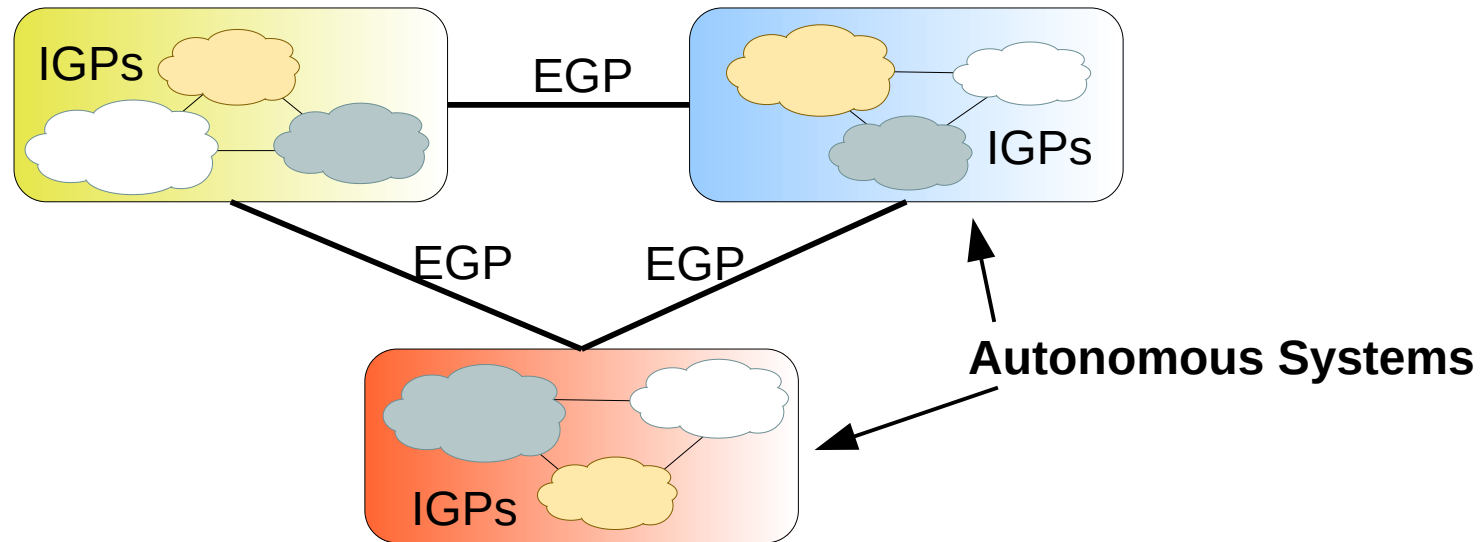


External Routing (BGP and MP-BGP)

Arquitectura de Comunicações

Border Gateway Protocol (BGP)



- Border Gateway Protocol Version 4 of the protocol (BGP4) was deployed in 1993 and currently is the protocol that assures Internet connectivity
- BGP is mainly used for routing between Autonomous Systems
- Autonomous System (AS) is a network under a single administration
 - ◆ One or more network operators with a common well defined global routing policy

AS Numbers

- Allocated ID by InterNIC and is globally unique
- RFC 4271 defines an AS number as 2-bytes
 - Private AS Numbers = 64512 through 65535
 - Public AS Numbers = 1 through 64511
 - ➔ 39000+ have already been allocated
 - ➔ We will eventually run out of AS numbers
- Need to expand AS size from 2-bytes to 4-bytes
- RFC4893 defines BGP support for 4-bytes AS numbers
 - 4,294,967,295 AS numbers
 - As of January 1, 2009, all new Autonomous System numbers issued will be 4-byte by default, unless otherwise requested.
 - The full binary 4-byte AS number is split two words of 16 bits each
 - ➔ Notation:
 - ➔ <higher2bytes in decimal>.<lower2bytes in decimal>
 - ➔ Example1: AS 65546 is represented as “1.10”
 - ➔ Example2: AS 50000 is represented as “0.50000”
 - Cannot have a “flag day” solution



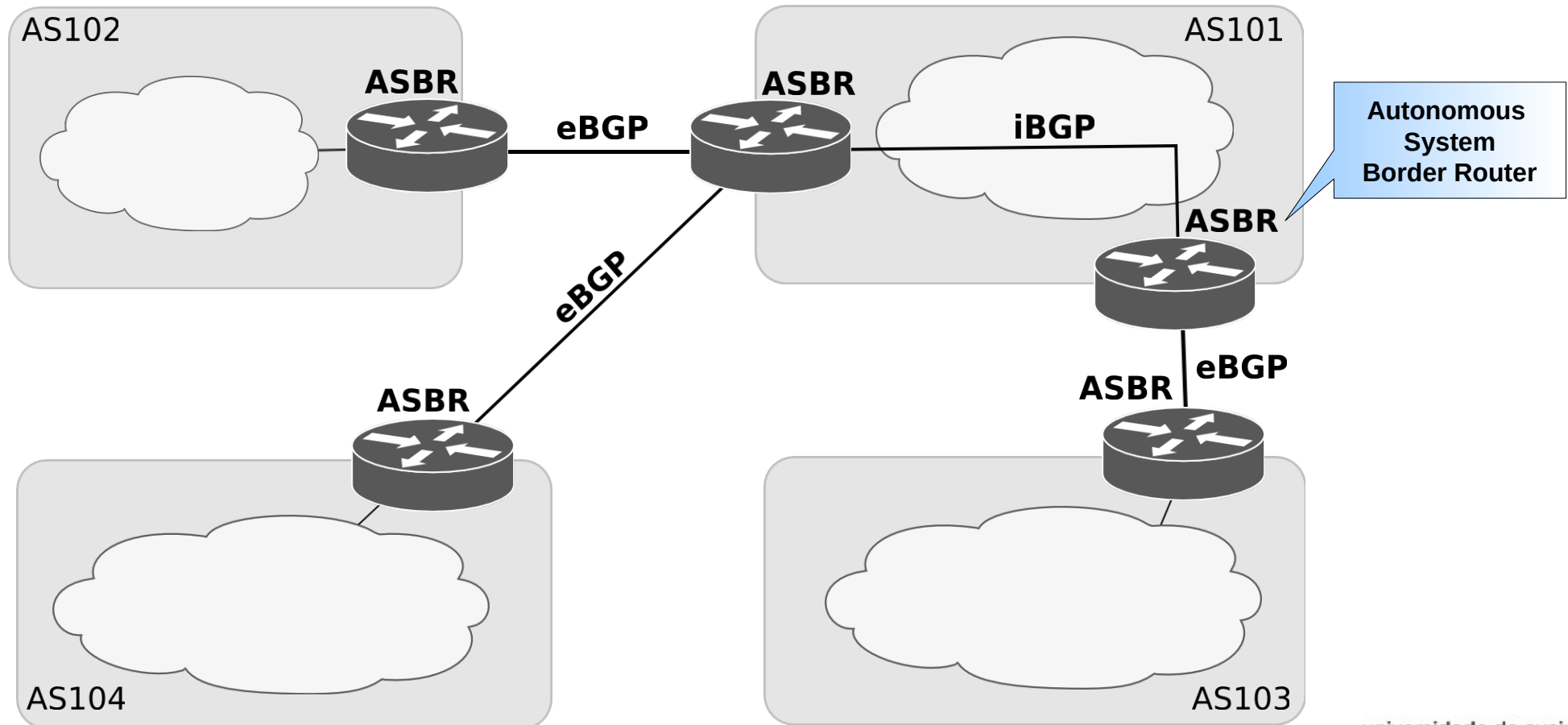
BGP Neighbor Relationships

- Often called peering
 - ♦ Usually manually configured into routers by the administrator
- Each neighbor session runs over TCP (port 179)
 - ♦ Ensures reliable data delivery
- Peers exchange all their routes when the session is first established
- Updates are also sent when there is a topology change in the network or a change in routing policy
- BGP peers exchange session KEEPALIVE messages
 - ♦ To avoid extended periods of inactivity.
 - ♦ Low keepalive intervals can be set if a fast fail-over is required



Internal BGP (iBGP) & External BGP (eBGP)

- Neighbor relations can be established between
 - ♦ Same AS routers (Internal BGP – iBGP).
 - ♦ Different AS routers (External BGP – eBGP).
- Routers that implement neighbor relations are called an Autonomous System Border Router (ASBR).



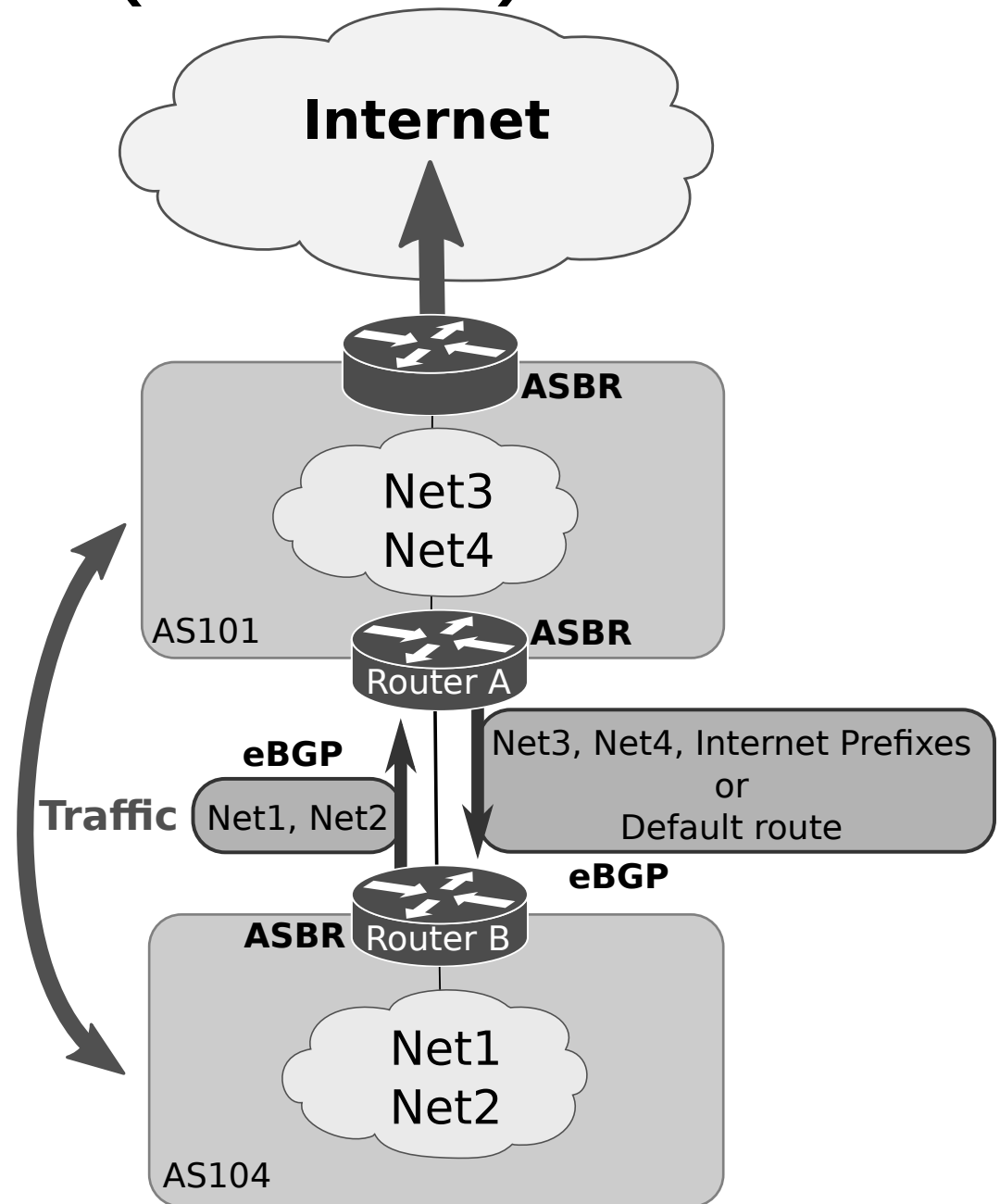
External and Internal BGP

- External BGP (eBGP) is used between AS.
- Internal BGP (iBGP) is used within AS.
- A BGP router never forwards a path learned from one iBGP peer to another iBGP peer even if that path is the best path.
 - An exception is when a router is configured as route-reflector.
- A BGP forward the routes learned from one eBGP peer to both eBGP and iBGP peers.
 - Filters can be used to modify this behavior.
- iBGP routers in an AS **must maintain an iBGP session with all other iBGP routers** in the AS (iBGP Mesh).
 - To obtain complete routing information about external networks.
 - Most networks also use an IGP, such as OSPF.
 - Additional methods can be used to reduce iBGP Mesh complexity.
 - ➔ Route reflectors, private AS, ...



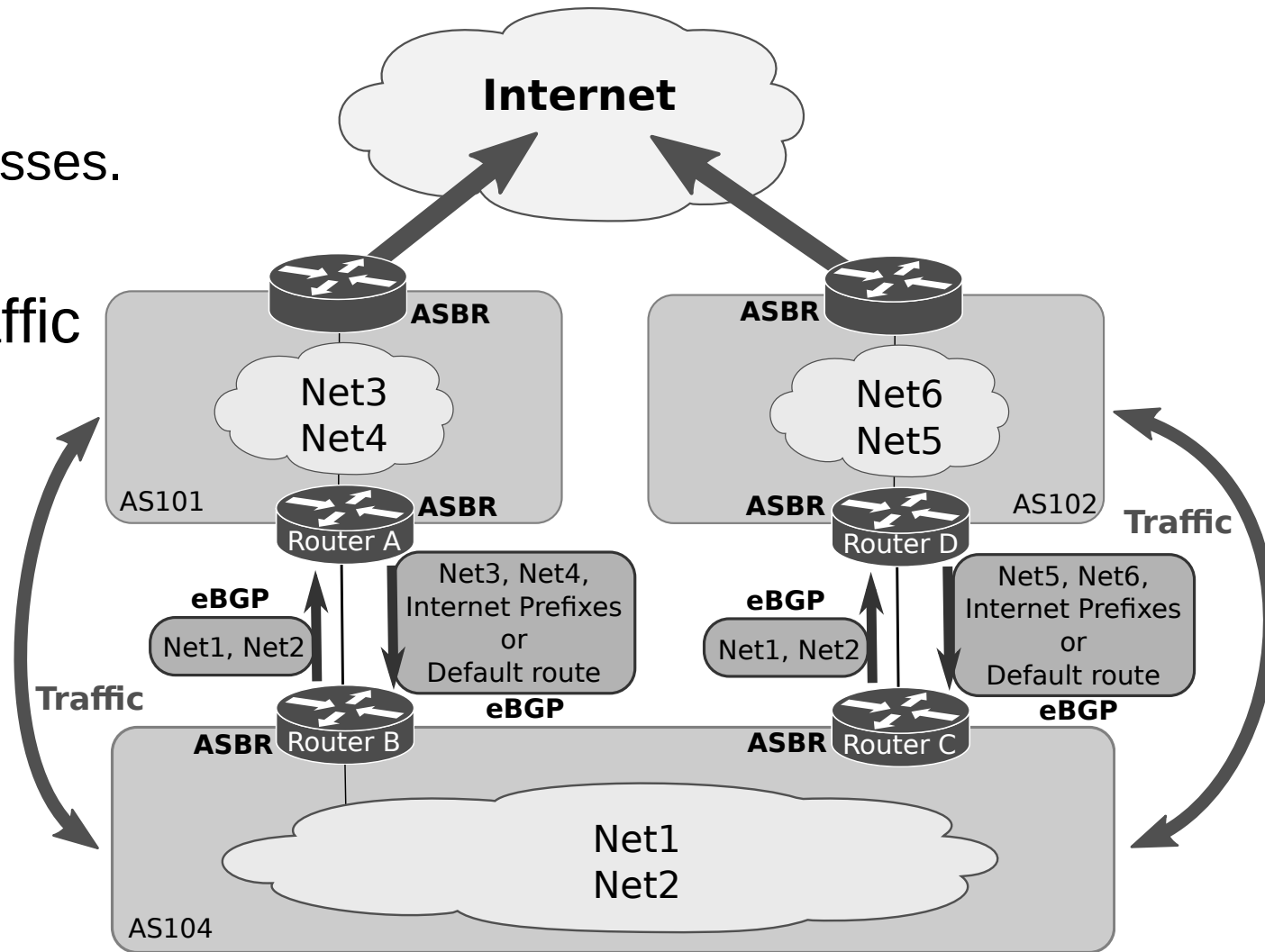
Single-homed (or Stub) AS

- AS has only one border router (ASBR)
 - Single Internet access.
 - Single ISP.



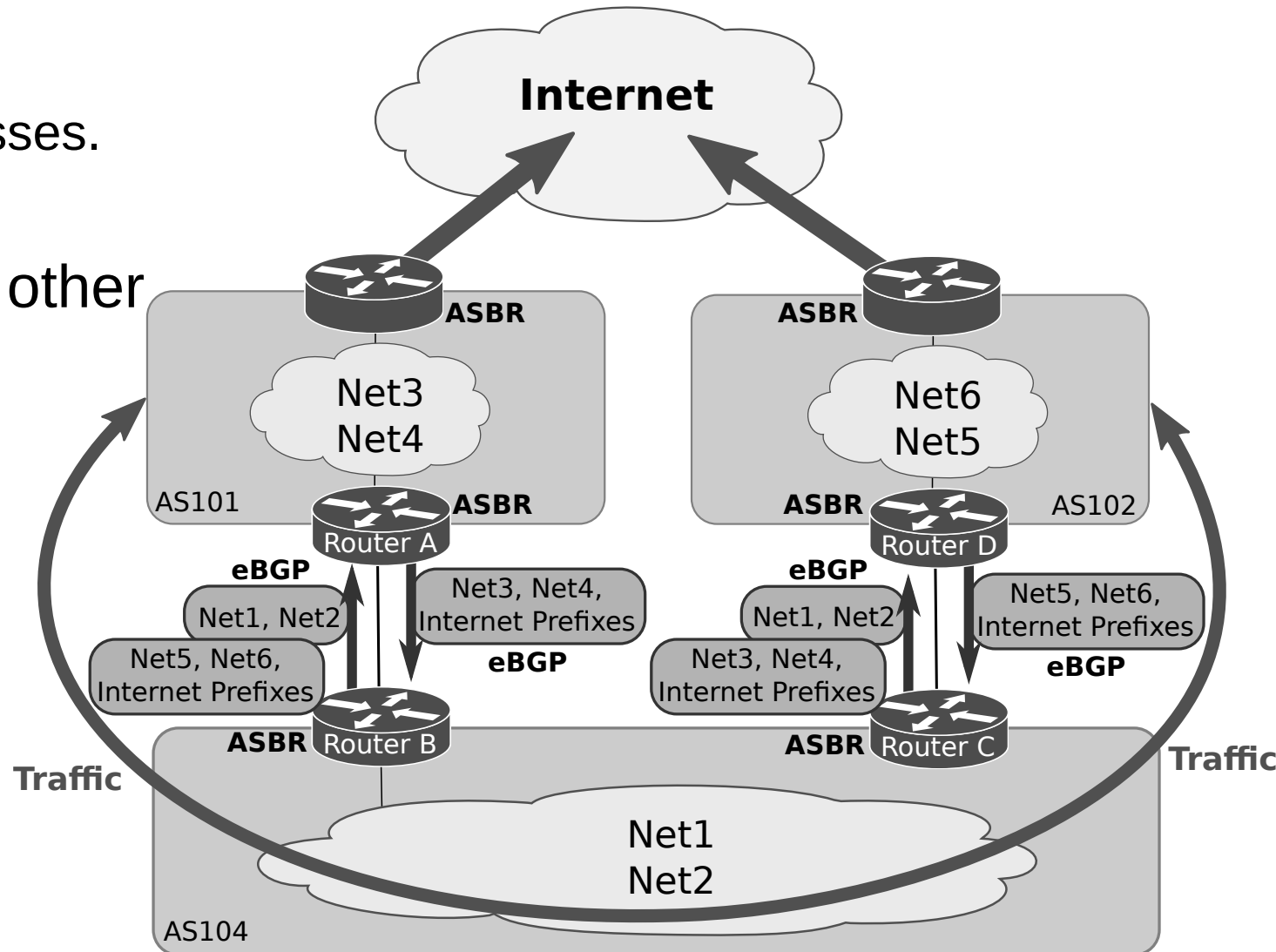
Multi-homed Non-transit AS

- AS has more than one border router (ASBR)
 - Multiple Internet accesses.
 - Multiple ISP.
- Does not transport traffic from other AS.



Multi-homed Transit AS

- AS has more than one border router (ASBR).
 - Multiple Internet accesses.
 - Multiple ISP.
- Transports traffic from other AS.

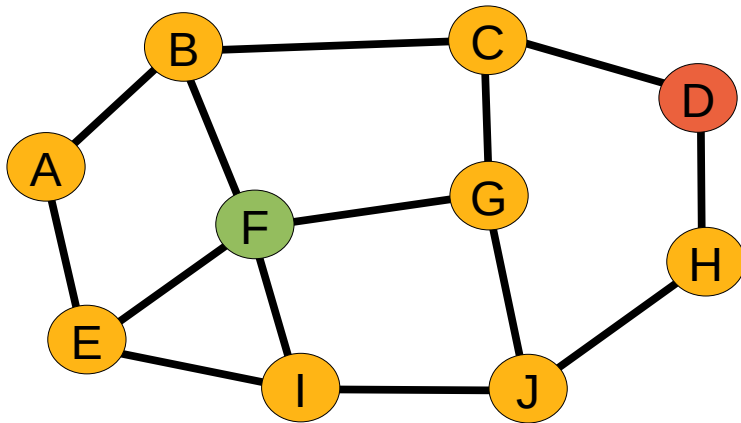


Path-vector

- BGP is a path-vector protocol
- Although it is essentially a distance-vector protocol that carries a list of the AS traversed by the route
 - ♦ Provides loop detection
- An EBGP speaker adds its own AS to this list before forwarding a route to another EBGP peer
- An IBGP speaker does not modify the list because it is sending the route to a peer within the same AS
 - ♦ AS list cannot be used to detect the IBGP routing loops

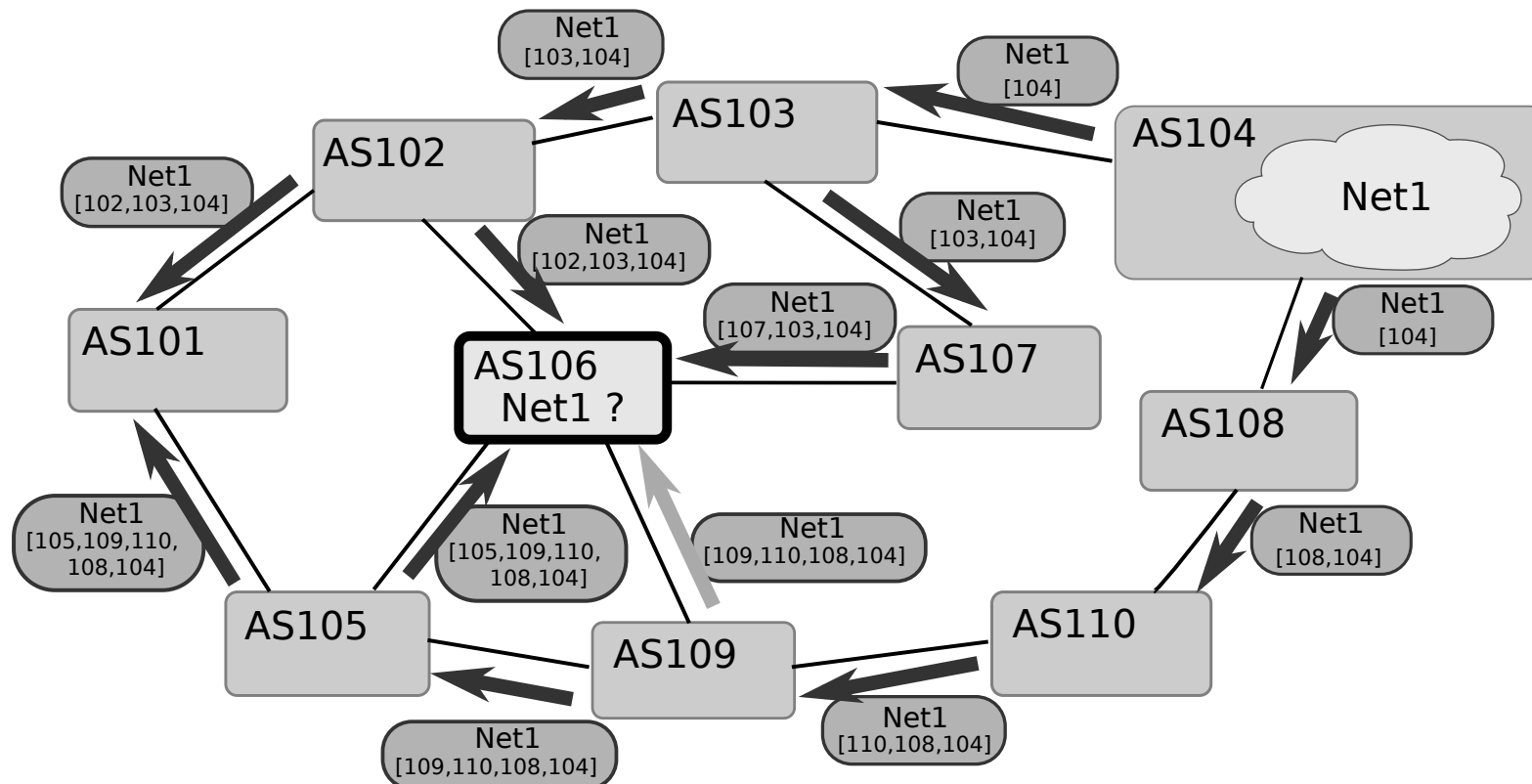


Path vector



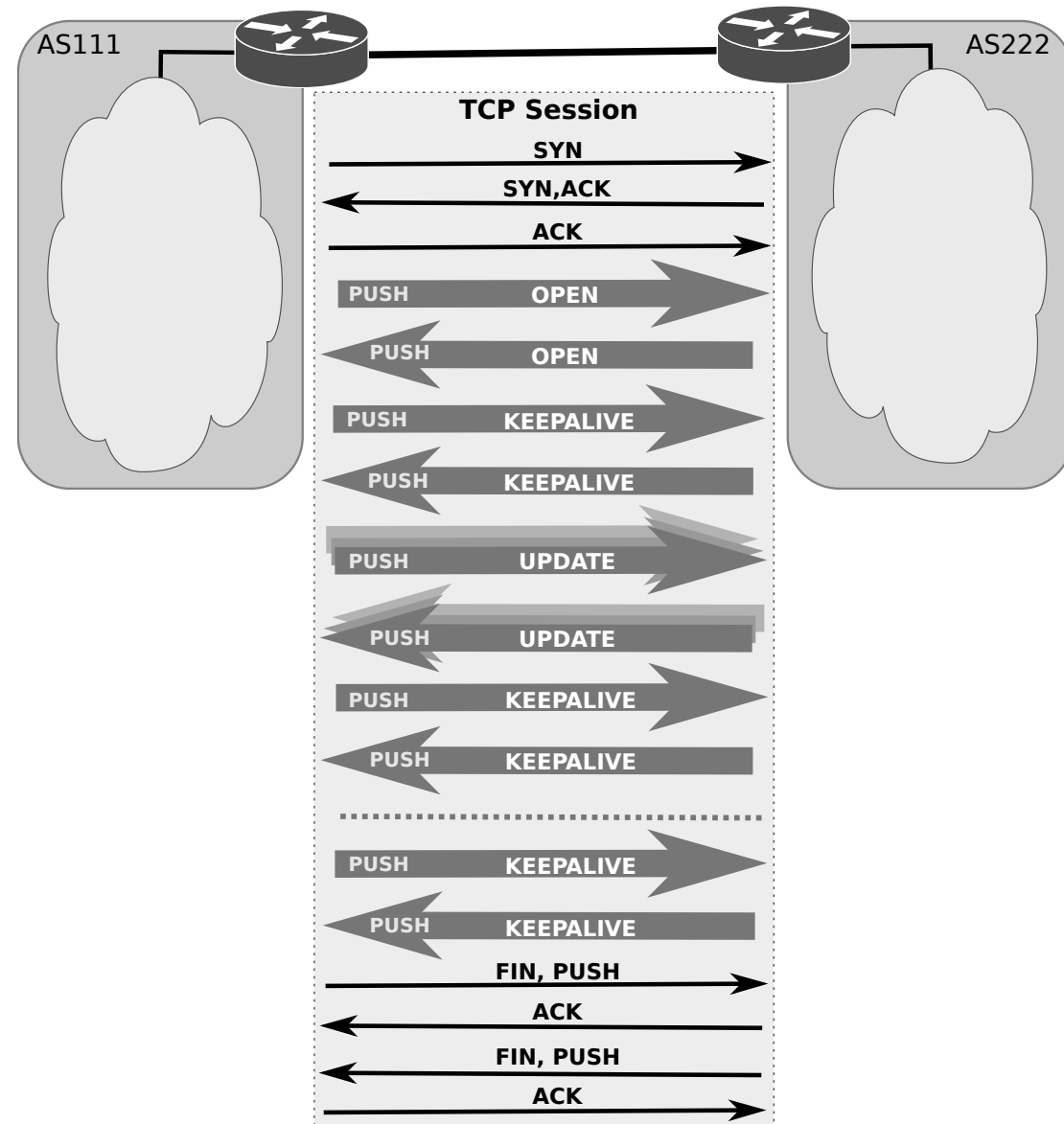
- F receives from its neighbors different paths to D:

- ◆ De B: "I use BCD"
- ◆ De G: "I use GCD"
- ◆ De I: "I use IFGCD"
- ◆ De E: "I use EFGCD"



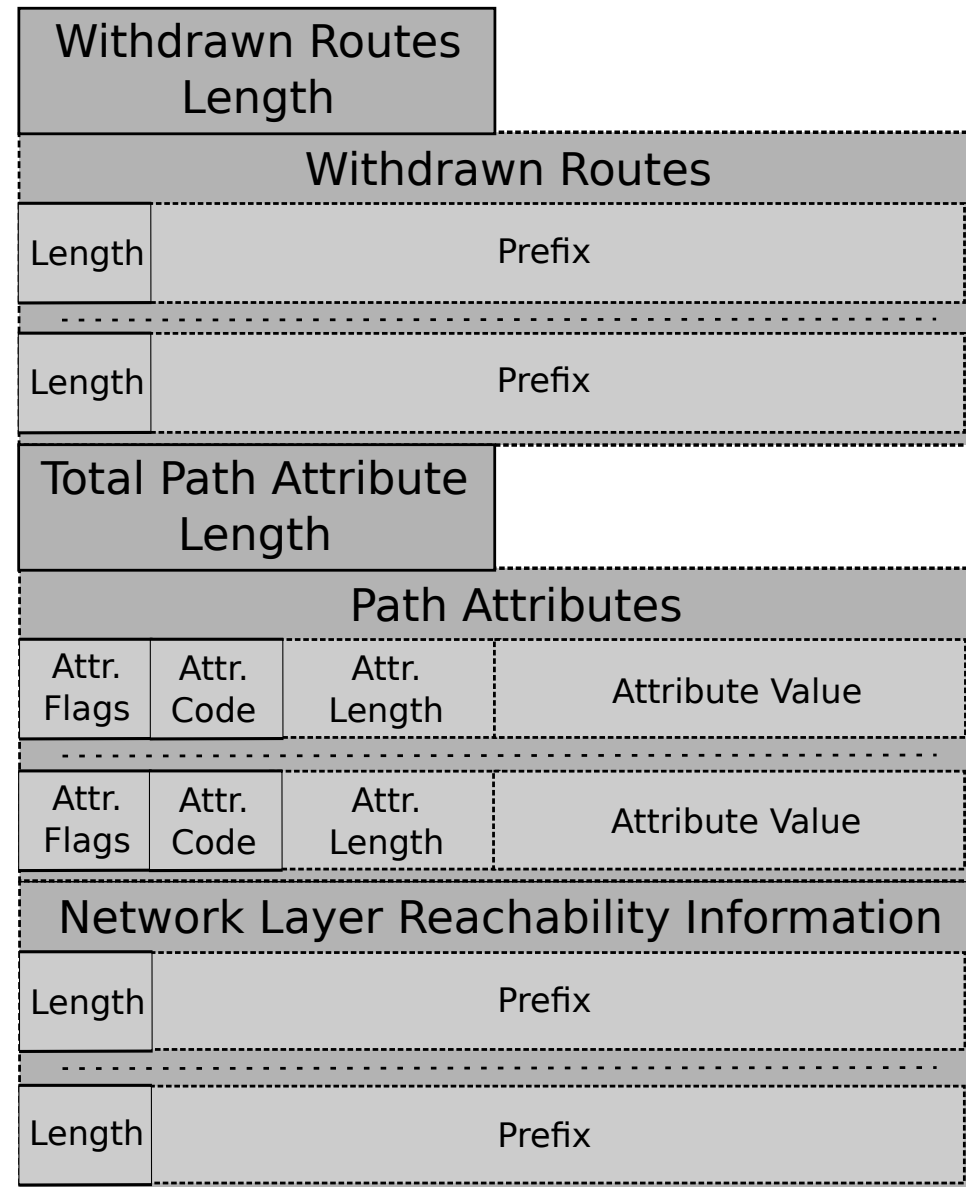
BGP Messages

- OPEN messages are used to establish the BGP session.
- UPDATE messages are used to send routing prefixes, along with their associated BGP attributes (such as the AS-PATH).
- KEEPALIVE messages are exchanged whenever the keepalive period is exceeded, without an update being exchanged.
- NOTIFICATION messages are sent whenever a protocol error is detected, after which the BGP session is closed.

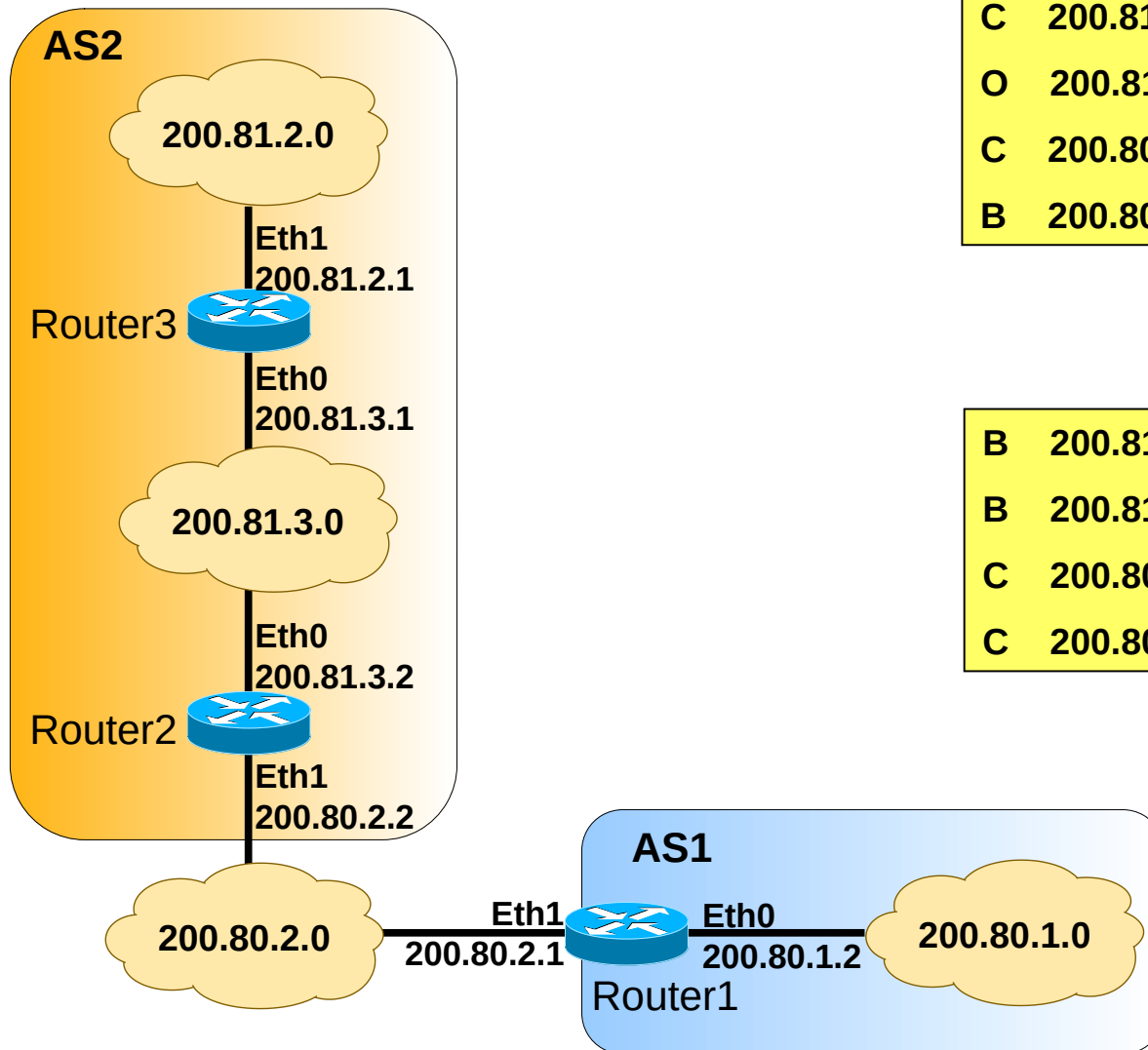


Update Message

- Withdrawn routes – List of IP networks no longer accessible.
- Path attributes – parameters used to define routing and routing policies.
- Network layer reachability information – List of IP networks with connectivity.



Example



C 200.81.3.0/24 is directly connected, Ethernet0
O 200.81.2.0/24 [110/20] via 200.81.3.1, 00:01:12
C 200.80.2.0/24 is directly connected, Ethernet1
B 200.80.1.0/24 [20/0] via 200.80.2.1, 00:00:29

Router 2's routing table

B 200.81.3.0/24 [20/0] via 200.80.2.2, 00:01:58
B 200.81.2.0/24 [20/0] via 200.80.2.2, 00:01:57
C 200.80.2.0/24 is directly connected, Ethernet1
C 200.80.1.0/24 is directly connected, Ethernet0

Router 1's routing table

Example – BGP networks aggregation

Operador prefere rede mais pequena ou seja mask maior

Before aggregation

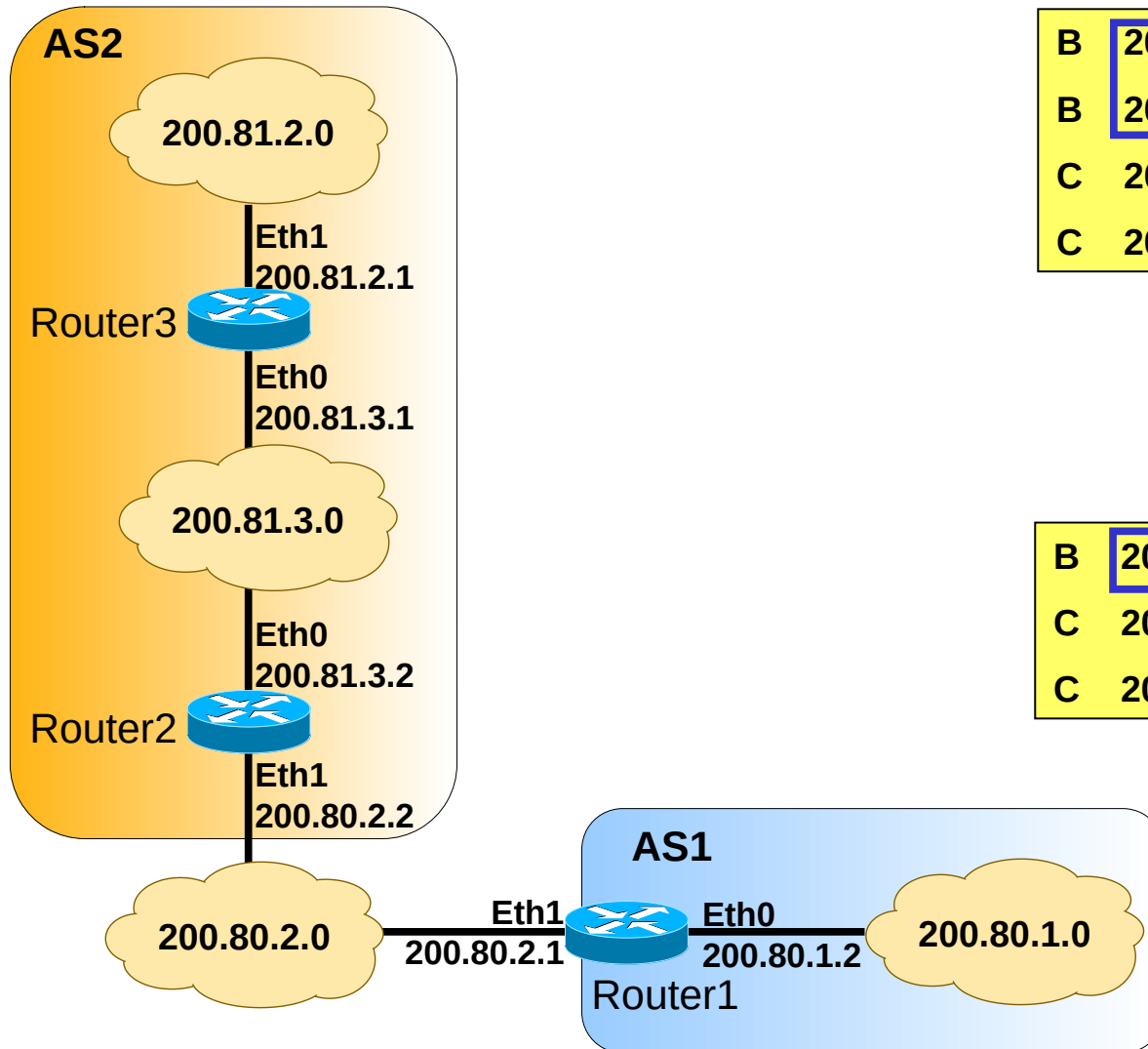
B 200.81.3.0/24 [20/0] via 200.80.2.2, 00:01:58
B 200.81.2.0/24 [20/0] via 200.80.2.2, 00:01:57
C 200.80.2.0/24 is directly connected, Ethernet1
C 200.80.1.0/24 is directly connected, Ethernet0

Router 1

After aggregation

B 200.81.2.0/23 [20/0] via 200.80.2.2, 00:01:06
C 200.80.2.0/24 is directly connected, Ethernet1
C 200.80.1.0/24 is directly connected, Ethernet0

Router 1



BGP Attributes

- A BGP attribute, or path attribute, is a metric used to describe the characteristics of a BGP path.
- Attributes are contained in update messages passed between BGP peers to advertise routes. There are 4+1 categories of BGP attributes.
 - ◆ Well-known Mandatory (included in BGP updates)
 - AS-path, Next-hop, Origin.
 - ◆ Well-known Discretionary (may or may not be included in BGP updates)
 - Local Preference, Atomic Aggregate.
 - ◆ Optional Transitive (may not be supported by all BGP implementations)
 - Agregator, Community, AS4_Aggregator, AS4_path.
diz quem agregou tem q ir à parte noutro attrb à routers que n aguentam 4 bytes
 - ◆ Optional Non-transitive (may not be supported by all BGP implementations)
 - If the neighbor doesn't support that attribute it is deleted
 - Multi-exit-discriminator (MED).
 - ◆ Cisco-defined (local to router, not advertised)
 - Weight



AS-PATH and ORIGIN Attributes

- AS-PATH

- When a route advertisement passes through an autonomous system, the AS number is added to an ordered list of AS numbers that the route advertisement has traversed.

- ORIGIN

- Indicates how BGP learned about a particular route. Can take three possible values:
 - ➔ IGP (0) value is set if the route is interior to the originating AS, resulting from an explicit inclusion of a network within the BGP routing process by means of manual configuration.
 - ➔ INCOMPLETE (2) value is set if the route is learned by other means, namely, route redistribution from other routing processes into the BGP routing process.
 - ➔ EGP (1) is no longer used in modern networks.

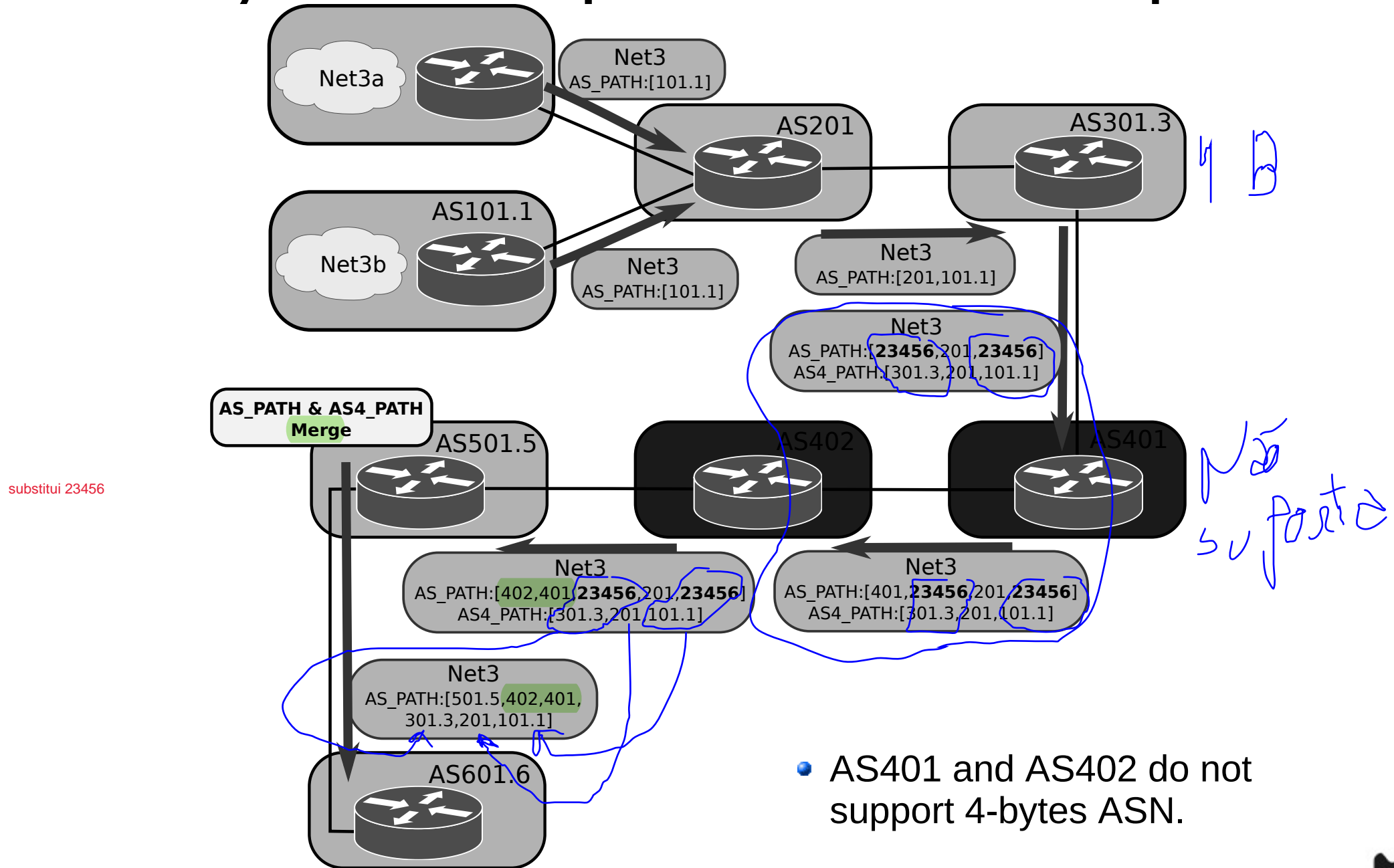


AS4_PATH & AS4_AGGREGATOR

- AS4_PATH attribute has the same semantics as the AS_PATH attribute, except that it is optional transitive, and it carries 4-bytes AS numbers.
- AS4_AGGREGATOR attribute has the same semantics as the AGGREGATOR attribute, except that it carries a 4-bytes AS number.
- 4-byte AS support is advertised via BGP capability negotiation
 - ◆ Speakers who support 4-byte AS are known as NEW BGP speakers
 - ◆ Those who do not are known as OLD BGP speakers
- New Reserved AS number
 - ◆ AS_TRANS = AS 23456
 - ➔ 2-byte placeholder for a 4-byte AS number
 - ➔ Used for backward compatibility between OLD and NEW BGP speakers
- Receiving UPDATES from a NEW speaker
 - ◆ Decode each AS number as 4-bytes
 - ◆ AS_PATH and AGGREGATOR are effected
- Receiving UPDATES from an OLD speaker
 - ◆ AS4_AGGREGATOR will override AGGREGATOR
 - ◆ AS4_PATH and AS_PATH must be merged to form the correct as-path
- Merging AS4_PATH and AS_PATH
 - ◆ AS_PATH → [275 250 225 23456 23456 200 23456 175]
 - ◆ AS4_PATH → [100.1 100.2 200 100.3 175]
 - ◆ Merged AS-PATH → [275 250 225 100.1 100.2 200 100.3 175]



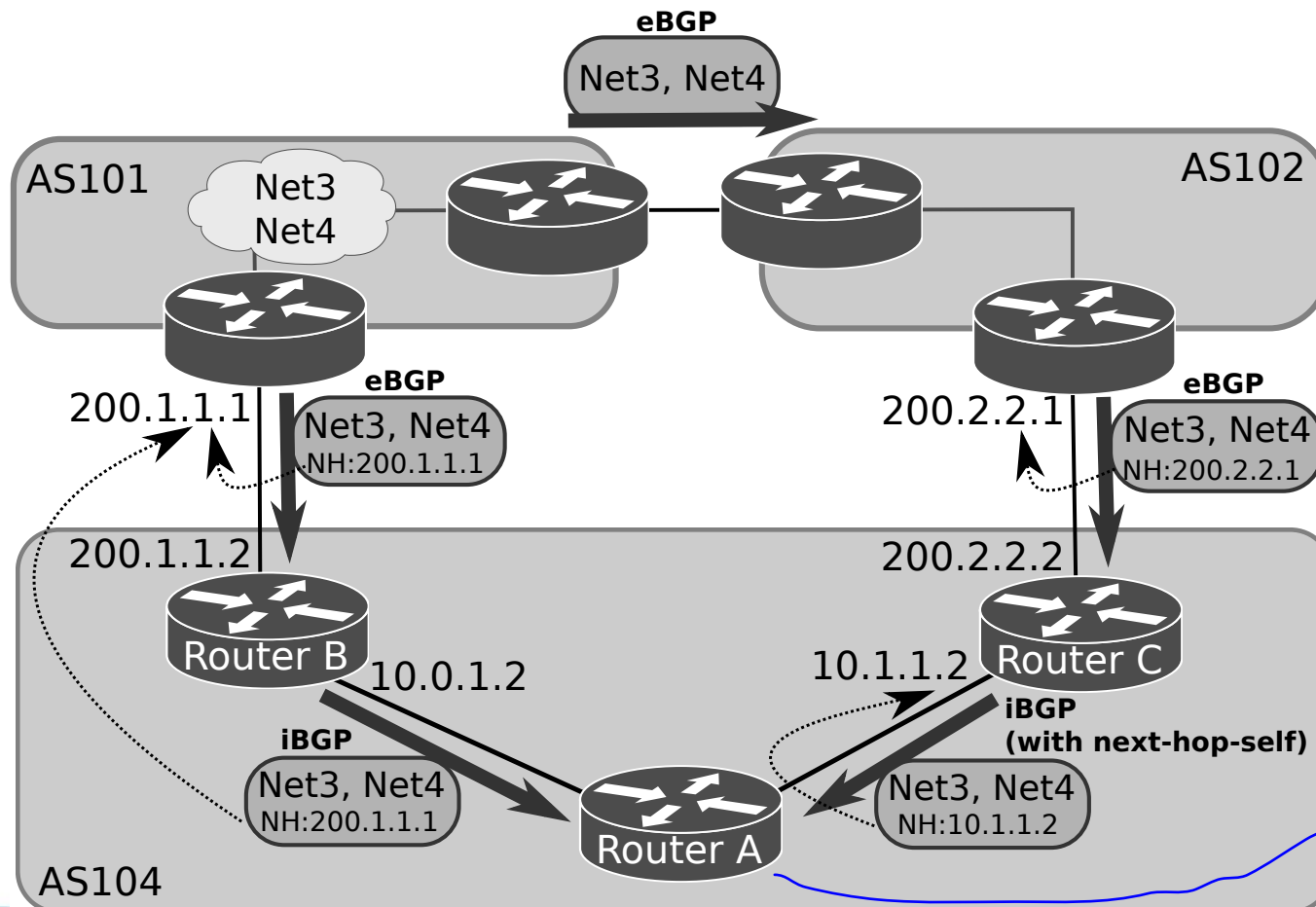
4-bytes AS Operational Example



- AS401 and AS402 do not support 4-bytes ASN.

Next-Hop Attribute

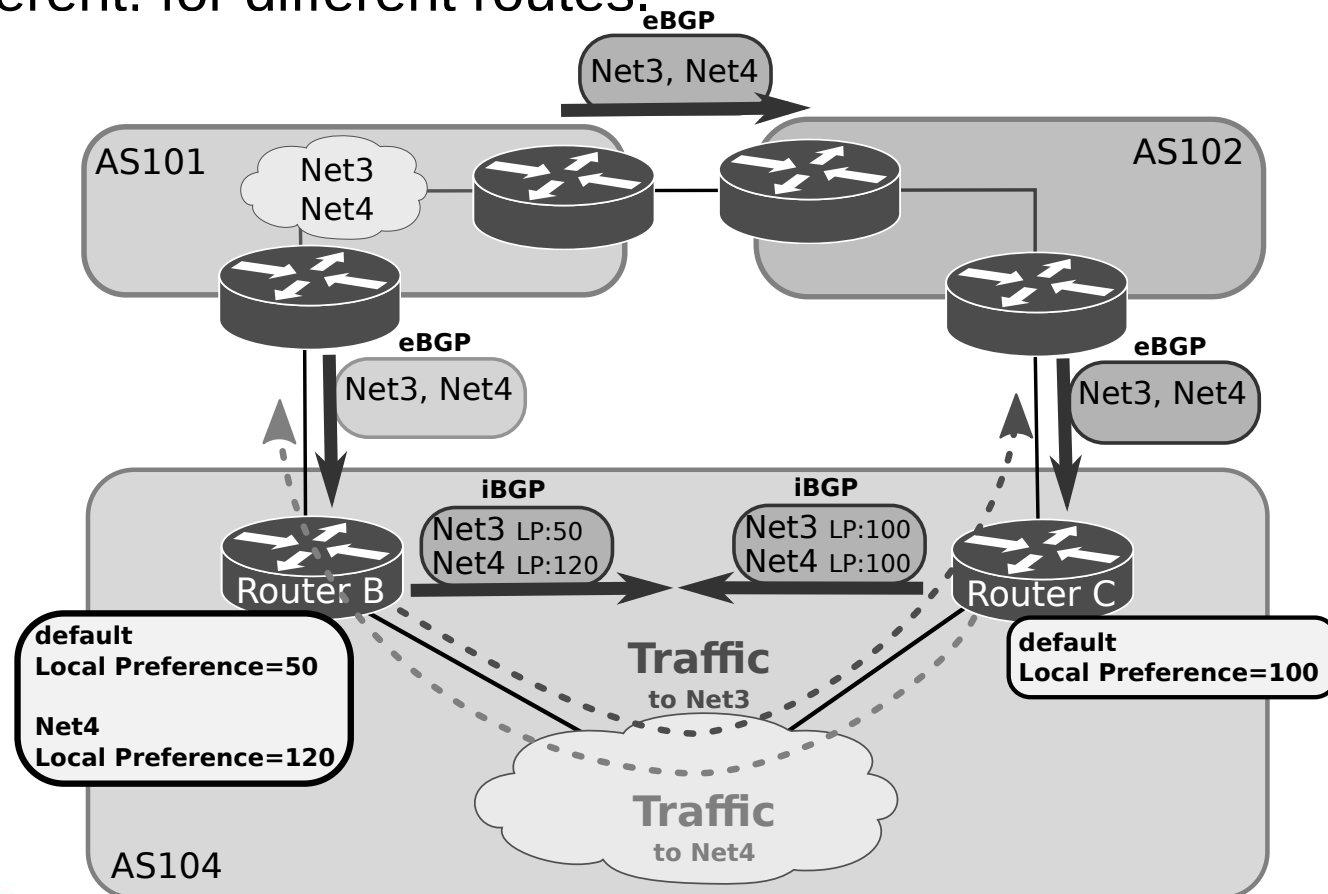
- The eBGP next-hop attribute is the IP address that is used to reach the advertising router
- For eBGP, the next-hop address is the IP address of the connection between the peers
- For iBGP, the eBGP next-hop address is carried into the local AS
 - ◆ By configuration the AS border router can be the next-hop to iBGP neighbors



Local Preference Attribute

N passa para fora

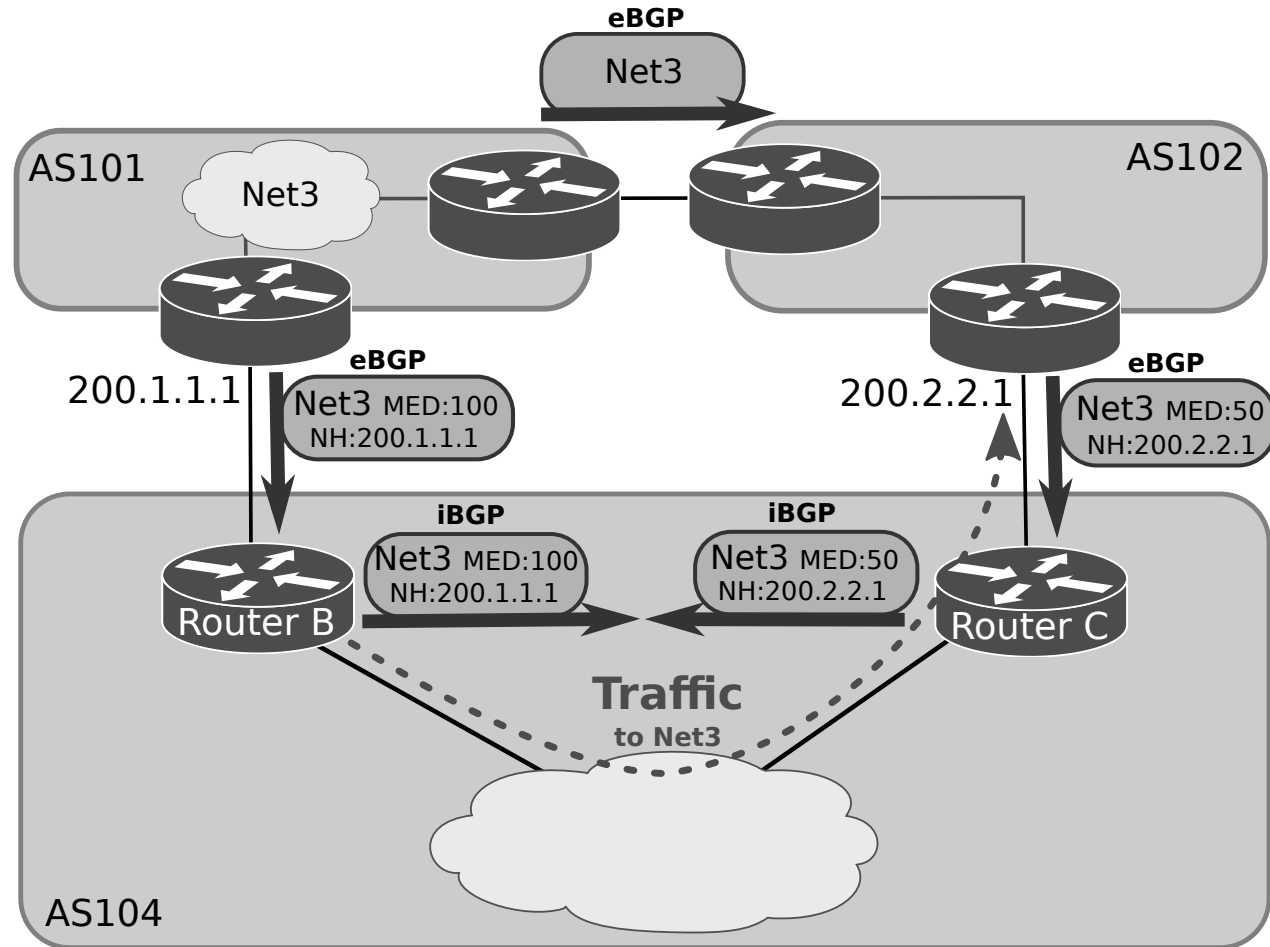
- The local preference attribute is used to choose an exit point from the local autonomous system (AS).
 - **Higher value** is preferred.
- The local preference attribute is propagated throughout the local AS.
- Can be different. for different routes.



Multi-Exit Discriminator Attribute (MED)

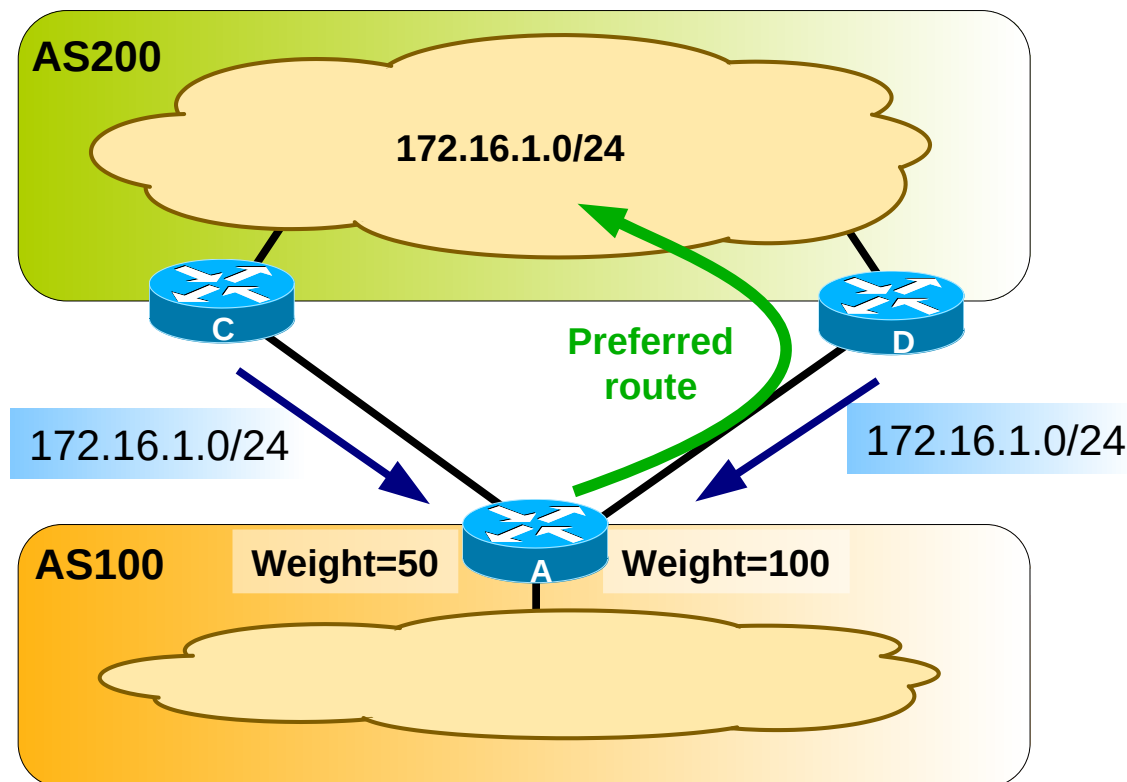
em vez de dizer o que prefiro é o meu vizinho a dizer o que prefere que eu faça

- The multi-exit discriminator (MED) or metric attribute is used as a suggestion to an external AS.
- The external AS that is receiving the MEDs may be using other BGP attributes for route selection.
- The **lower value** of the metric is preferred.
- MED is designed to influence incoming traffic.

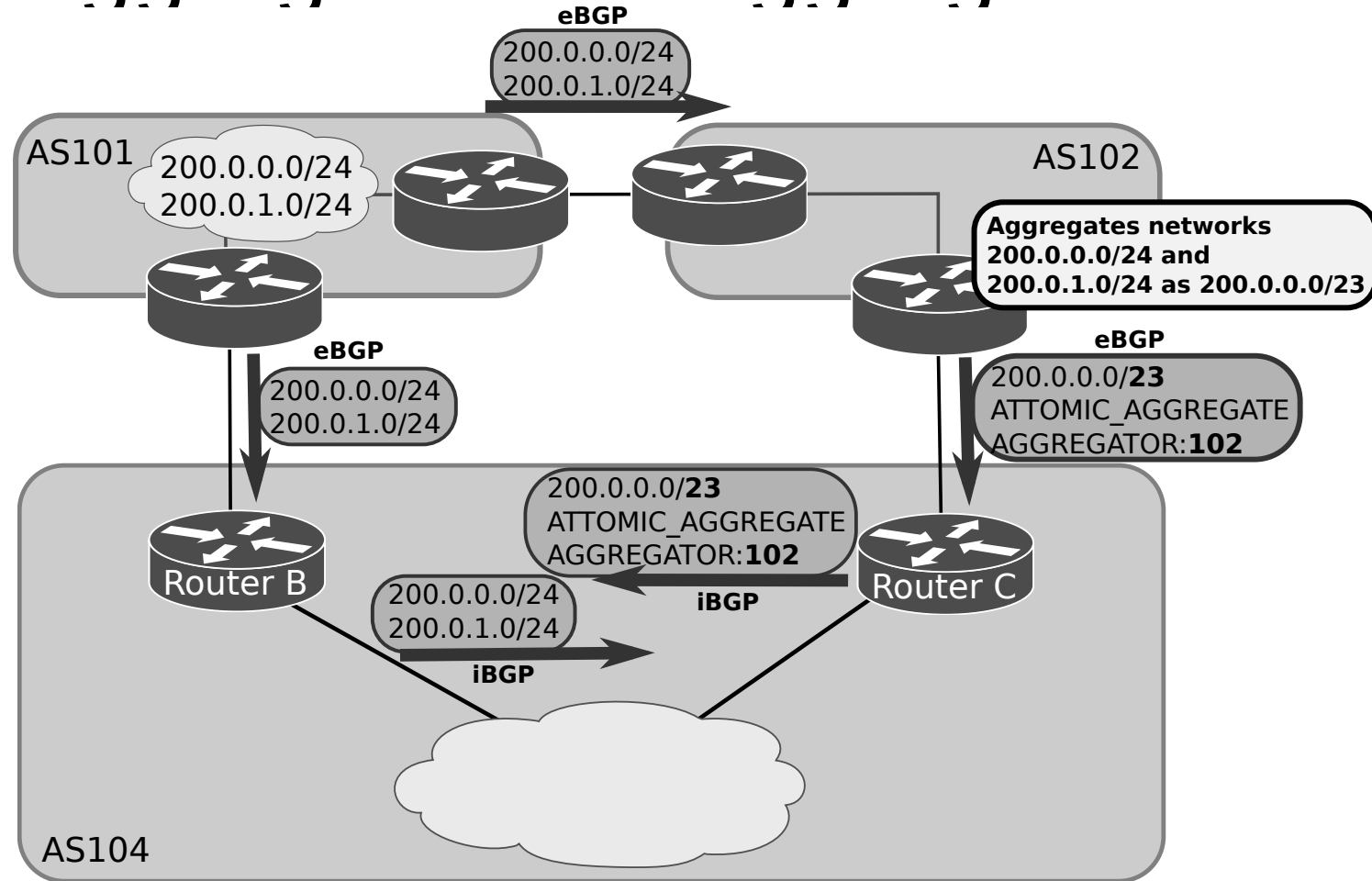


Weight Attribute

- Weight is a Cisco-defined attribute that is local to a router.
- The weight attribute is not advertised to neighboring routers.
- If the router learns about more than one route to the same destination, the route with the **highest weight** will be preferred.

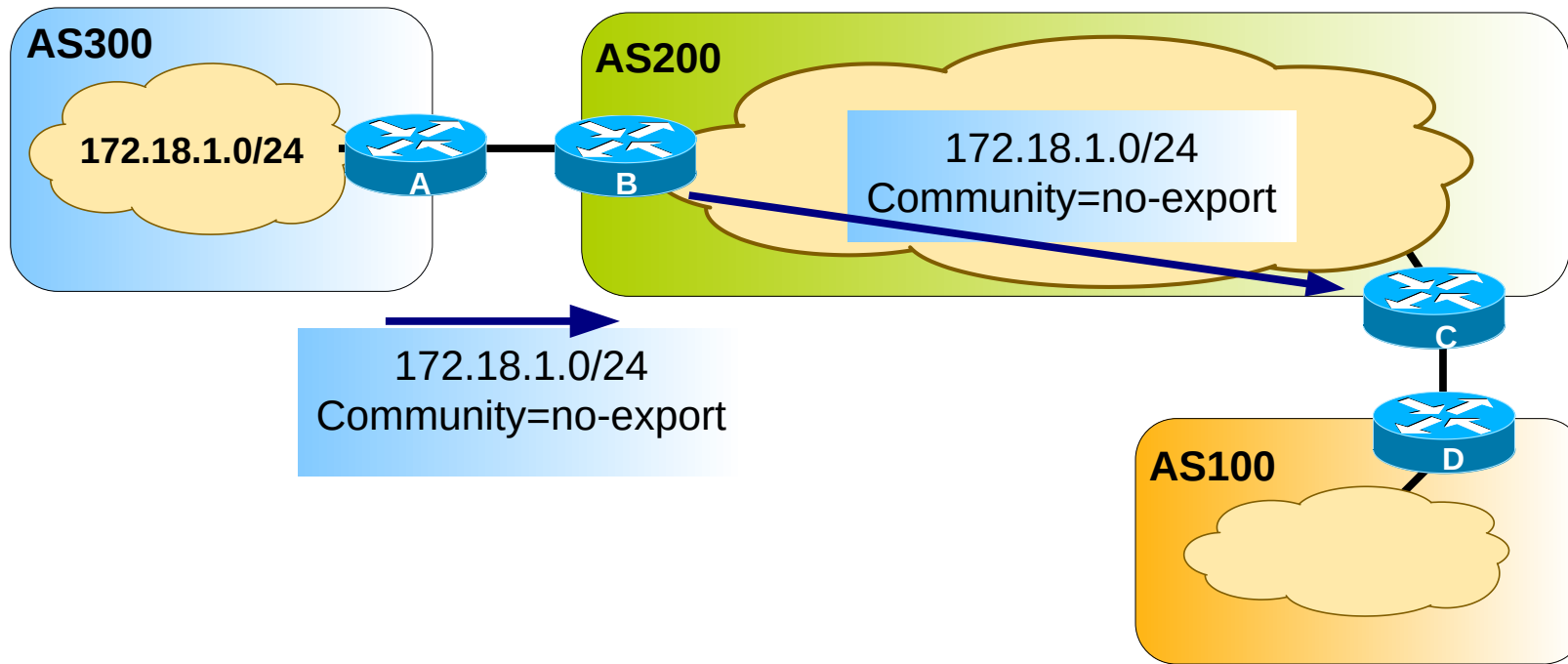


Atomic Aggregate and Aggregator Attributes



- Atomic Aggregate
 - ◆ Is used to alert routers that specific routes have been aggregated into a less specific route.
 - ◆ When aggregation like this occurs, more specific routes are lost.
- Aggregator
 - ◆ Provides information about which AS performed the aggregation.
 - ◆ And the IP address of the router that originated the aggregate.

Community Attribute



- Used to group routes that share common properties so that policies can be applied at the group level
- Predefined community attributes are:
 - ◆ no-export - Do not advertise this route to EBGp peers
 - ◆ no-advertise - Do not advertise this route to any peer
 - ◆ internet - Advertise this route to the Internet community; all routers in the network belong to it
- General communities format is ASnumber:Cnumber
 - ◆ e.g. 300:1, 200:38, etc...

BGP Path Selection

- BGP may receive multiple advertisements for the same route from multiple sources.
- BGP selects only one path as the best path.
- BGP puts the selected path in the IP routing table and propagates the path to its neighbors. BGP uses the following criteria, in the order:
 - ♦ Largest weight (Cisco only)
 - ♦ Largest local preference
 - ♦ Path that was originated locally
 - ♦ Shortest path *passa por menos AS*
 - ♦ Lowest origin type (IGP lower than EGP, EGP lower than incomplete)
 - ♦ Lowest MED attribute
 - ♦ Prefer the external path over the internal path
 - ♦ Closest IGP neighbor

sequencia



Multi-Protocol Border Gateway Protocol (MP-BGP)



MP-BGP Description

- Extension to the BGP protocol
- Carries routing information about other protocols/families:
 - IPv6 Unicast
 - Multicast (IPv4 and IPv6)
 - 6PE - IPv6 over IPv4 MPLS backbone
 - Multi-Protocol Label Switching (MPLS) VPN (IPv4 and IPv6)
- Exchange of Multi-Protocol Reachability Information (NLRI)



MP-BGP Attributes

- New non-transitive and optional attributes
 - ♦ MP_REACH_NLRI
 - Carry the set of reachable destinations together with the next- hop information to be used for forwarding to these destinations
 - ♦ MP_UNREACH_NLRI
 - Carry the set of unreachable destinations
- Attribute contains one or more triples
 - ♦ Address Family Information (AFI) with Sub-AFI
 - Identifies protocol information carried in the Network Layer Reachability Information
 - ♦ Next-hop information
 - Next-hop address must be of the same family
- Reachability information



MP-BGP Negotiation Capabilities

- MP-BGP routers establish BGP sessions through the OPEN message
 - OPEN message contains optional parameters
 - If OPEN parameters are not recognized, BGP session is terminated
 - A new optional parameter: CAPABILITIES
- OPEN message with CAPABILITIES containing:
 - Multi-Protocol extensions (AFI/SAFI)
 - Route Refresh
 - Outbound Route Filtering



MP-BGP New Features for IPv6

- IPv6 Unicast
 - MP-BGP enables the creation of IPv6 Inter-AS relations
- IPv6 Multicast
 - Unicast prefixes for Reverse Path Forwarding (RPF) checking
 - RPF information is disseminated between autonomous systems
 - Compatible with single domain Rendezvous Points or Protocol Independent Multicast-Source Specific Multicast (PIM-SSM)
 - Topology can be congruent or non-congruent with the unicast one
- IPv6 and label (6PE)
 - IPv6 packet is transported over an IPv4 MPLS backbone
- IPv6 VPN (6VPE)
 - Multiple IPv6 VPNs are created over an IPv4 MPLS backbone
- Layer 2 VPN

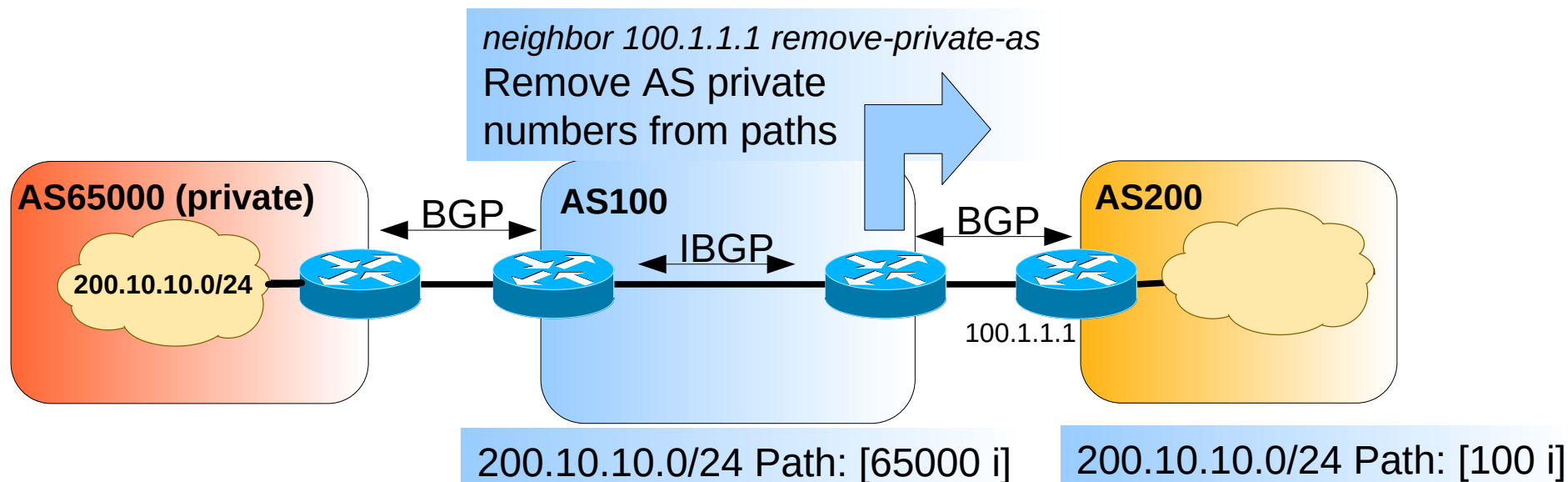


Advanced BGP



Private BGP AS

- Private autonomous system (AS) numbers range from 64512 to 65535
- When a customer network is large, the ISP may assign an AS number:
 - Permanently assigning a **Public** AS number in the range of 1 to 64511
 - ➔ Should have a unique AS number to propagate its BGP routes to Internet
 - ➔ Done when a customer network connects to two different ISPs, such as multihoming
 - Assigning a **Private** AS number in the range of 64512 to 65535.
 - ➔ It is not recommended that you use a private AS number when planning to connect to multiple ISPs in the future



BGP AS Routing Policies

aut-num: AS15525

as-name: **PTPRIMENET**

descr: PT Prime Autonomous System

descr: Corporate Data Communications Services

descr: Portugal

```
import:    from AS1930 action pref=100;
           accept AS-RCCN # RCCN
import:    from AS3243 action pref=200;
           accept AS-TELEPAC # Telepac
import:    from AS5516 action pref=100;
           accept AS5516 # INESC
import:    from AS5533 action pref=100;
           accept AS-VIAPT # Via NetWorks Portugal
import:    from AS8657 action pref=300;
           accept ANY # CPRM
import:    from AS12305 action pref=100;
           accept AS12305 # Nortenet
import:    from AS1897 action pref=100;
           accept AS1897 AS9190 AS13134 AS15931 # KPN Qwest
import:    from AS13156 action pref=100;
           accept AS13156 # Cabovisao
import:    from AS8824 action pref=100;
           accept AS8824 AS15919 # Eastecnica
.....
```

```
export:    to AS1897 announce RS-PTPRIME # KPNQwest
export:    to AS1930 announce RS-PTPRIME # RCCN
export:    to AS3243 announce RS-PTPRIME # Telepac
export:    to AS5516 announce {0.0.0.0/0} # INESC
export:    to AS5533 announce RS-PTPRIME # Via NetWorks Portugal
export:    to AS8657 announce RS-PTPRIME # CPRM
export:    to AS8824 announce RS-PTPRIME # Eastecnica
export:    to AS8826 announce {0.0.0.0/0} # Siemens
export:    to AS9186 announce RS-PTPRIME # ONI
export:    to AS12305 announce RS-PTPRIME # Nortenet
export:    to AS12353 announce RS-PTPRIME # Vodafone Portugal
export:    to AS13156 announce RS-PTPRIME # Cabovisao
export:    to AS13910 announce ANY # register.com
export:    to AS15931 announce ANY # YASP Hiperbit
export:    to AS24698 announce RS-PTPRIME # Optimus
export:    to AS25005 announce ANY # Finibanco
export:    to AS25253 announce {0.0.0.0/0} # CGDNet
export:    to AS28672 announce ANY # BPN
export:    to AS31401 announce {0.0.0.0/0} # SICAMSERV
export:    to AS39088 announce {0.0.0.0/0} # Santander-Totta
export:    to AS41345 announce RS-PTPRIME # Visabeira
export:    to AS43064 announce RS-PTPRIME # Teixeira Duarte
export:    to AS43643 announce ANY # TAP
.....
```

From RIPE database
<http://www.db.ripe.net>

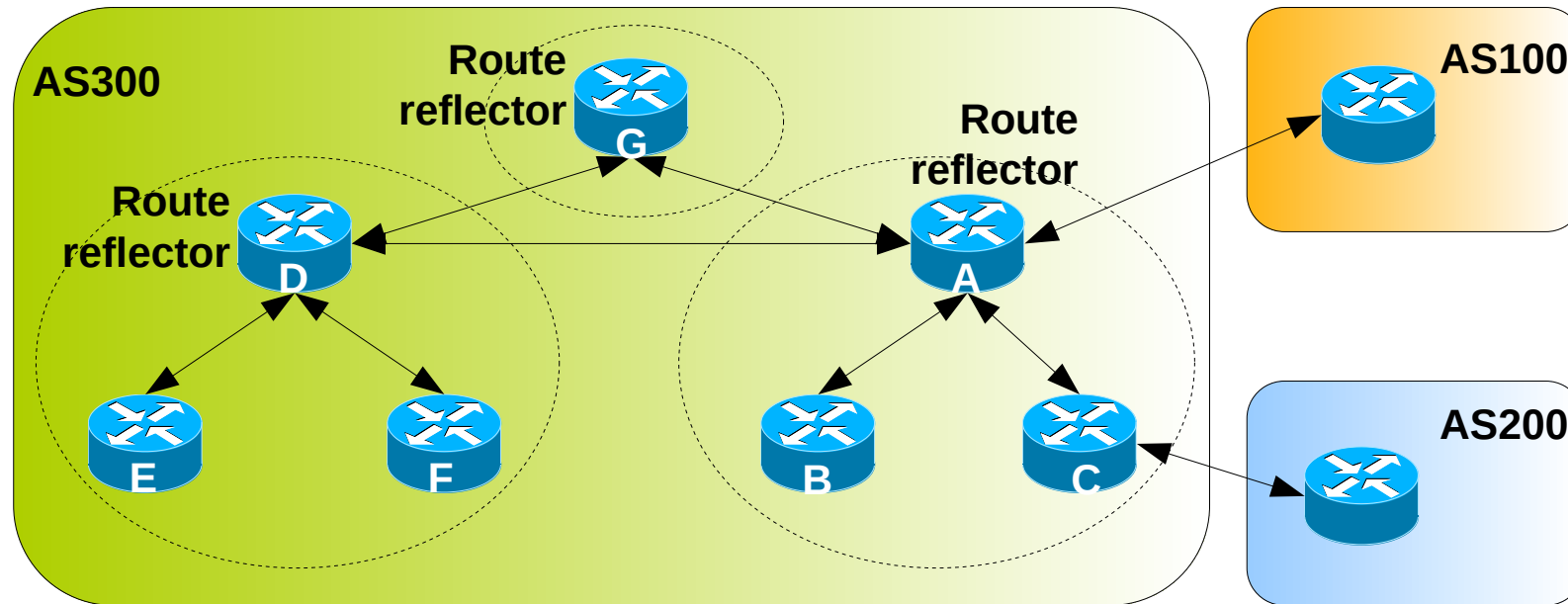


BGP Synchronization

- Synchronization states that, if your AS passes traffic from another AS to a third AS, BGP should not advertise a route before all the routers in your AS have learned about the route via IGP.
- BGP waits until IGP has propagated the route within the AS. Then, BGP advertises the route to external peers.

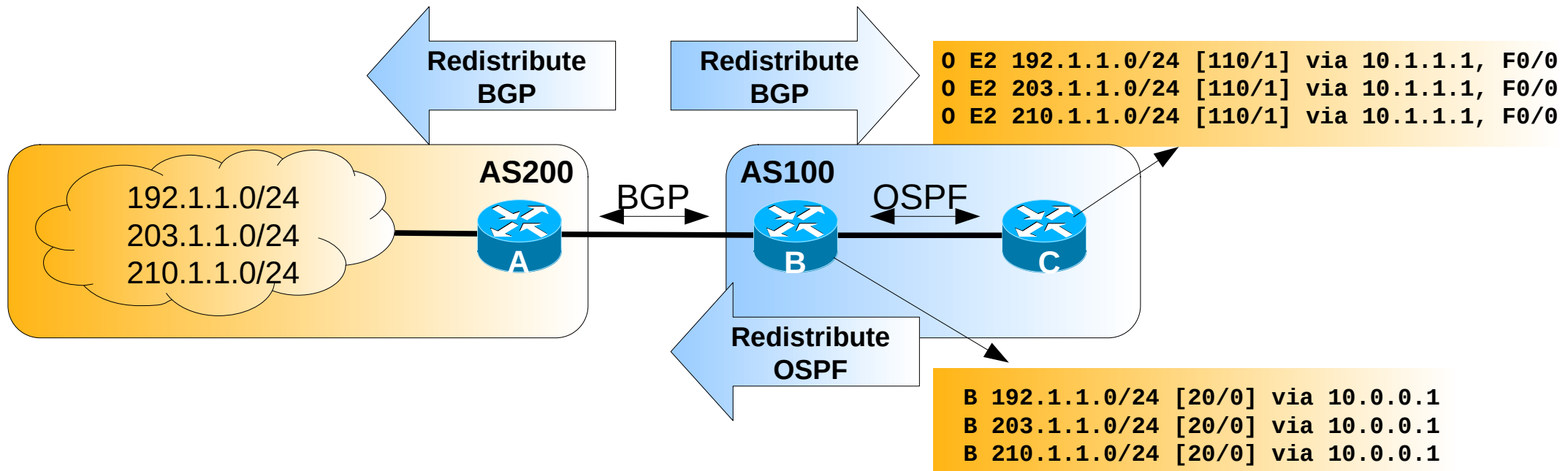


BGP Route Reflectors



- Without a route reflector, the network requires a full iBGP mesh within AS300.
- The route reflector and its clients are called a cluster.
 - Router A is configured as a route reflector, iBGP peering between Routers B and C (and others) is not required.
 - Router D is configured as a route reflector, iBGP peering between Routers E and F (and others) is not required.
- Full iBGP mesh between route reflector Routers.

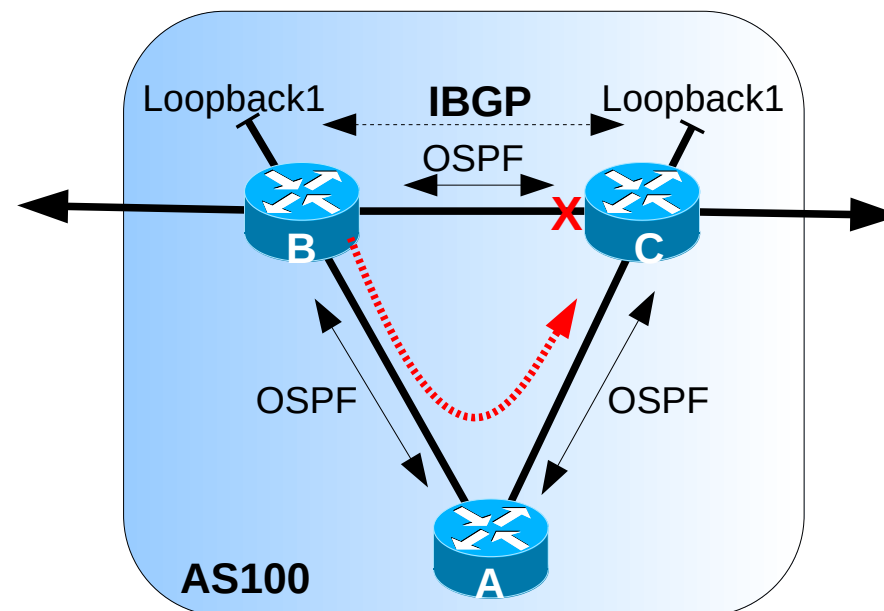
Routes Redistribution



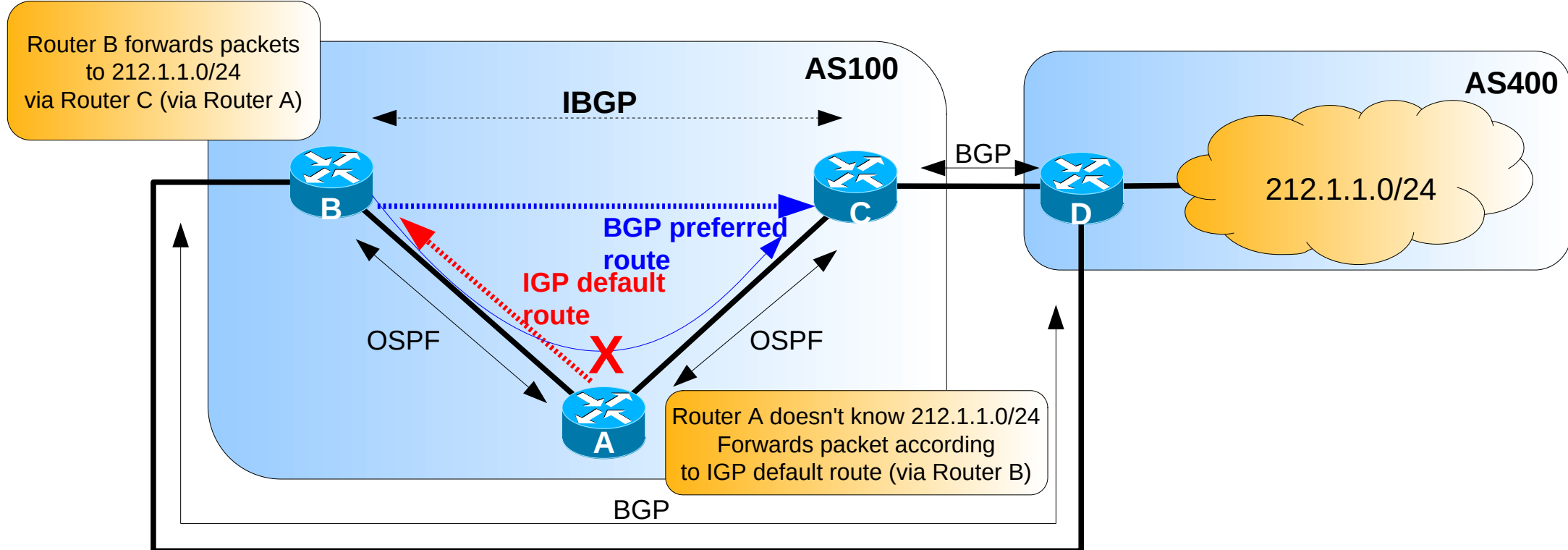
- Redistributing IGP routes by BGP will:
 - ◆ Simplify BGP configuration (advantage)
 - ◆ And BGP will announce only internal networks with connectivity (advantage)
- Redistributing BGP routes by IGP protocols will:
 - ◆ Make internal routes know all external routes (disadvantage/advantage?)
 - ◆ Increase routing tables size in internal routers (disadvantage)
 - ➔ Decrease routing time, imposes memory requirements, ...
 - ◆ Avoid the usage of internal default routes (disadvantage/advantage?)

BGP Neighborhood Resilience

- BGP neighbor relations between physical interfaces are dependent on interface stability/status
- (Virtual) neighbor relations using Loopback interfaces/addresses
 - ◆ Loopback interfaces are virtual and software based
 - ➔ If the router is active Loopback interfaces are always active
 - ◆ Neighbor relation is active while a path exists between the virtual networks
 - ➔ (Alternative) Routing provided by IGPs

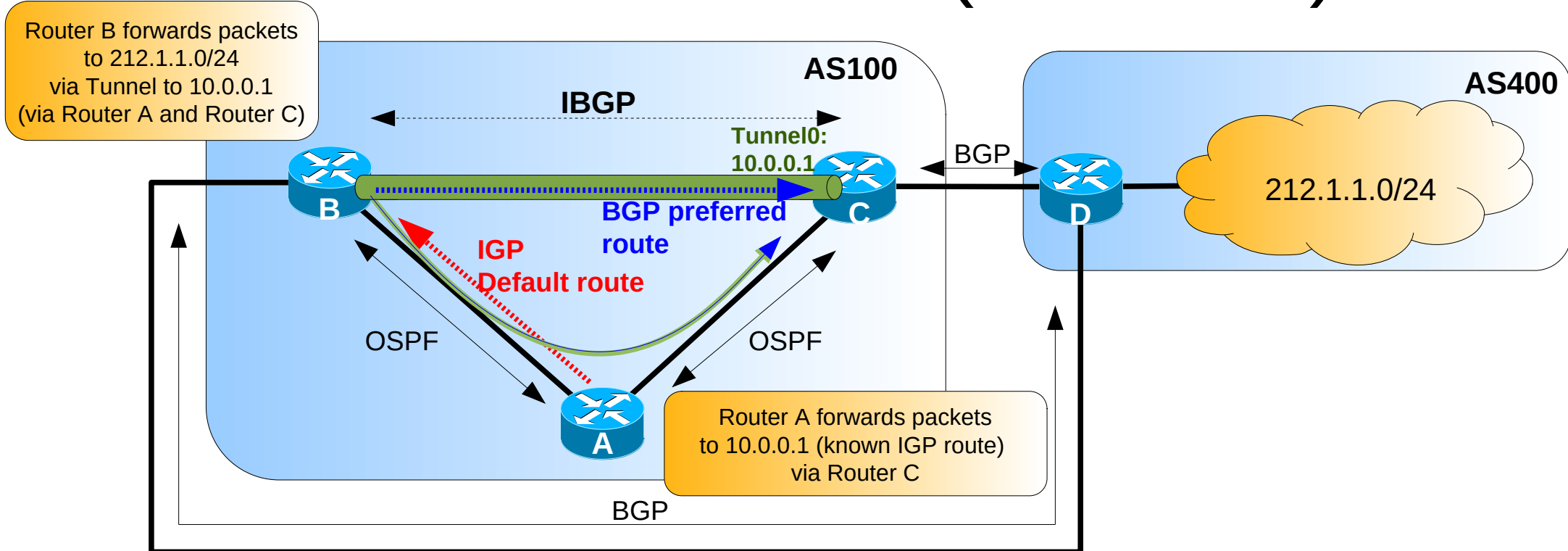


BGP and IGP conflicts



- Routing conflicts may arise with
 - Internal routers without BGP
 - No redistribution of BGP routes by IGP
 - IGP default routes
 - BGP preferred routes (with no agreement with IGP default routes)
- Solutions
 - Adjust IGP default routes
 - Adjust BGP preferred routes (e.g. with local preference)
 - BGP neighborhood and Internal routing via IP-IP tunnels

BGP over Tunnels (over IGP)



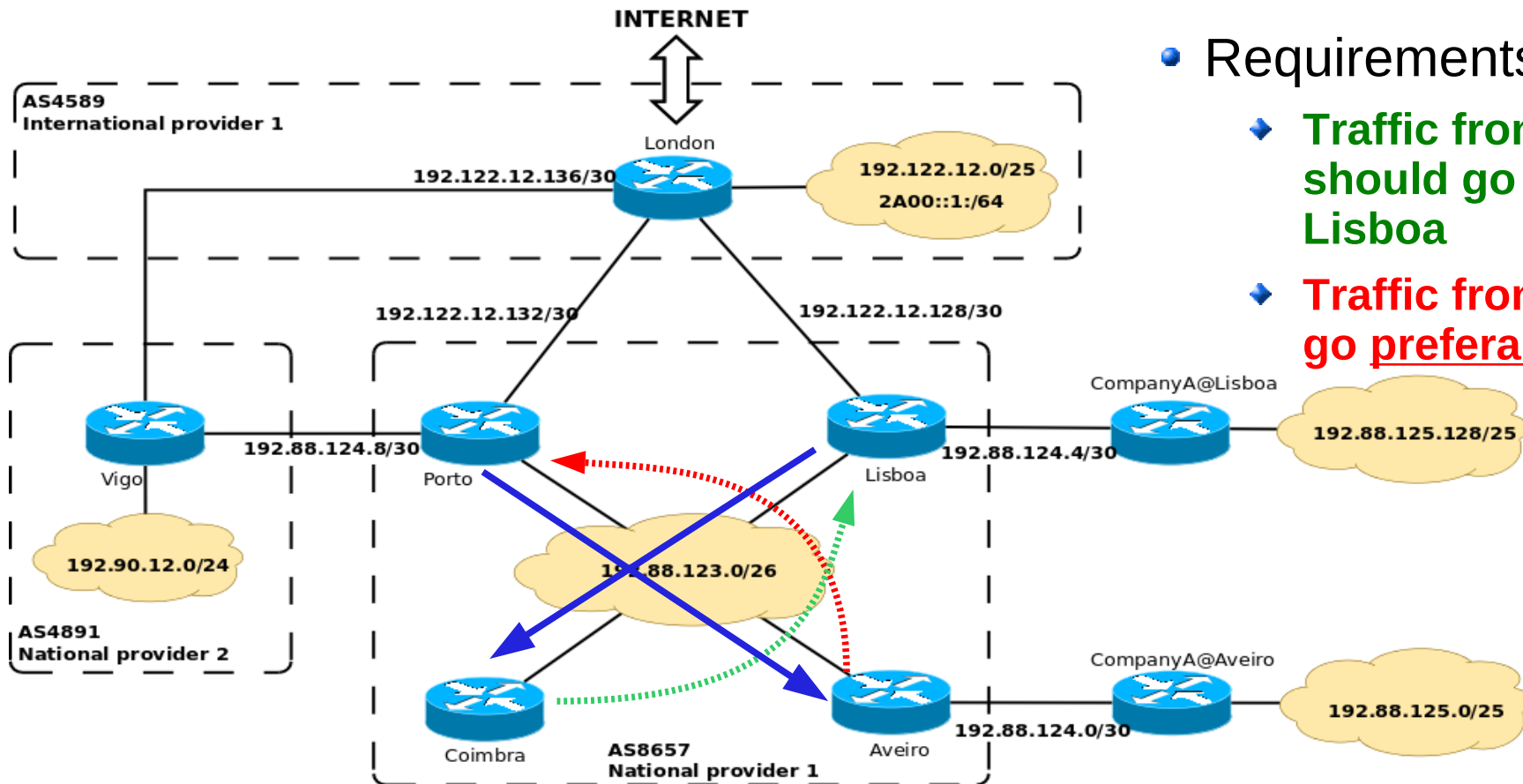
- IP-IP tunnels to solve BGP/IGP routing conflicts
 - ◆ Tunnels manually configured
 - ➔ Between physical or Loopback interfaces
 - ◆ BGP neighborhood via Tunnel
 - ◆ BGP routes learned via Tunnel (next hop is remote Tunnel end-point)
 - ◆ Tunnel “network” distributed internally via IGP
- In Router A, to any packet destined to an outside network it's forwarded via Tunnel
 - ◆ A new IP header is added, new IP destination address is the remote Tunnel end-point
 - ◆ Internally, packet is routed according to the new IP header (Tunnel end-points IP addresses)

BGP Filtering and Route Maps

- Sending and receiving BGP updates can be controlled by using a number of different filtering methods.
- BGP updates can be filtered based on:
 - ♦ Route information,
 - ♦ Path information,
 - ♦ Communities.
- Route maps are used with BGP to
 - ♦ Control and modify routing information.
 - ♦ Define the conditions by which routes are redistributed between routing domains.



BGP Case Studies



Requirements

- ♦ Traffic from Coimbra should go preferably by Lisboa
- ♦ Traffic from Aveiro should go preferably by Porto

@Porto

- ♦ Nothing to do besides peering!

@Lisboa

- ♦ Nothing to do besides peering!

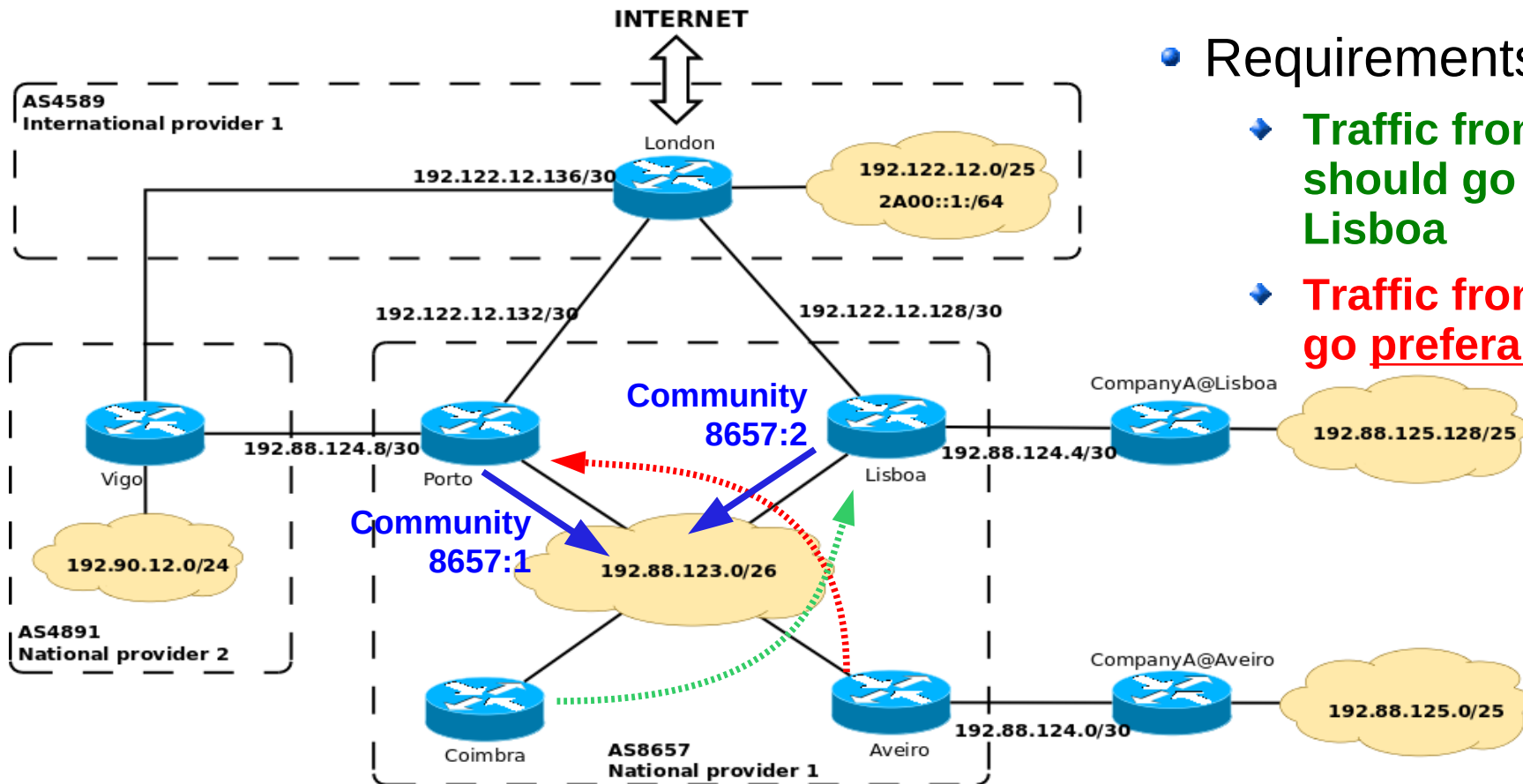
@Aveiro

- ♦ If UPDATE is from Porto → **Local-preference 200**
- ♦ If UPDATE is not from Porto → **Local-preference 100**

@Coimbra

- ♦ If UPDATE is from Lisboa → **Local-preference 200**
- ♦ If UPDATE is not from Lisboa → **Local-preference 100**

BGP Case Studies



Requirements

- ◆ Traffic from Coimbra should go preferably by Lisboa
- ◆ Traffic from Aveiro should go preferably by Porto

@Porto

- ◆ Route-map applied to all BGP announced external routes/nets
- ◆ Adds BGP attribute: **Community 8657:1**

@Lisboa

- ◆ Route-map applied to all BGP announced external routes/nets
- ◆ Adds BGP attribute: **Community 8657:2**

@Aveiro

- ◆ Route-map applied to all BGP received routes/nets
- ◆ If **Community 8657:1** → **Local-preference 200**
- ◆ If **Community 8657:2** → **Local-preference 100**

@Coimbra

- ◆ Route-map applied to all BGP received routes/nets
- ◆ If **Community 8657:1** → **Local-preference 100**
- ◆ If **Community 8657:2** → **Local-preference 200**



BGP Community Attribute (real data)

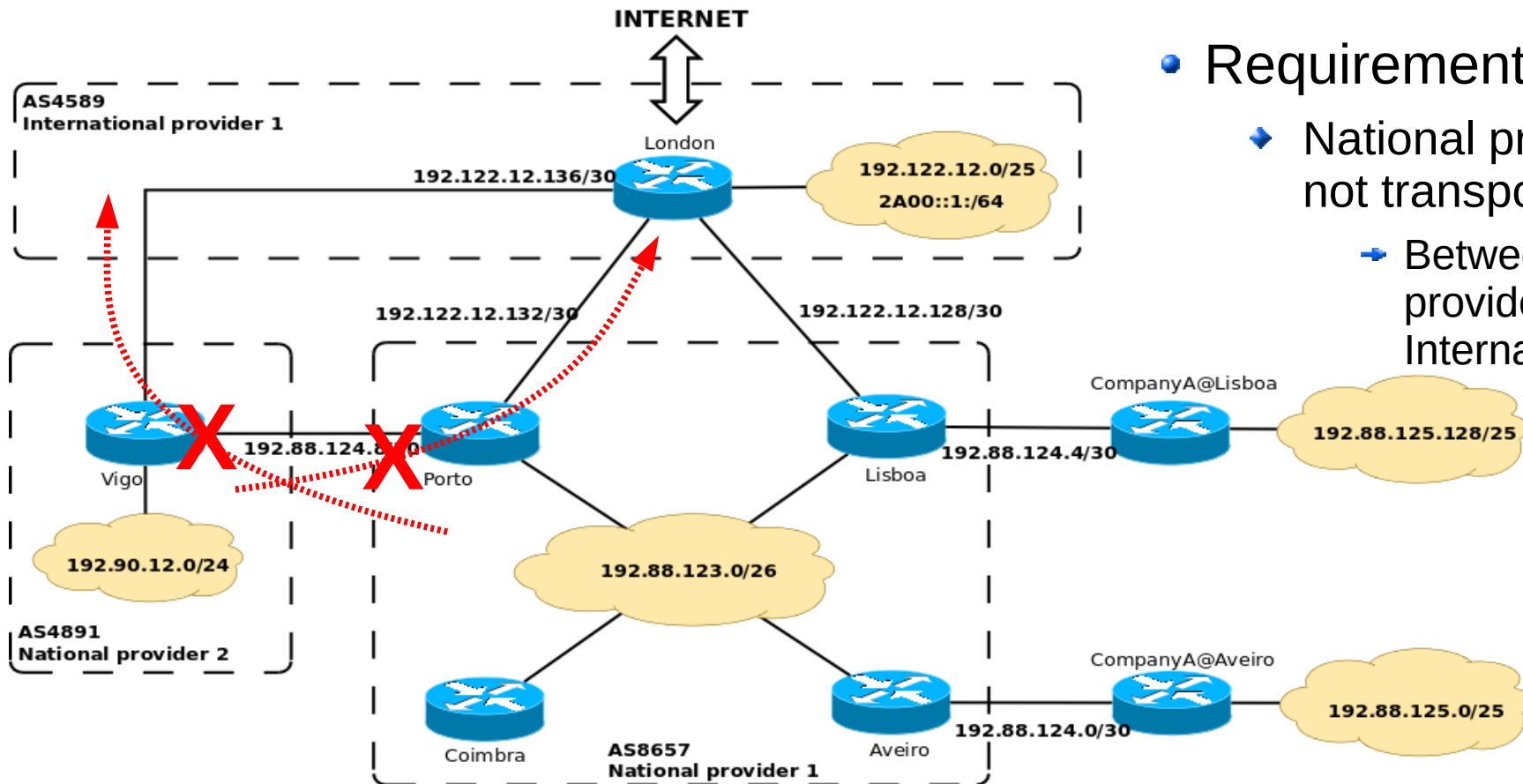
 TeliaNet Global Network

```
remarks: BGP COMMUNITY SUPPORT FOR AS1299 TRANSIT CUSTOMERS:
remarks:
remarks: Community Action
remarks: -----
remarks: 1299:50 Set local pref 50 within AS1299 (lowest possible)
remarks: 1299:150 Set local pref 150 within AS1299 (equal to peer, backup)
remarks:
remarks: European peers/ix-points    US peers/ix-points    Asia peers/ix-points
remarks: Community Action            Community Action      Community Action
remarks: -----
remarks: 1299:200x All peers Europe incl: 1299:500x All peers US incl: 1299:700x All peers Asia incl:
...
remarks: 1299:250x Sprint/1239      1299:550x Sprint/1239      -
remarks: 1299:251x Savvis/3561        1299:551x Savvis/3561      -
remarks: 1299:252x Verio/2914          1299:552x Verio/2914      -
remarks: 1299:253x Abovenet/6461       1299:553x Abovenet/6461    -
remarks: 1299:254x FT/5511             1299:554x FT/5511          1299:754x FT/5511
remarks: 1299:255x GBLX/3549           1299:555x GBLX/3549        1299:755x GBLX/3549
remarks: 1299:256x Level3/3356         1299:556x Level3/3356      -
remarks: 1299:257x UUnet/702           1299:557x UUnet/701        -
remarks: 1299:558x AT&T/7018          1299:758x AT&T/2687
remarks: 1299:259x Telefonica/12956    1299:559x Telefonica/12956  -
remarks: 1299:260x BT/Concert/5400     -                          -
remarks: 1299:261x Qwest/209           1299:561x Qwest/209        -
remarks: 1299:263x Teleglobe/6453       1299:563x Teleglobe/6453   -
remarks: 1299:264x DTAG/3320           1299:564x DTAG/3320        -
remarks: 1299:268x AOL/1668            1299:568x AOL/1668         -
remarks: 1299:269x Tiscali/3257         1299:569x Tiscali/3257     1299:769x Tiscali/3257
remarks: 1299:270x UPC/6830            -                          -
remarks: 1299:273x Cogent/174           1299:573x Cogent/174        -
remarks: 1299:274x Telecom Italia/6762  1299:574x Telecom Italia/6762 1299:774x Telecom Italia/6762
remarks: 1299:275x Tele2/1257          -                          -
...
remarks: 1299:284x Cable & Wireless DE/1273 1299:584x Cable & Wireless DE/1273 -
remarks: 1299:286x KPN/286              -                          -
remarks: 1299:287x China Netcom/4837       1299:587x China Netcom/4837 1299:787x China Netcom/4837
remarks: 1299:288x China Telecom/4134      1299:588x China Telecom/4134 1299:788x China Telecom/4134
```

From RIPE database
<https://apps.db.ripe.net/>

e.g., <https://apps.db.ripe.net/db-web-ui/#!/query?bflag=false&dflag=false&rflag=true&searchtext=as1299>

BGP Case Studies



Requirements

- ◆ National providers should not transport traffic
 - ➔ Between other national providers and the International provider

@Porto, @Lisboa

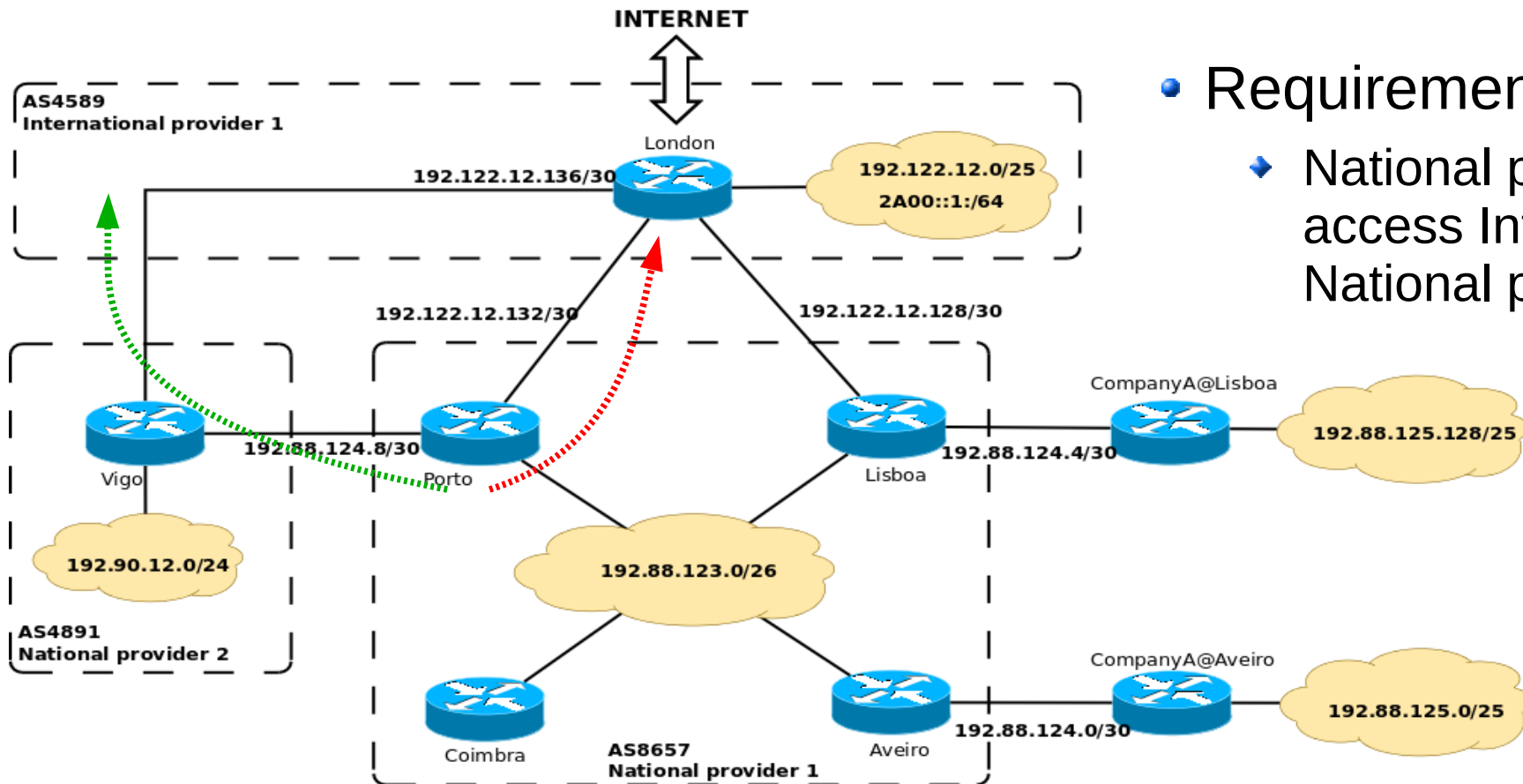
- ◆ Route-map applied to all external BGP announcements
- ◆ Announce only internal routes/nets
 - ➔ Empty path “^\$”

@Vigo

- ◆ Route-map applied to all external BGP announcements
- ◆ Announce only internal routes/nets
 - ➔ Empty path “^\$”



BGP Case Studies



- Requirements

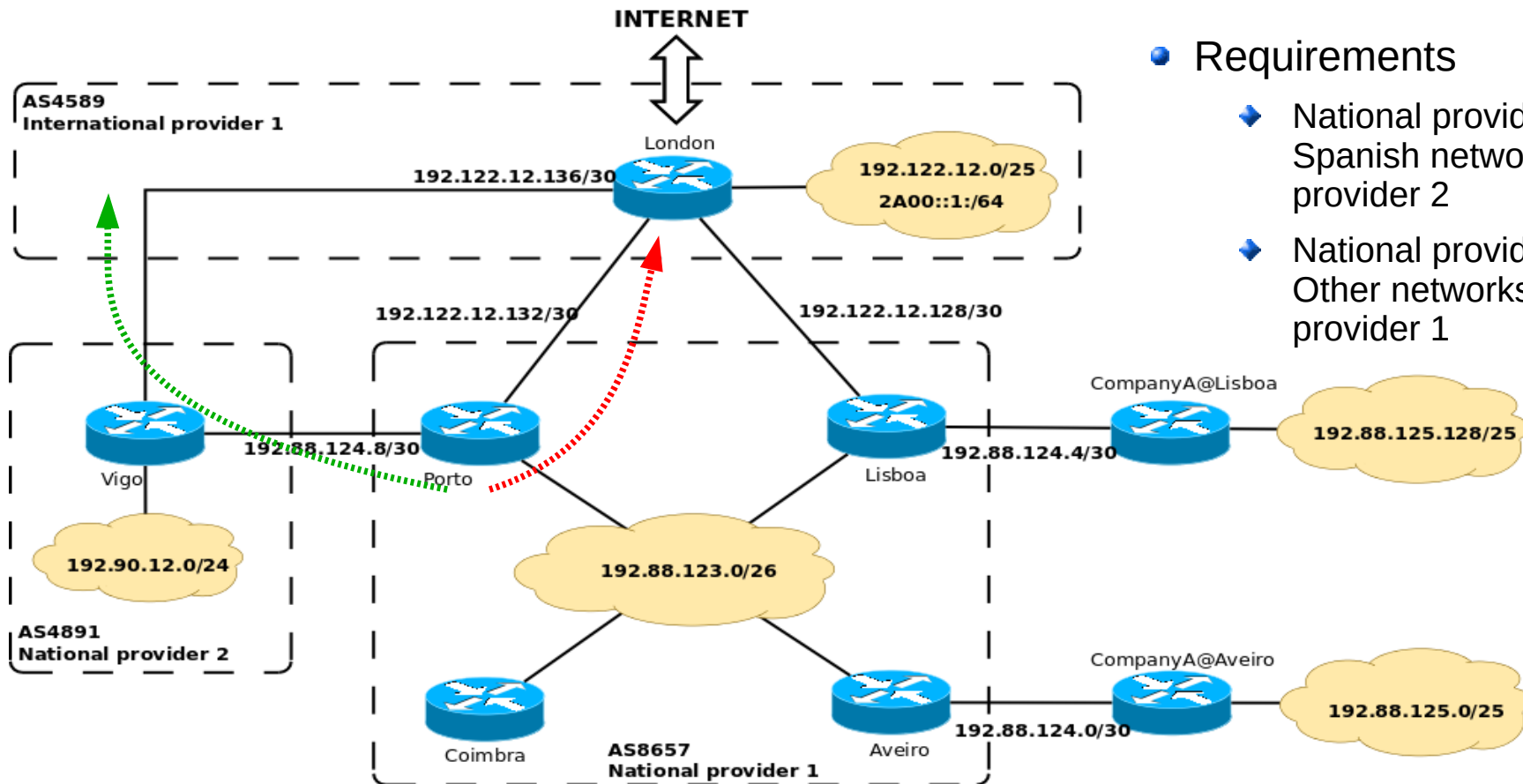
- ◆ National provider 1 should access Internet using National provider 2

- @Porto, @Lisboa

- ◆ Route-map applied to all BGP announcements received
- ◆ If Path contains “4891” → **Local-preference 200**
- ◆ If Path does not contain “4891” → **Local-preference 100**



BGP Case Studies



Requirements

- ◆ National provider 1 should access Spanish networks using National provider 2
- ◆ National provider 1 should access Other networks using International provider 1

@Porto, @Lisboa

- ◆ Route-map applied to all BGP announcements received
 - E.g. known Spanish operators AS: 4891, 7654, 9876 and 3352
- ◆ If Path starts (from right to left) with “4891\$ or 7654\$ or 9876\$ or 3352\$” and ends in “^4891” → **Local-preference 200**
- ◆ If Path does not start with “4891\$ or 7654\$ or 9876\$ or 3352\$” and ends in “^4891” → **Local-preference 50**
- ◆ Assuming default Local-preference 100.

BGP Case Studies

- Requirements

- AS104 wants to avoid paths to Net3 that use “slow” links.

