BGP Attributes and Policy Control

ISP/IXP Workshops

Agenda

- **BGP Attributes**
- **BGP Path Selection**
- **Applying Policy**

BGP Attributes

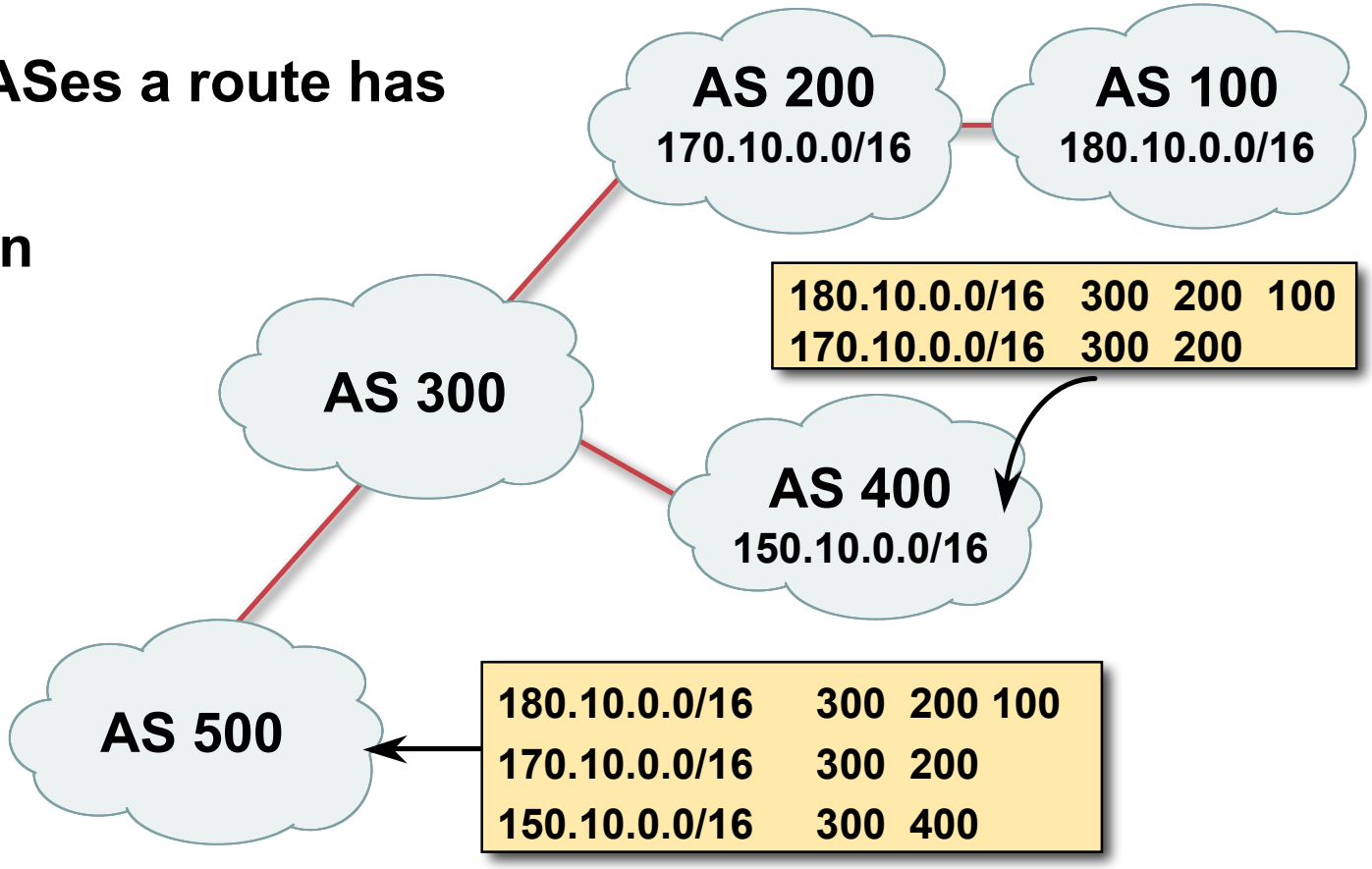
The “tools” available for the job

What Is an Attribute?

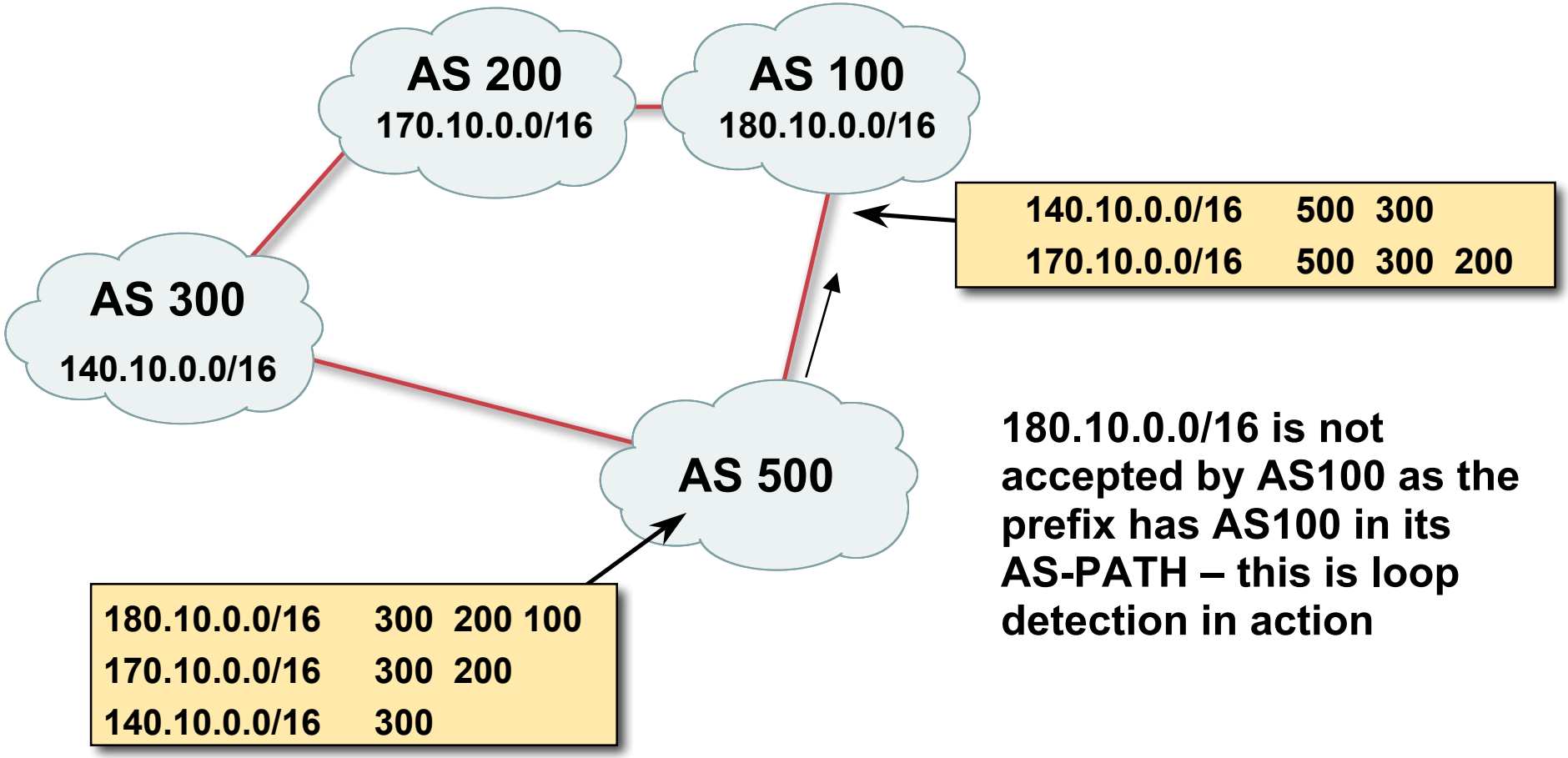
- Describes the characteristics of prefix
- Transitive or non-transitive
- Some are mandatory

AS-Path

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

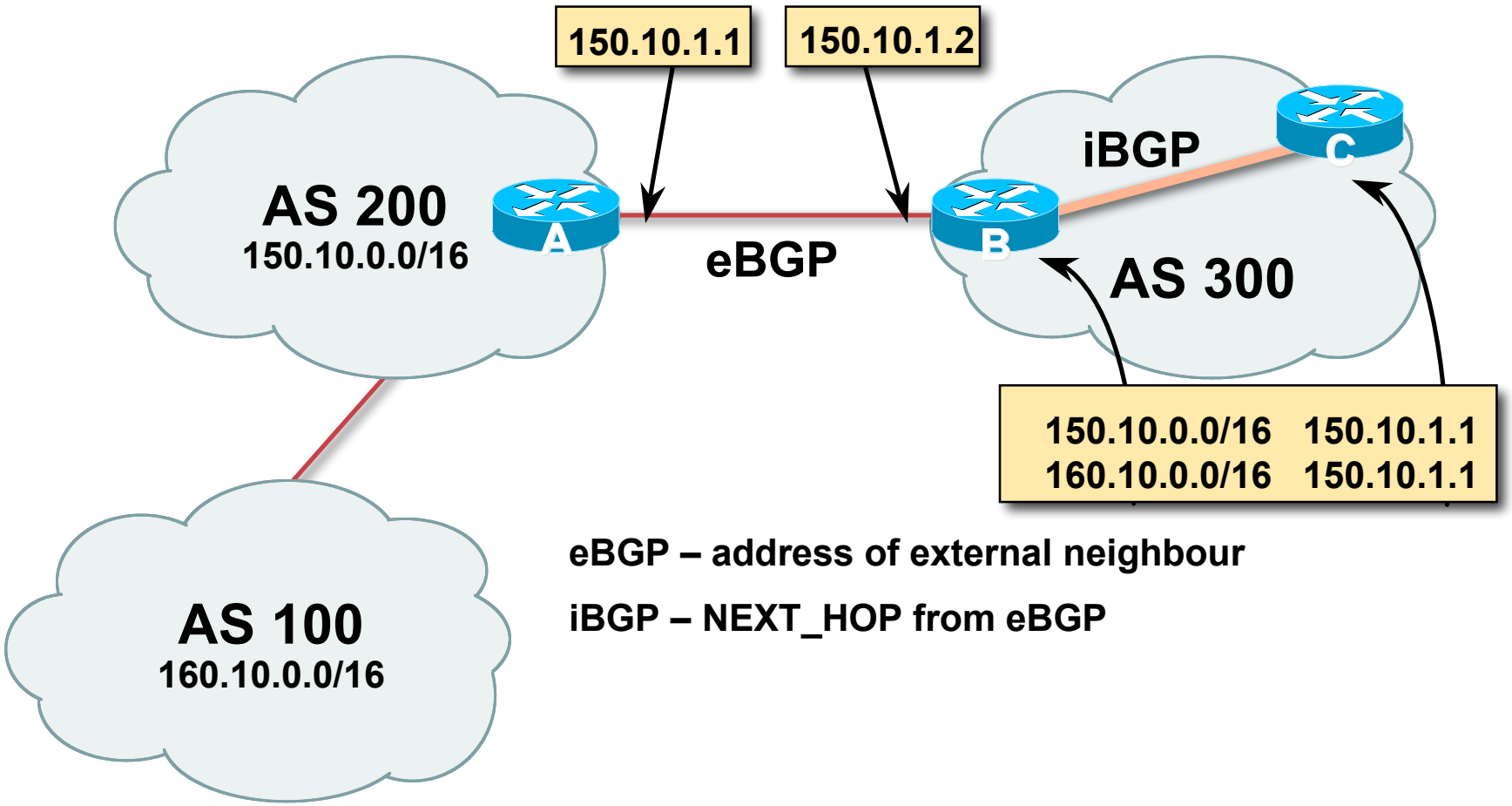


AS-Path loop detection

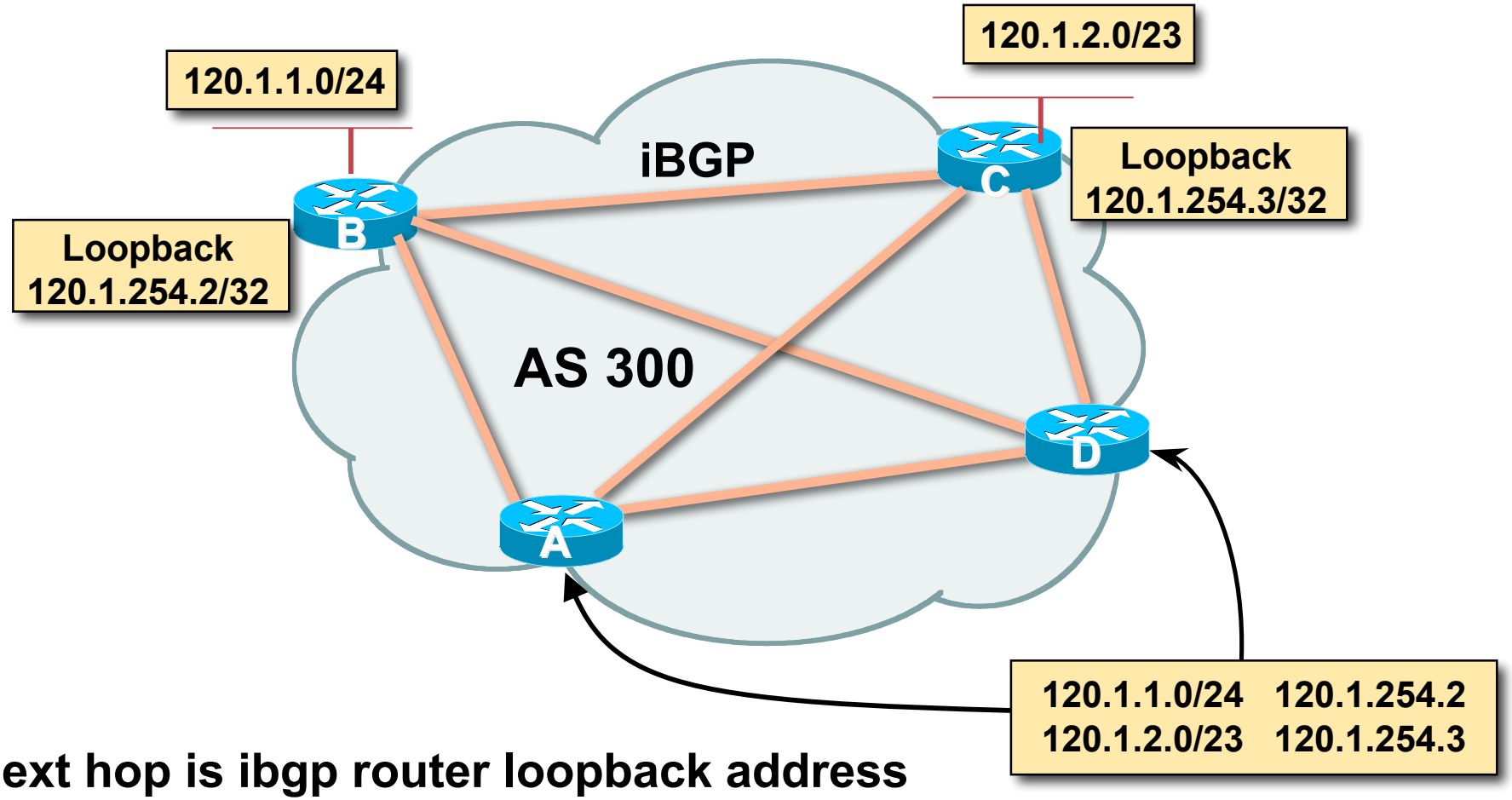


180.10.0.0/16 is not accepted by AS100 as the prefix has AS100 in its AS-PATH – this is loop detection in action

Next Hop



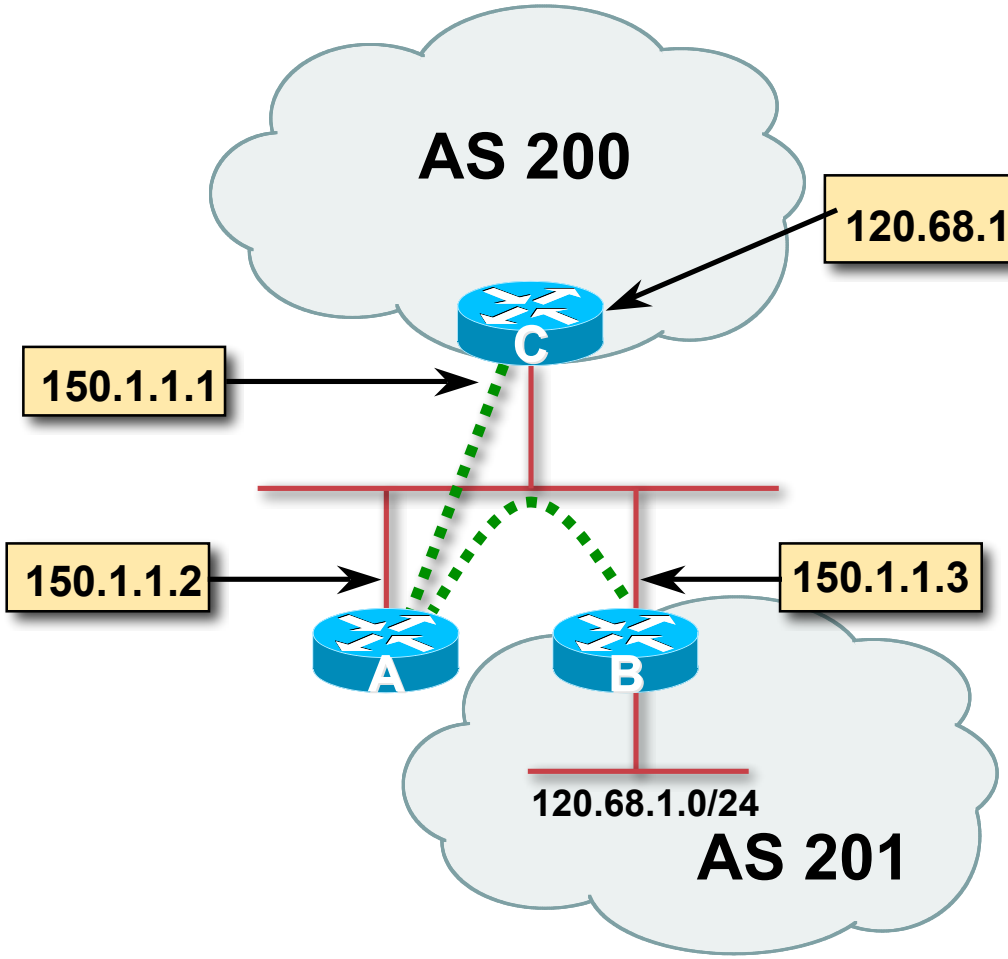
iBGP Next Hop



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 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

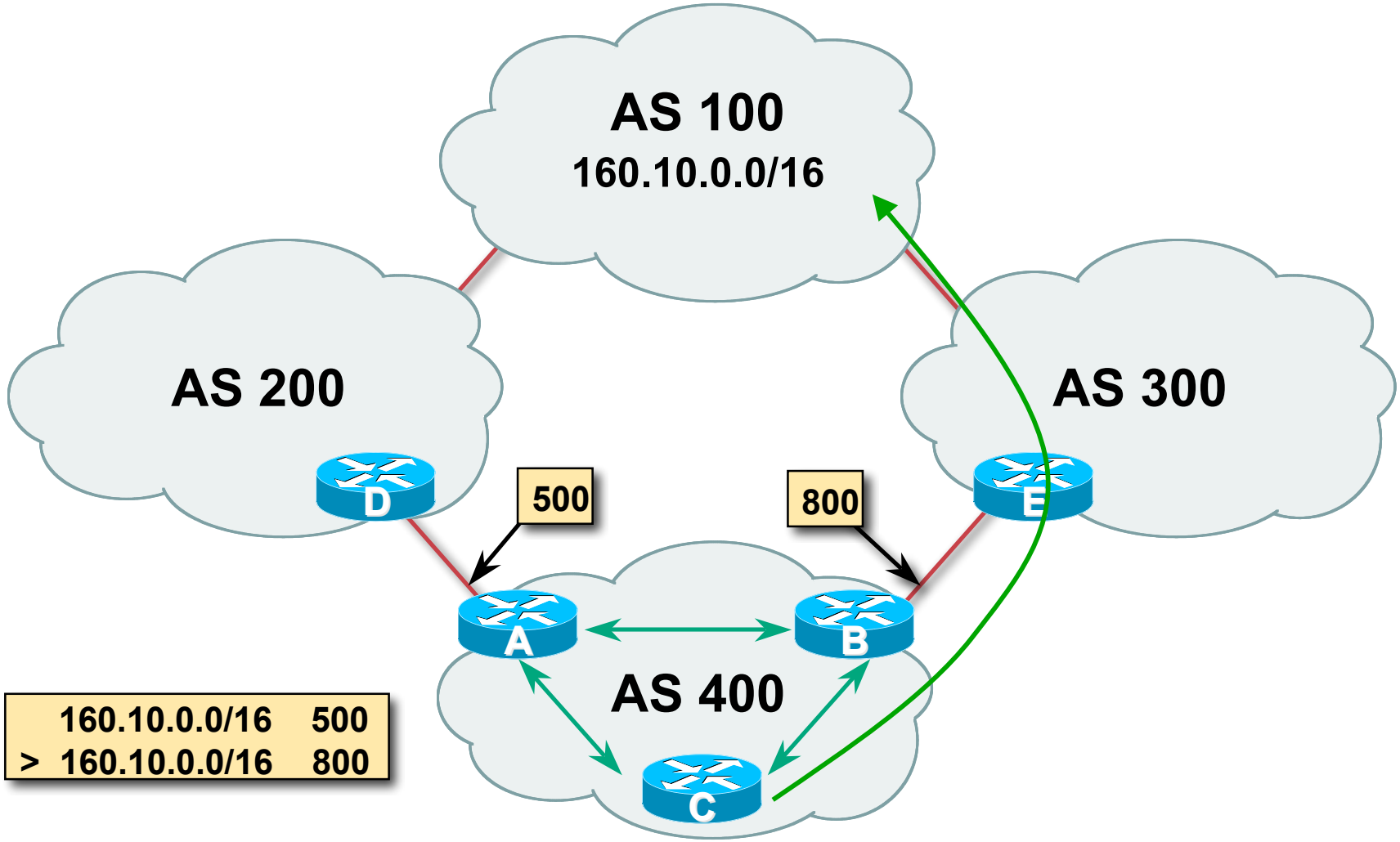
Origin

- Conveys the origin of the prefix
- Historical attribute
  - Used in transition from EGP to BGP
- 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
- Useful for debugging purposes
- Does not influence best path selection

Local Preference



Local Preference

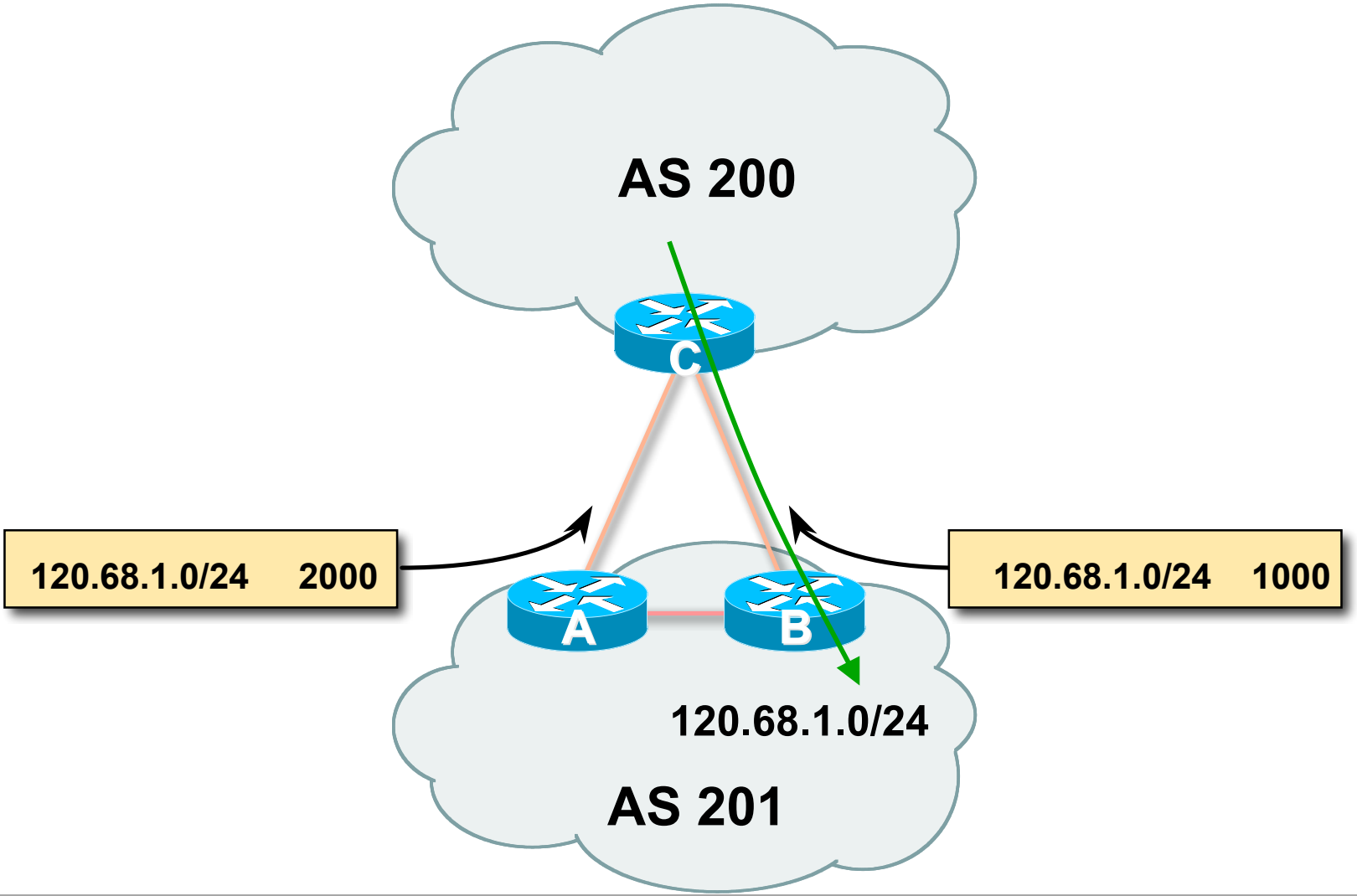
- **Local to an AS – non-transitive**
  - **Default local preference is 100 (IOS)**
- **Used to influence BGP path selection**
  - **determines best path for *outbound* traffic**
- **Path with highest local preference wins**

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

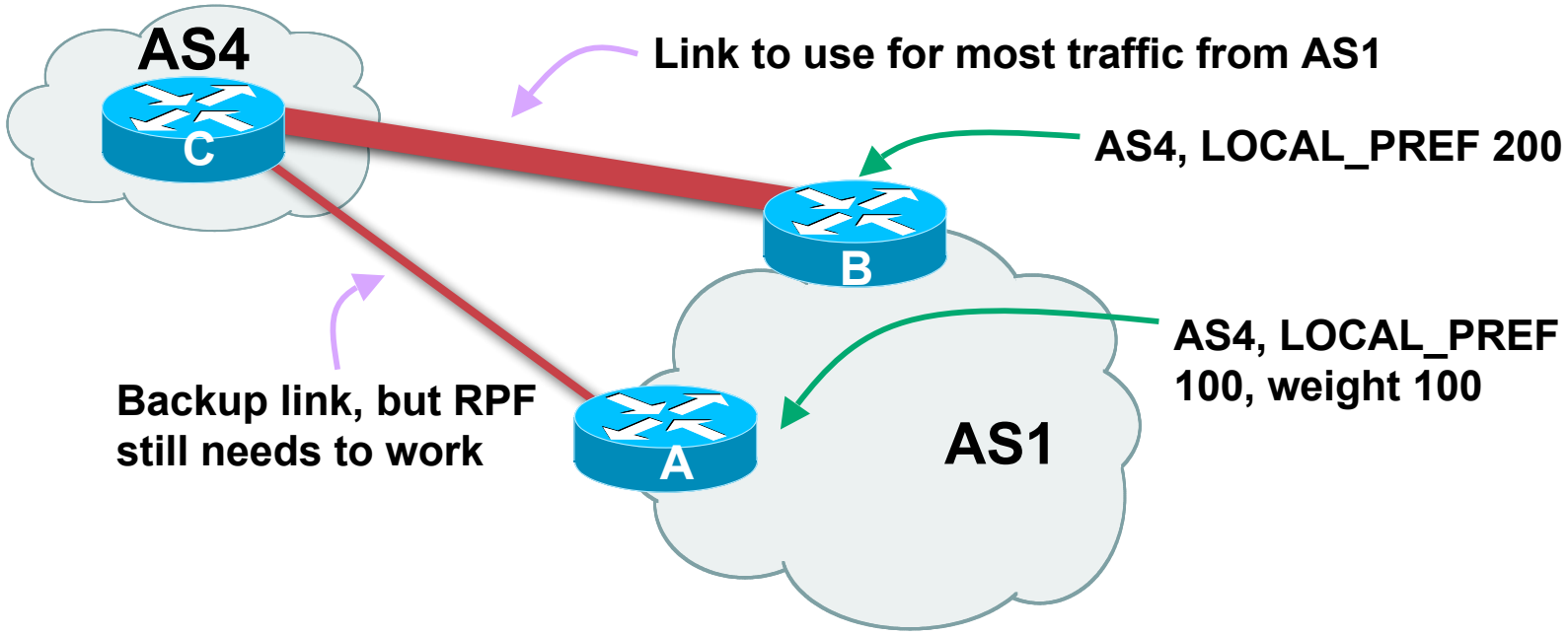
- Not really an attribute – local to router
- Highest weight wins
- Applied to all routes from a neighbour

```
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



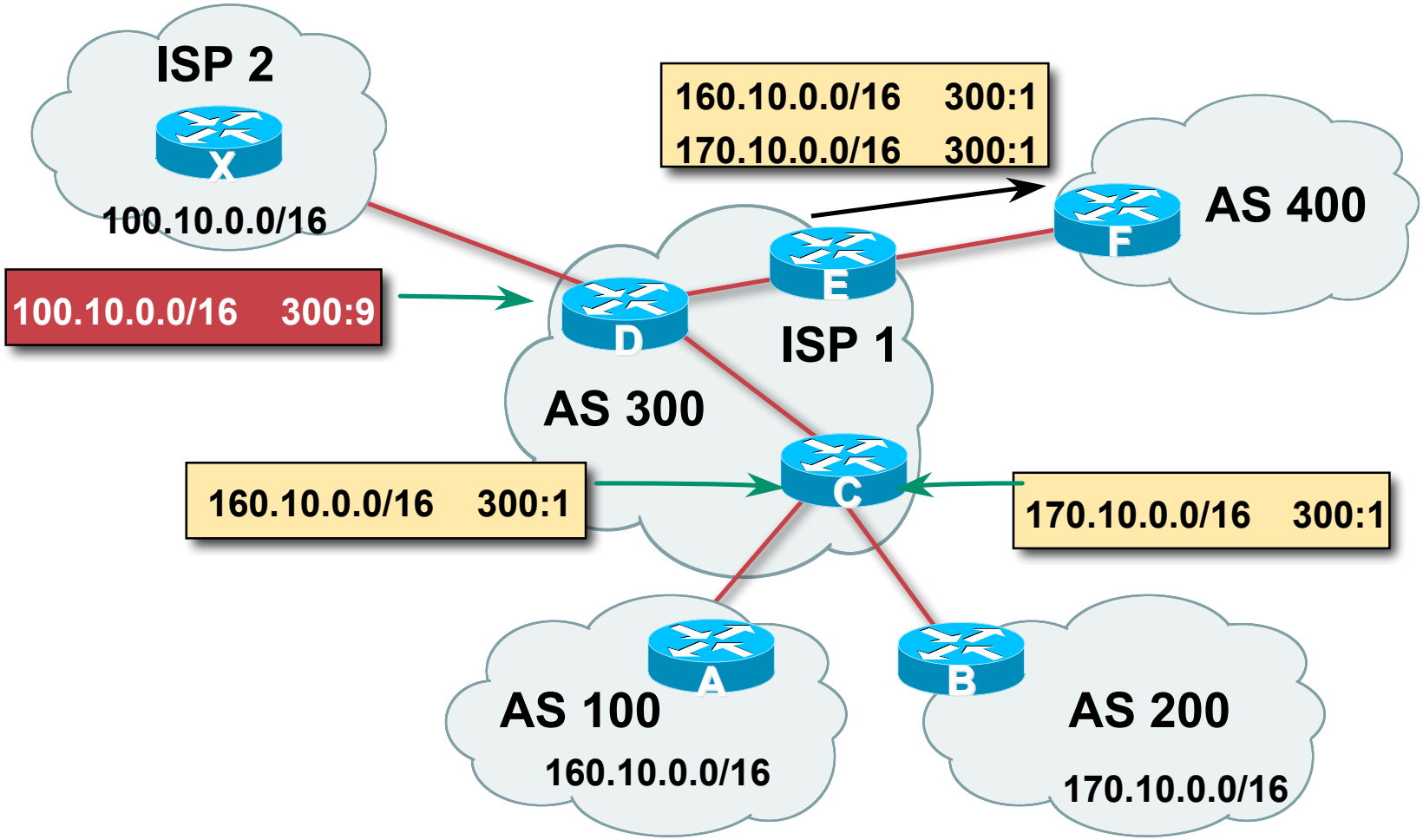
- Best path to AS4 from AS1 is always via B due to local-pref
- But packets arriving at A from AS4 over the direct C to A link will pass the RPF check as that path has a priority due to the weight being set

  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



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

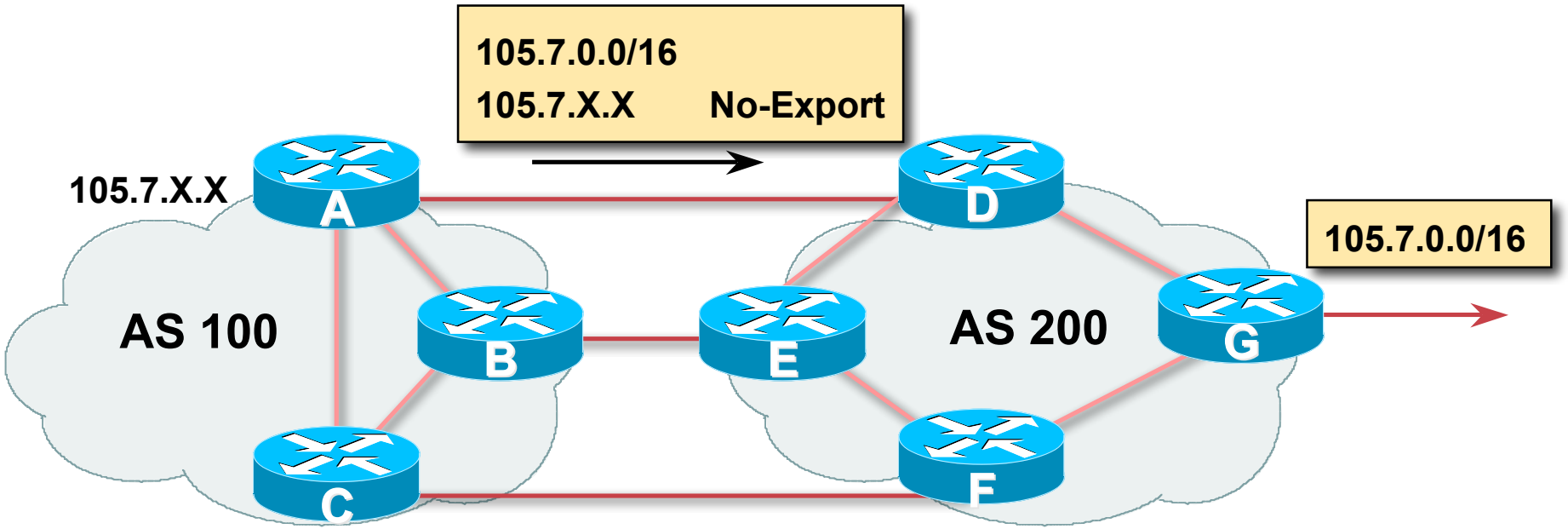
- **no-export-subconfed** 65535:65283

  do not advertise outside local AS (only used with confederations)

- **no-peer** 65535:65284

  do not advertise to bi-lateral peers (RFC3765)

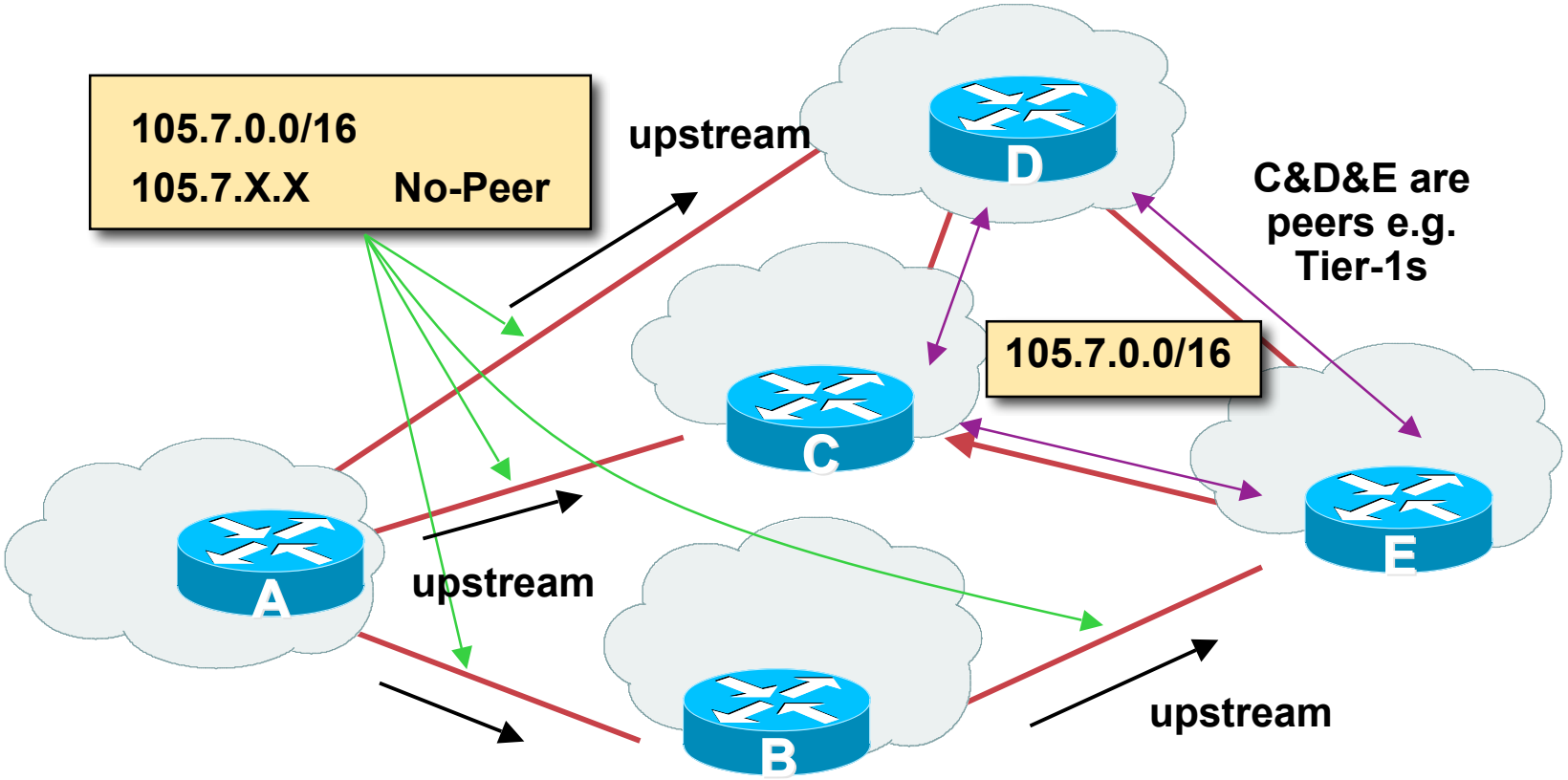
No-Export Community



- 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 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

- **[no] ip prefix-list** *list-name* **[seq** *seq-value***] permit|deny** *networkIlen* **[ge** *ge-value***] [le** *le-value***]**

  networkIlen: **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** *networkIlen*
- **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 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 – 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
```

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**