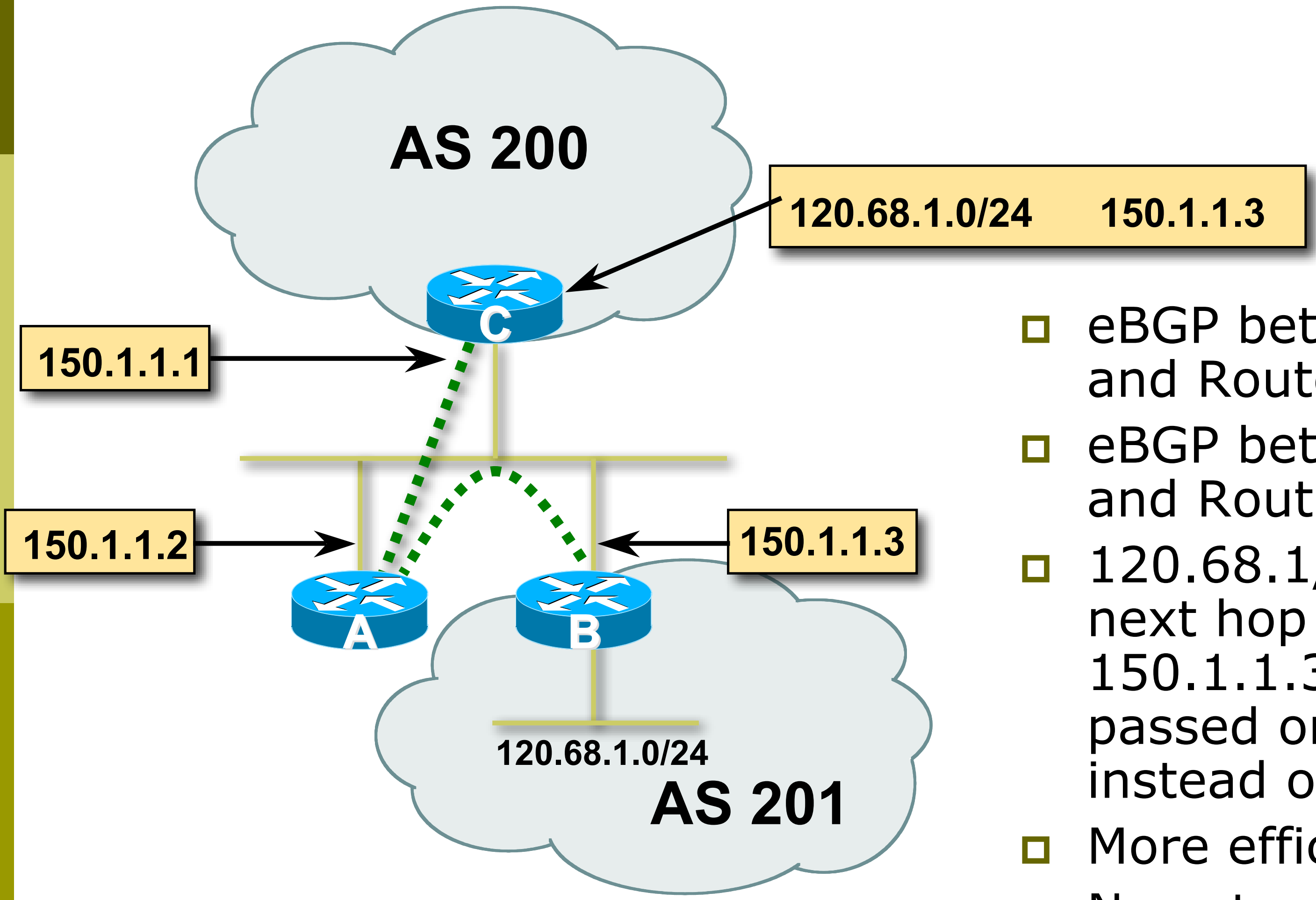
- eBGP – address of external neighbour
- iBGP – NEXT_HOP from eBGP
- Mandatory non-transitive attribute

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 Best Practice

- Cisco 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

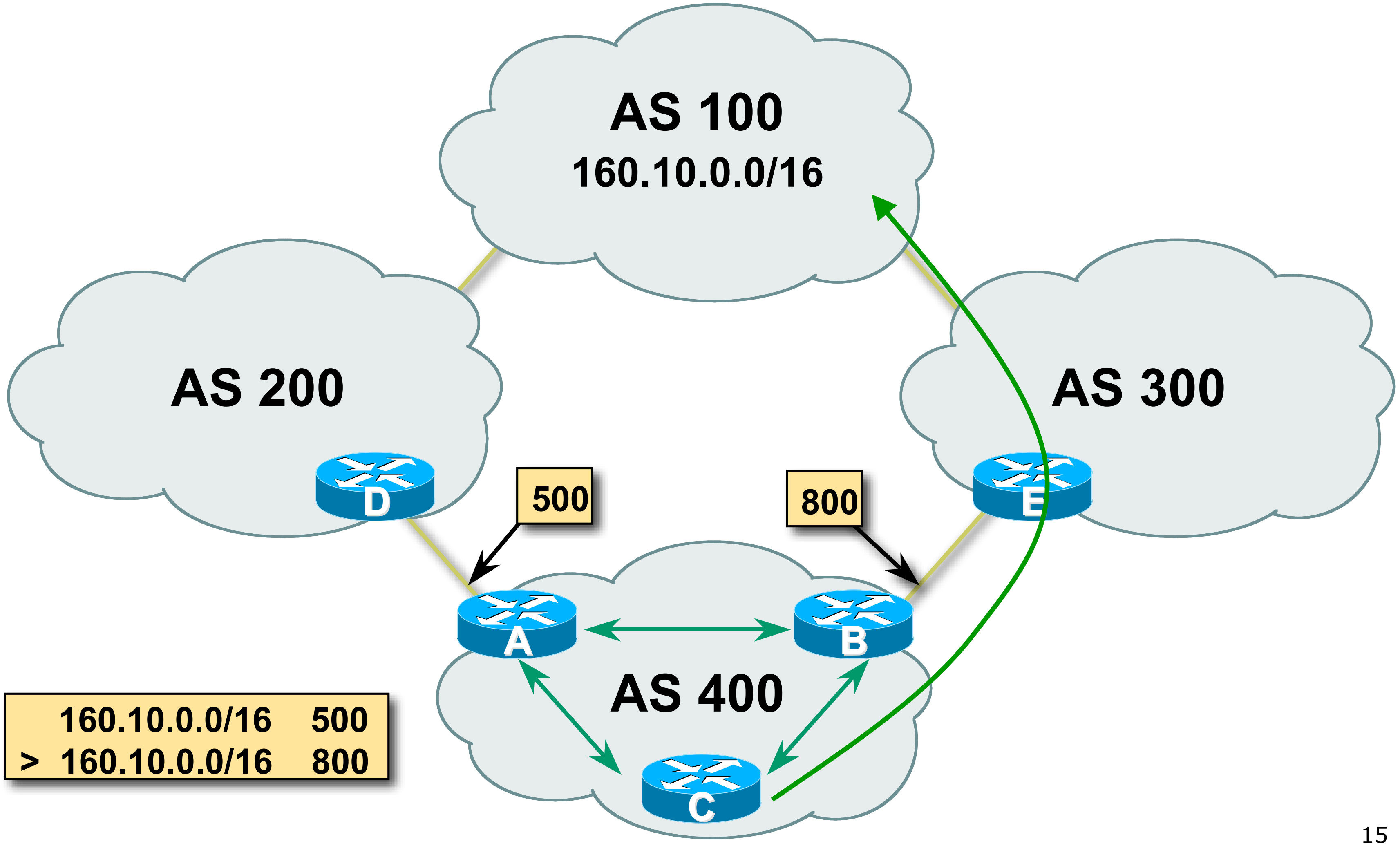
- Conveys the origin of the prefix
- Historical attribute
  - Used in transition from EGP to BGP
- Transitive and Mandatory Attribute
- Influences best path selection
- Three values: IGP, EGP, incomplete
  - IGP – generated by BGP network statement
  - EGP – generated by EGP
  - incomplete – redistributed 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



	160.10.0.0/16	500
>	160.10.0.0/16	800

Local Preference

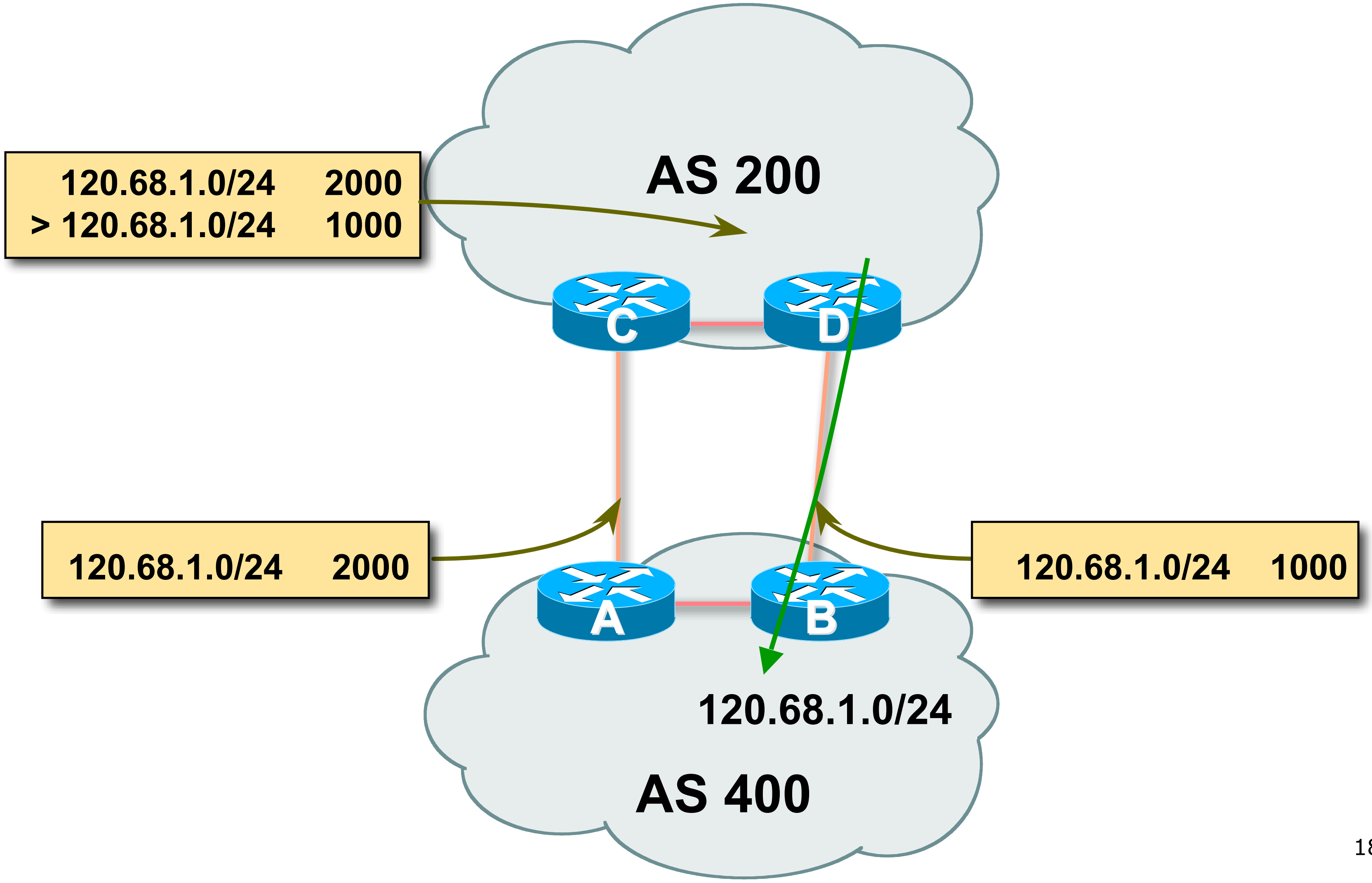
- Non-transitive and optional attribute
- Local to an AS only
  - Default local preference is 100 (IOS)
- Used to influence BGP path selection
  - determines best path for *outbound* traffic
- Path with highest local preference wins

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
route-map local-pref permit 20
!
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
route-map set-med permit 20
!
ip prefix-list MATCH permit 120.68.1.0/24
```

Weight

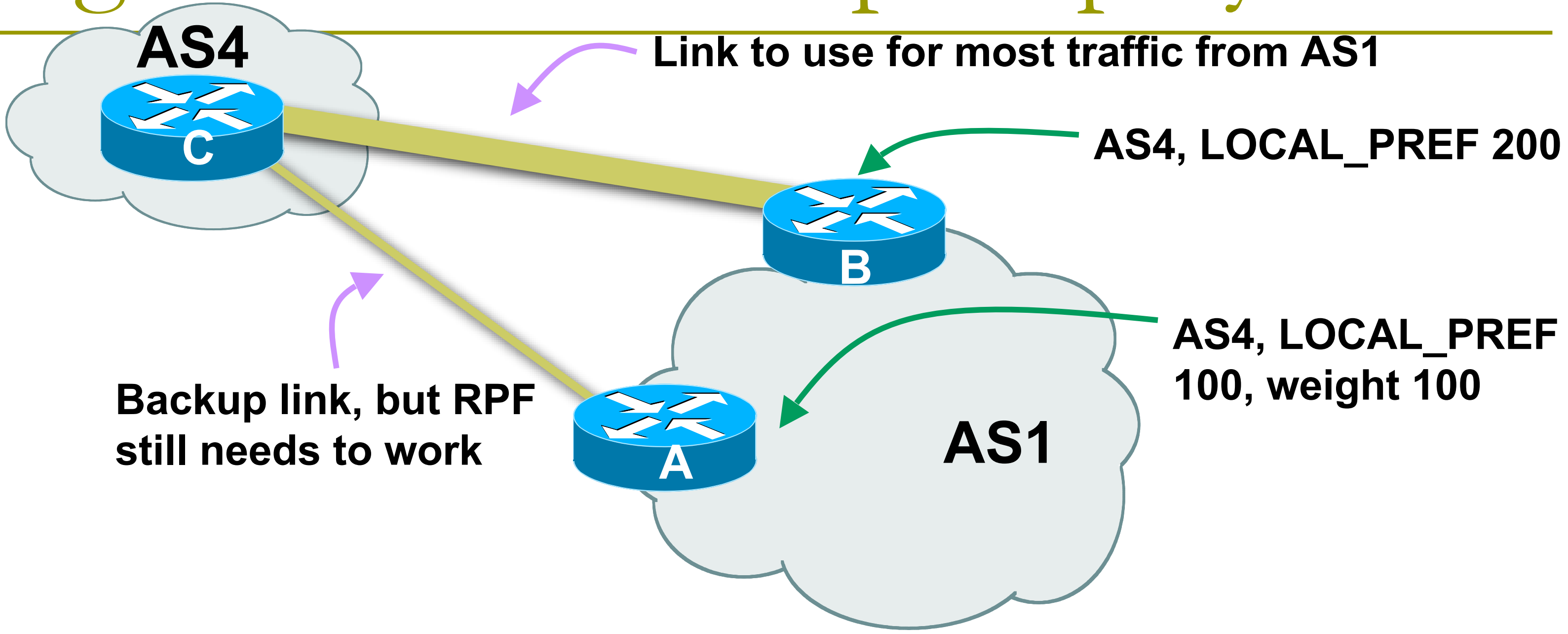
- Not really an attribute – local to router
- Highest weight wins
- Applied to all routes from a neighbour

```
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

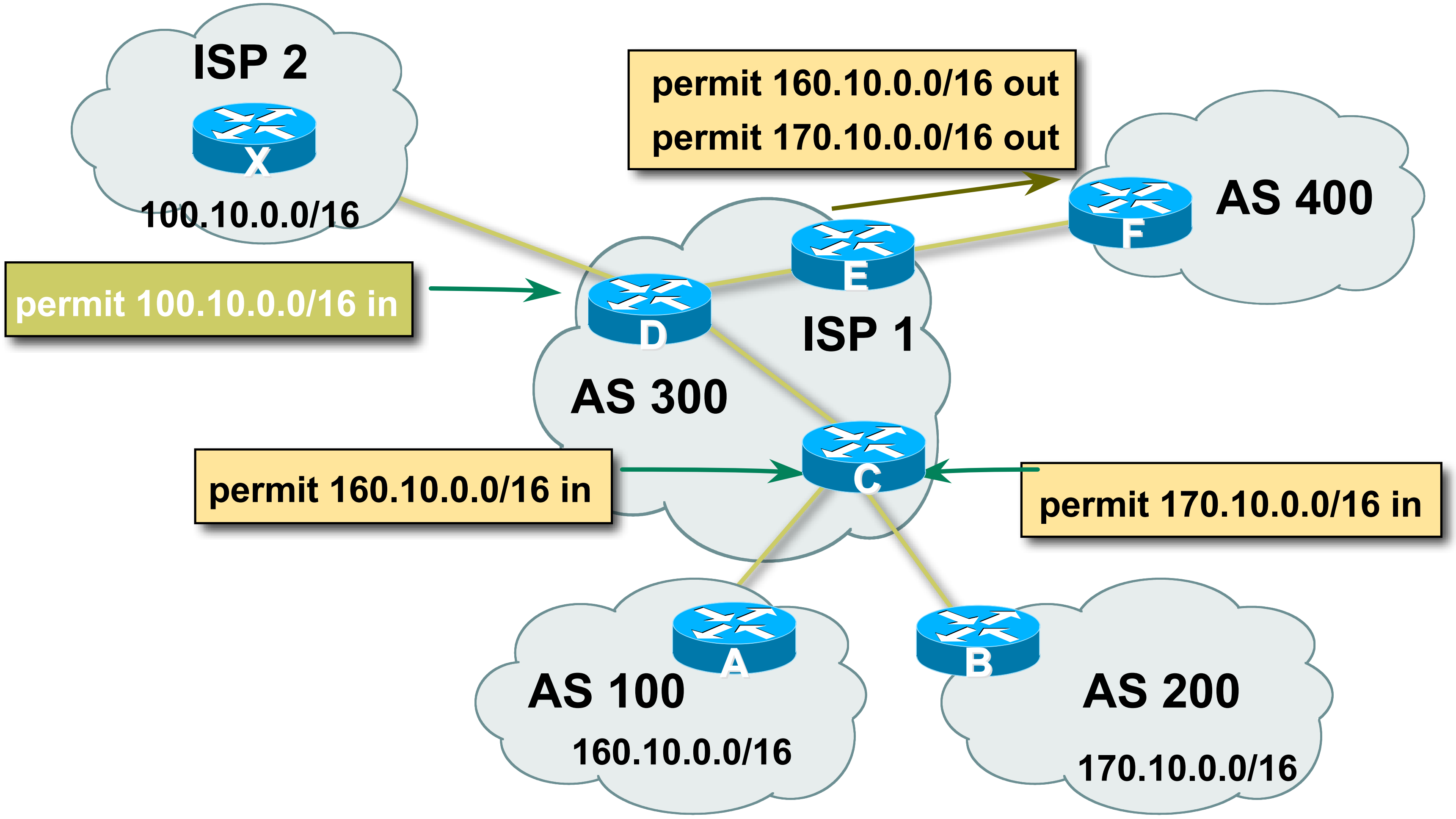

AS4
C
Link to use for most traffic from AS1
AS4, LOCAL_PREF 200
B
AS4, LOCAL_PREF 100, weight 100
Backup link, but RPF still needs to work
A
AS1

- 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

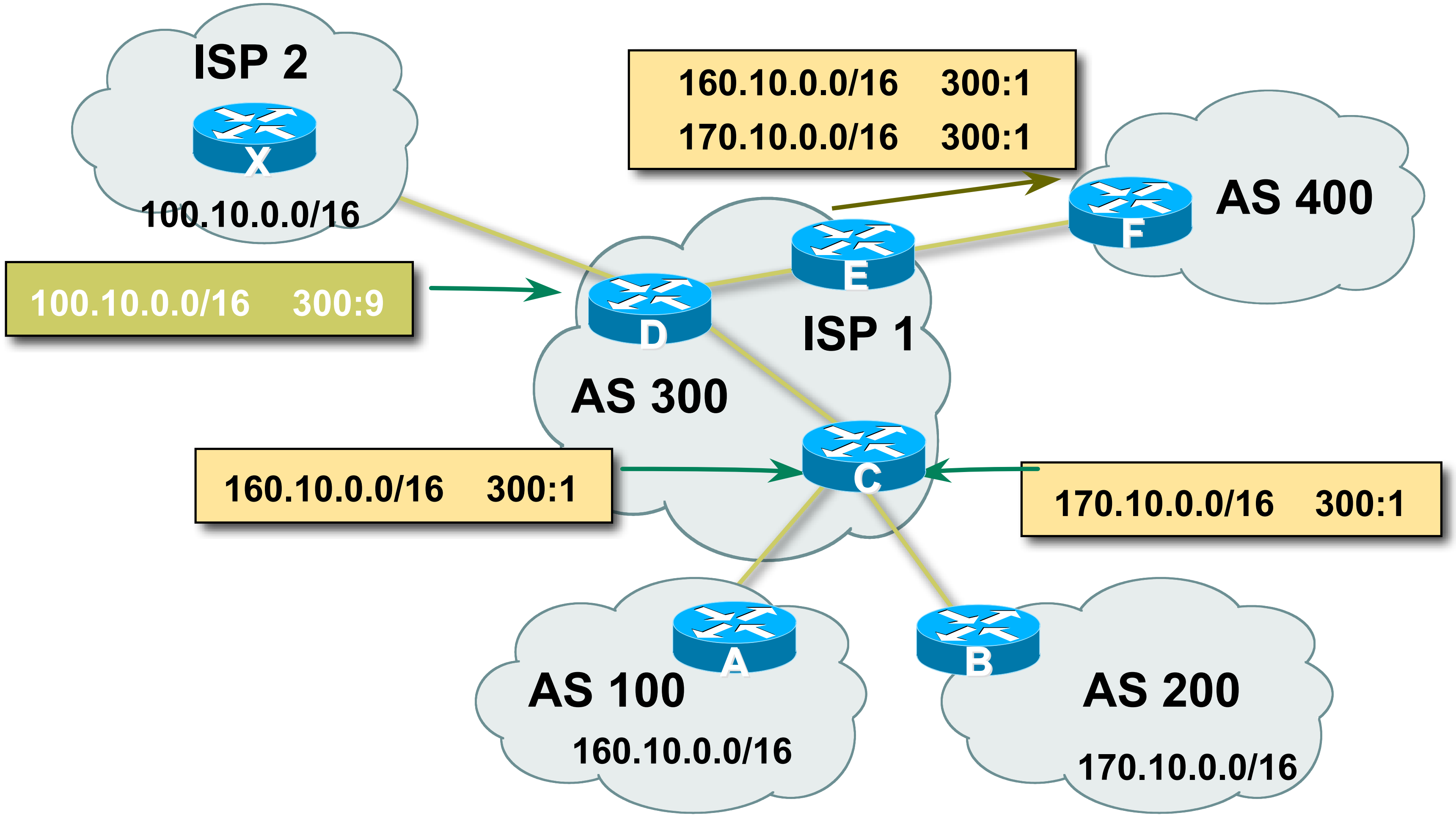
Community

- 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)



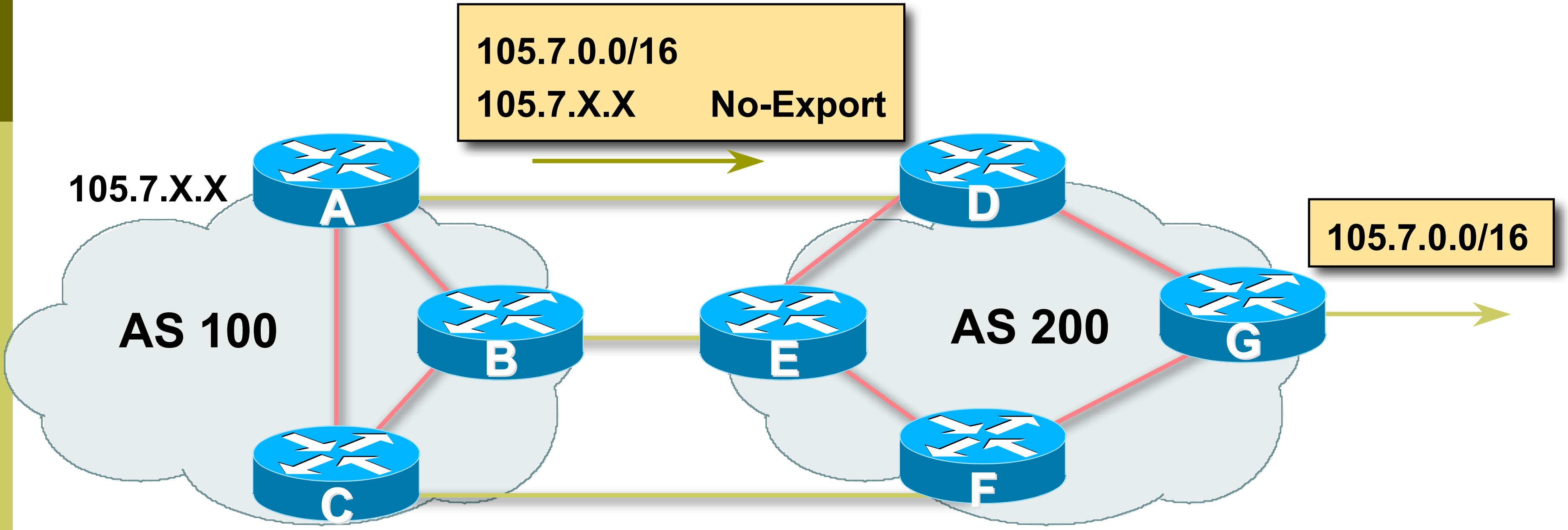
Community Example (after)



Well-Known Communities

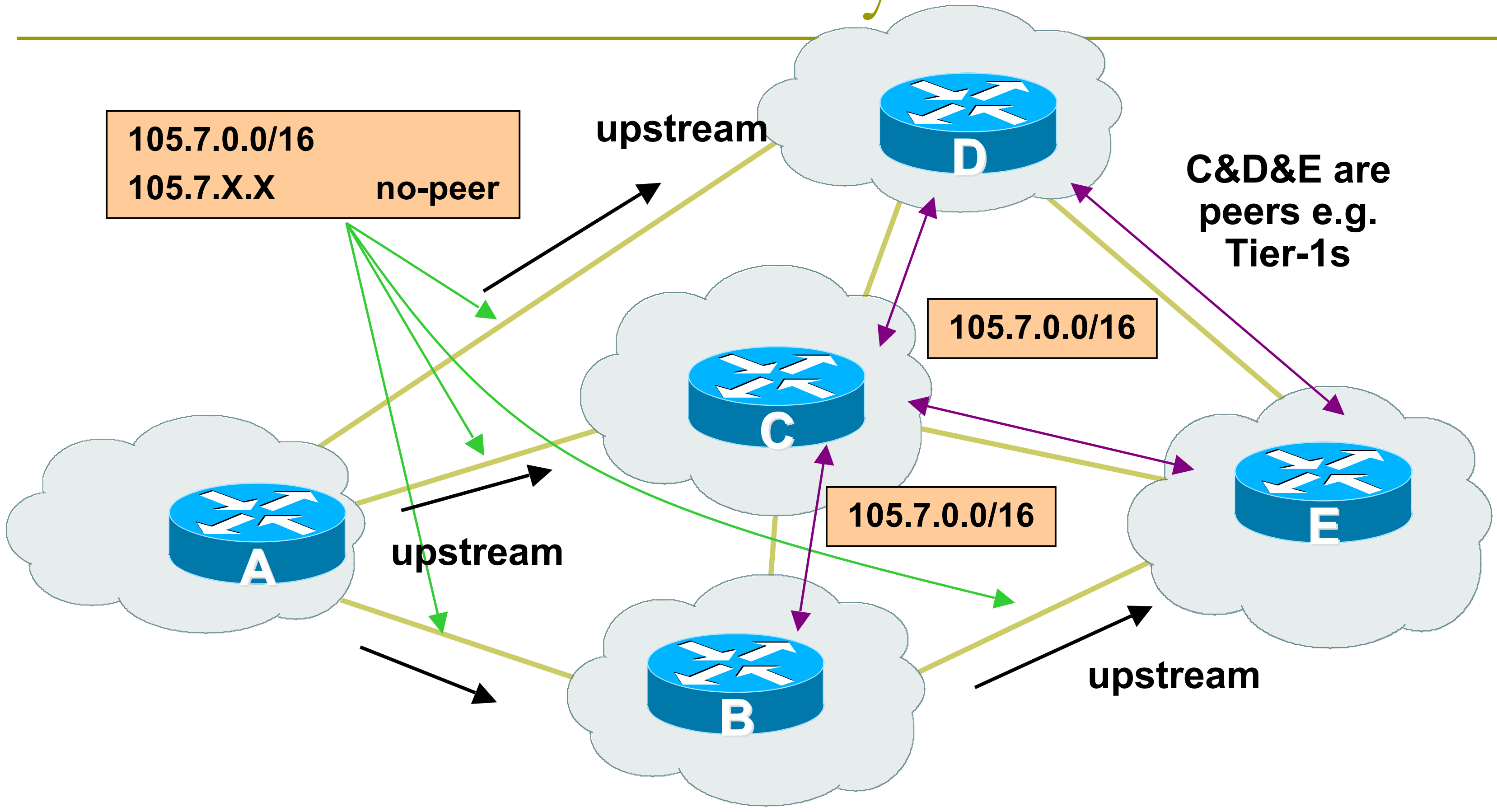
- Several well known communities
  - www.iana.org/assignments/bgp-well-known-communities
- no-export 65535:65281
  - do not advertise to any eBGP peers
- no-advertise 65535:65282
  - do not advertise to any BGP peer
- no-export-subconfed 65535:65283
  - do not advertise outside local AS (only used with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

What about 4-byte ASNs?

- Communities are widely used for encoding ISP routing policy
  - 32 bit attribute
- RFC1998 format is now "standard" practice
  - ***ASN:number***
- Fine for 2-byte ASNs, but 4-byte ASNs cannot be encoded
- Solutions:
  - Use "private ASN" for the first 16 bits
  - Wait for http://datatracker.ietf.org/doc/draft-ietf-idr-as4octet-extcomm-generic-subtype/ to be implemented

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 Cisco 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 Cisco 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 Cisco 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 Cisco 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

^[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-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

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