Interconnecting networks

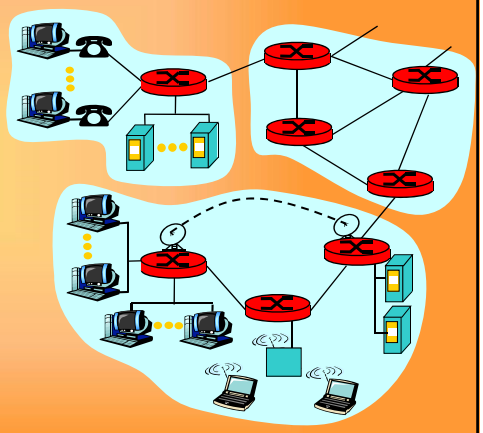
External Routing

What you should learn…

- Notion of Autonomous System
- The role and diferences of External Routing protocols
- Features of BGP
- Attributes and advanced usage of BGP

Networks: service vision

- Distributed communications infrastructure supporting applications, also potentially distributed
  - WWW, email, games, e-commerce, databases, voting
- Communications services supporting:
  - Connection-oriented
  - Connection-less
- Service platforms for millions of devices: *hosts, end-systems*
  - Pc's, workstations, servers
  - PDA's, phones, fridges...



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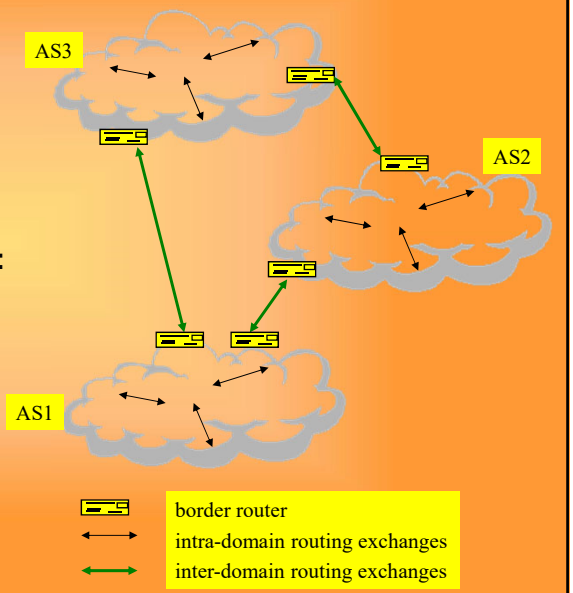
Network structure

- Administrative borders define:
  - Autonomous systems(AS)
    - **Intradomain routing**
    - Internal policies
    - Different metrics can be used on different domains protocols: RIPv2, OSPFv2
  - Interconnection of ASs
    - **Interdomain routing**
    - Connectivity information protocols: BGP



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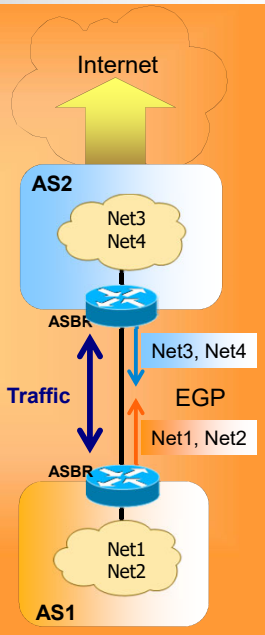
Single-homed (or Stub) AS

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

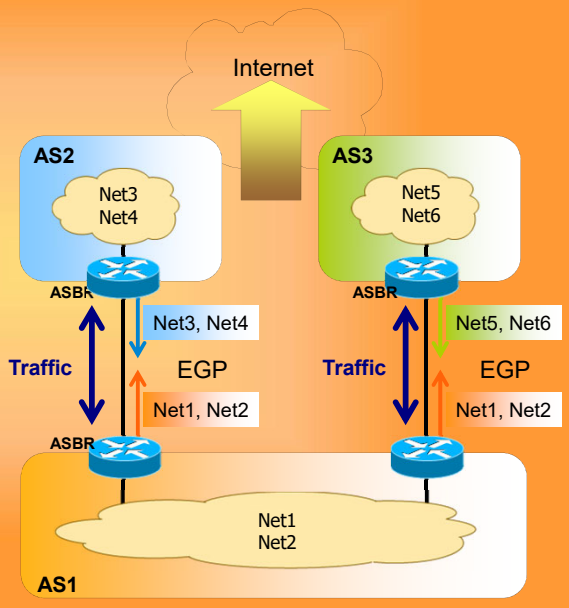
This also reflects the typical home network connection.



5

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



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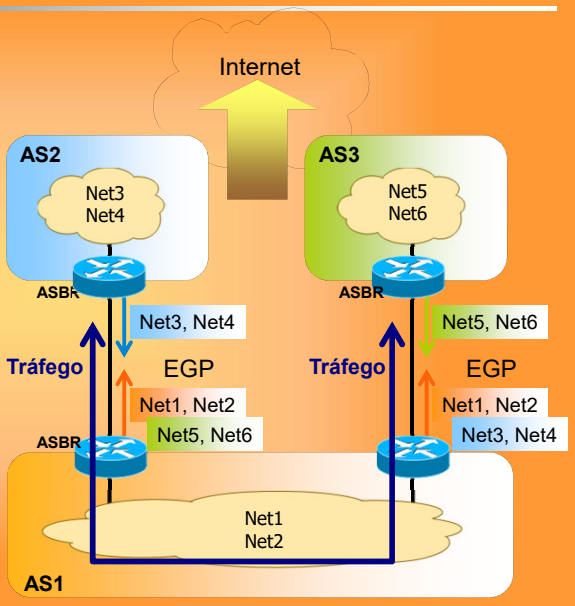
Multi-homed Transit AS

- AS has more than one border router (ASBR)
  - Multiple Internet accesses
  - Multiple ISP
- Transports traffic from other AS
- Announces networks cross-domains



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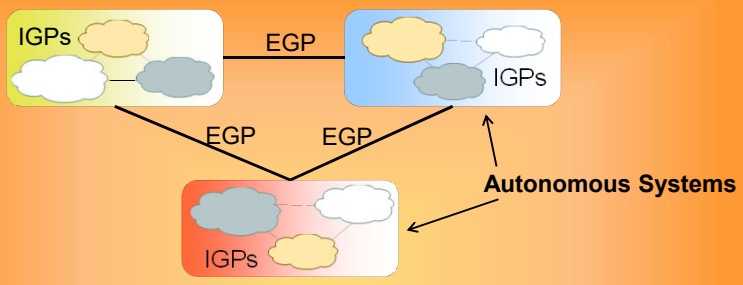
External Routing (BGP and MP-BGP)

Purpose:

If you are an operator (ISP) how do you control how your traffic flows inward (and outward) your domain?

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.
  - It has a very clear objective: provide a tool that ISPs may trust to build the Internet
  - Hint: traffic flow across links in AS correspond to different costs and profits, according with finantial agreements.
- Autonomous System (AS) is a network under a single administration
  - One (rarely more than one) network operators with a common well defined global routing policy

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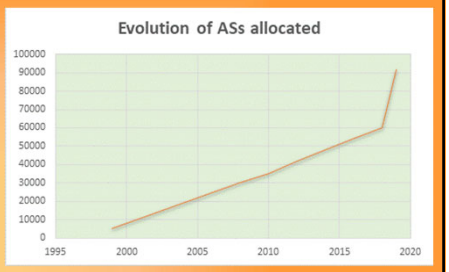
AS Numbers

- 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
    - 92000+ have already been allocated
    - We would have 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 potential AS numbers (more than 54K used in 2016)
  - As of January 1, 2009, all new Autonomous System numbers issued were 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

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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
  - Reflect contracts!!!!
- 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

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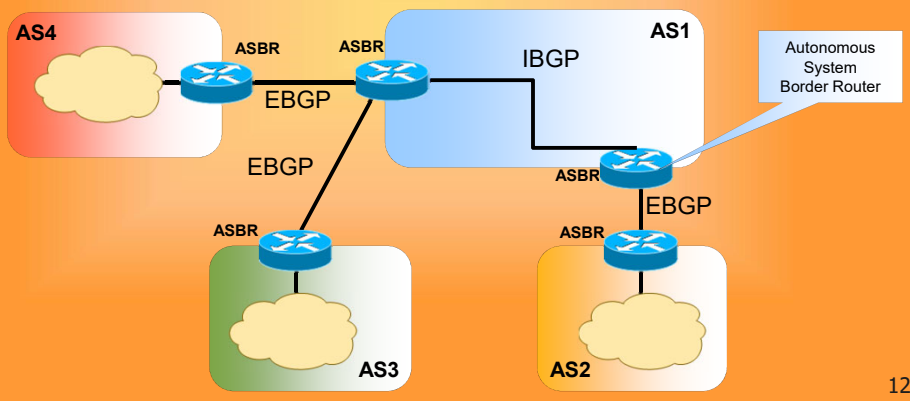
Internal BGP (IBGP) & External BGP (EBGP)

- Neighbor relations can be established between
  - Same AS routers (Internal BGP – IBGP)
    - Why? To provide information (inside the AS) about its multiple borders.
  - Different AS routers (External BGP - EBGP)
    - Why? To provide information (between ASs) on what to do.



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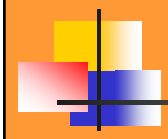

External and Internal BGP

- 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 internally an IGP, such as OSPF
    - For all the routers in the AS, not only border routers.
  - Additional methods can be used to reduce IBGP Mesh complexity
    - Route reflectors, private AS, ...

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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

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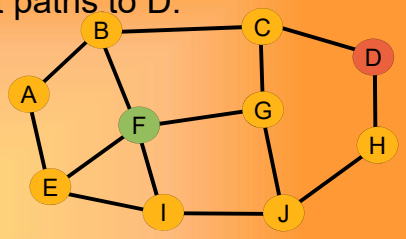
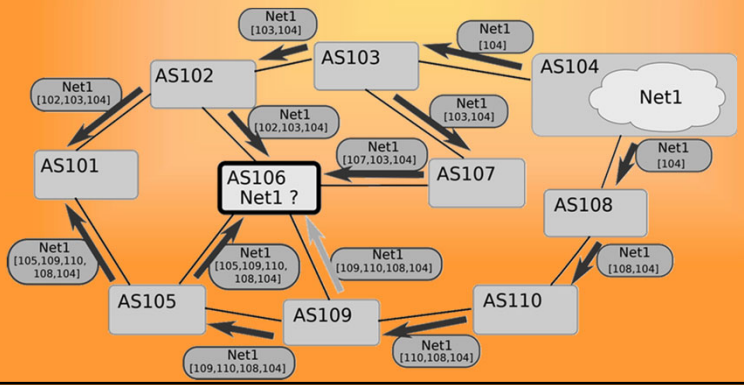
Path vectors (attribute AS_PATH)

- F receives from its neighbors different paths to D:
  - De B: “I use BCD”
  - De G: “I use GCD”
  - De I: “I use IJH”
  - De E: “I use EIJH”





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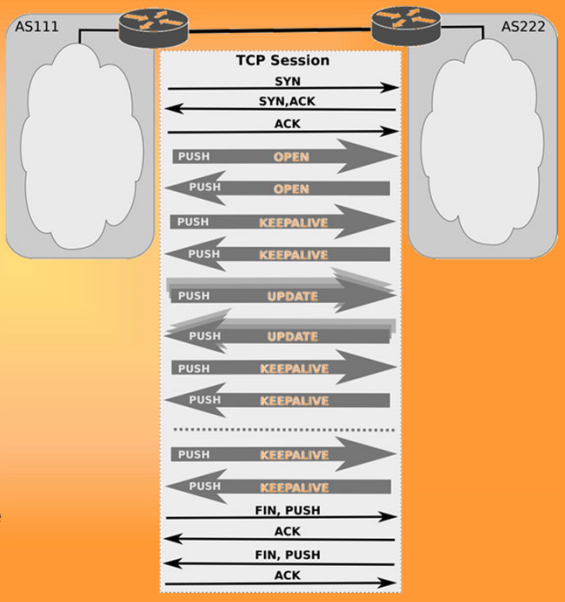
BGP Messages

- 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)
- NOTIFICATION messages are sent whenever a protocol error is detected, after which the BGP session is closed
- KEEPALIVE messages are exchanged whenever the keepalive period is exceeded, without an update being exchanged



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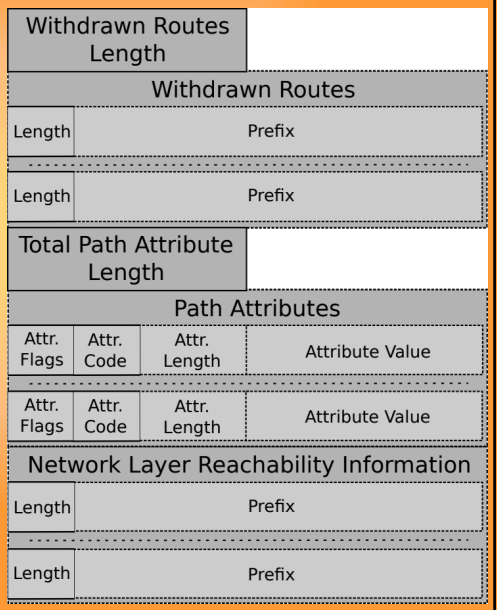
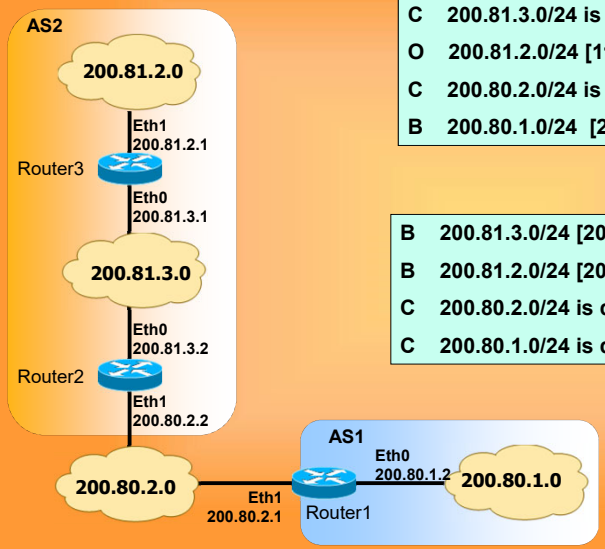
Update Message

- Widrawn 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

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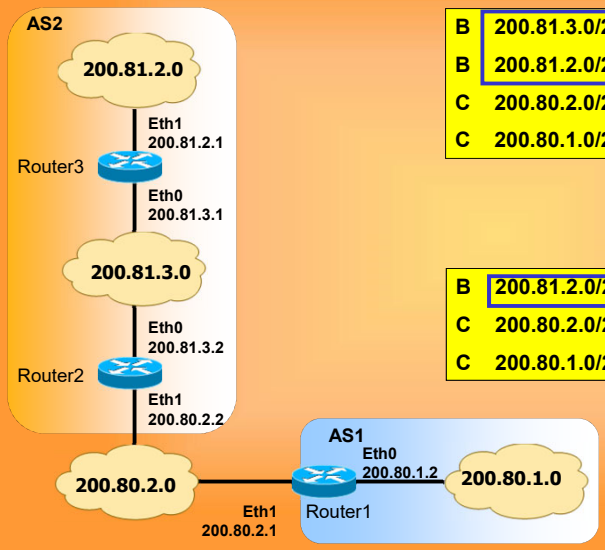
Example – BGP networks aggregation



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

Route aggregation is associated with the IP address allocation management performed globally in the Internet by ISOC.

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)
    - –Aggregator, Community, AS4_Aggregator, AS4_path.
  - 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

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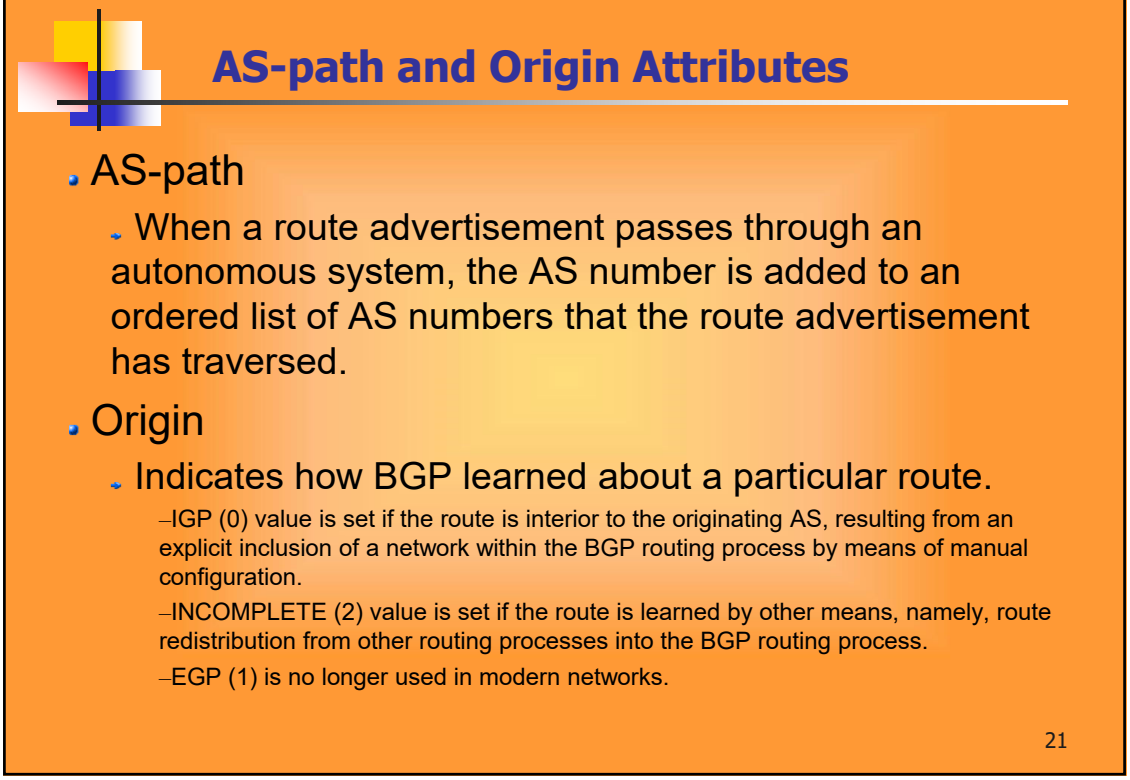

AS-path and Origin Attributes

- 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.
    - –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.

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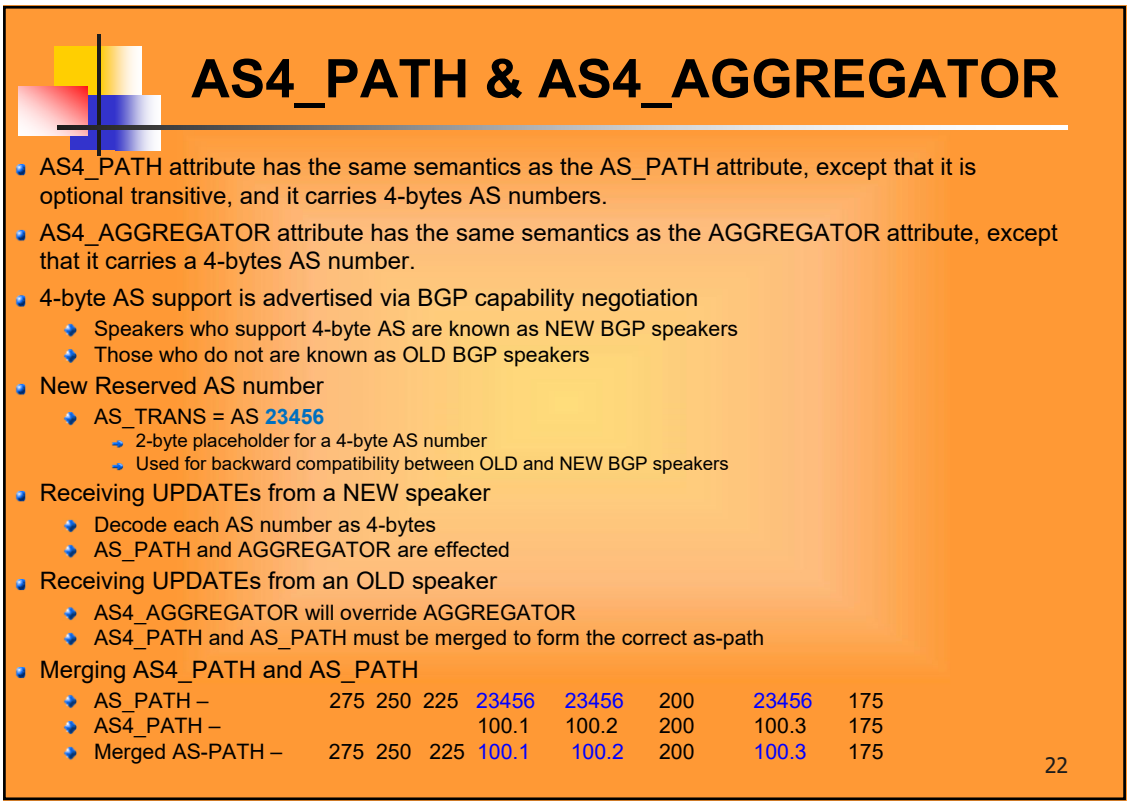

AS4_PATH & AS4_AGGREGATOR

- 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

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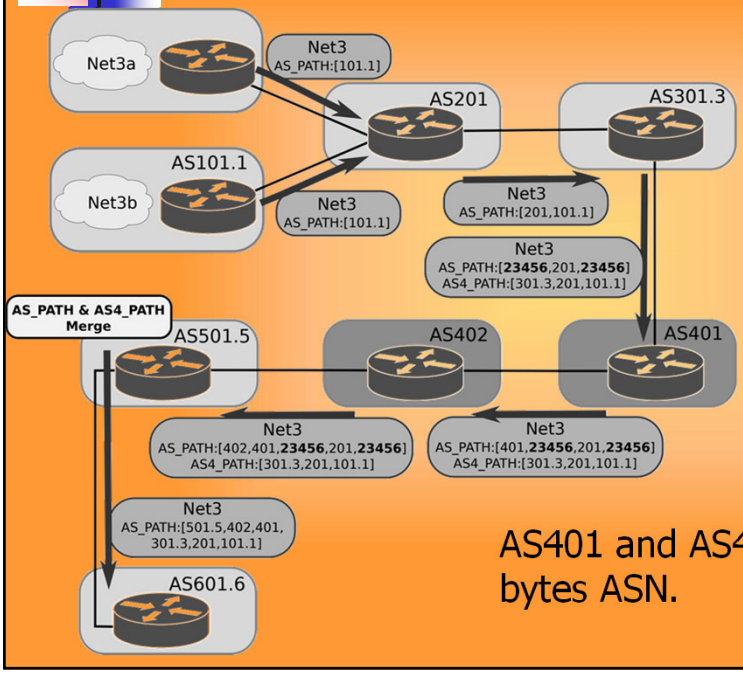
4-bytes AS Operational Example



AS401 and AS402 do not support 4-bytes ASN.

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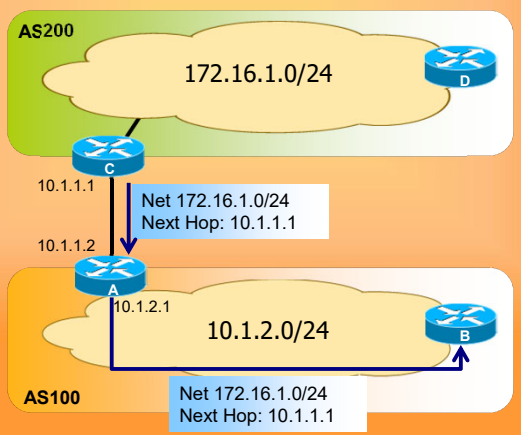
Next-Hop Attribute

- 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



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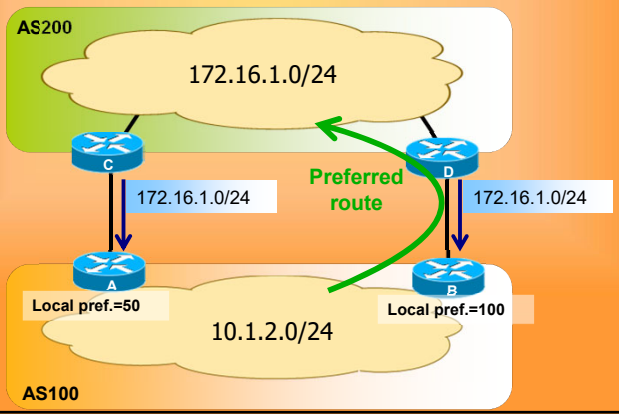
Local Preference Attribute

- The local preference attribute is used to choose an exit point from the local autonomous system (AS)
- The local preference attribute is propagated throughout the local AS
- If there are multiple exit points from the AS, the local preference attribute is used to select the exit point for a specific route



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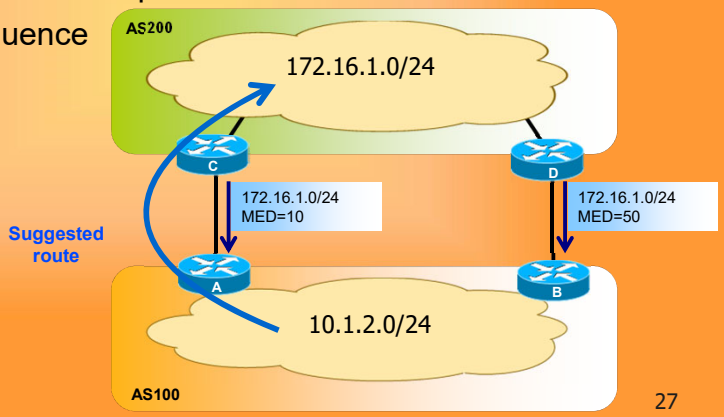
Multi-Exit Discriminator Attribute (MED)

- 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



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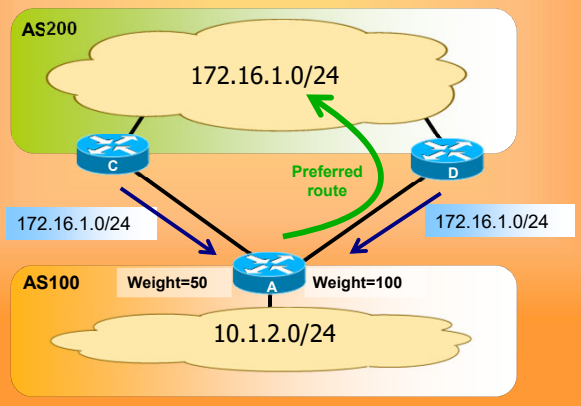
Weight Attribute

- 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.



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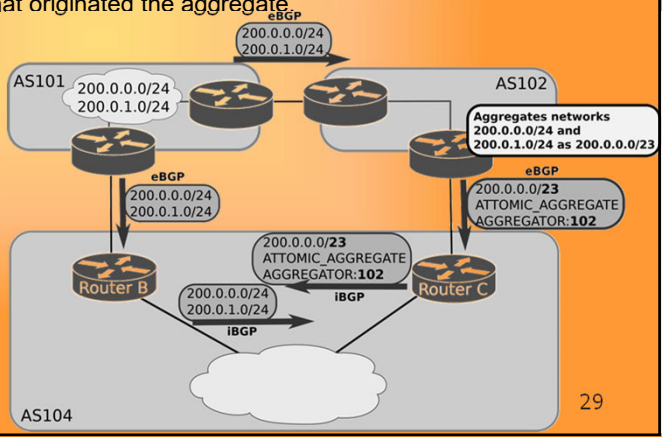
Atomic Aggregate and Aggregator Attributes

- 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.



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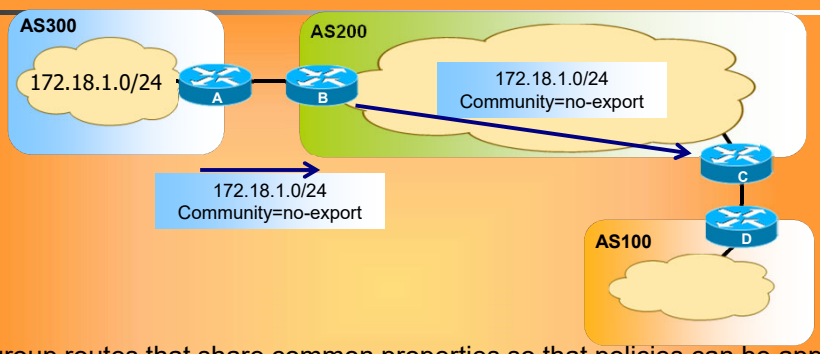
Community Attribute



- 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 *(transitive property)*
  - e.g. 300:1, 200:38, etc...

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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
  - 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

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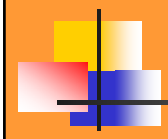

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- Features of BGP
- Attributes and advanced usage of BGP

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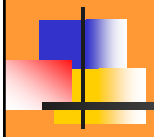

Multi-Protocol Border Gateway Protocol (MP-BGP)

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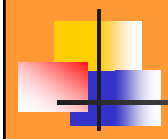

MP-BGP Description

- Extension to the BGP protocol
- Carries routing information about other protocols:
  - 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)

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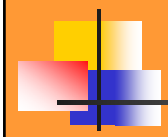

MP-BGP Attributes

- 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

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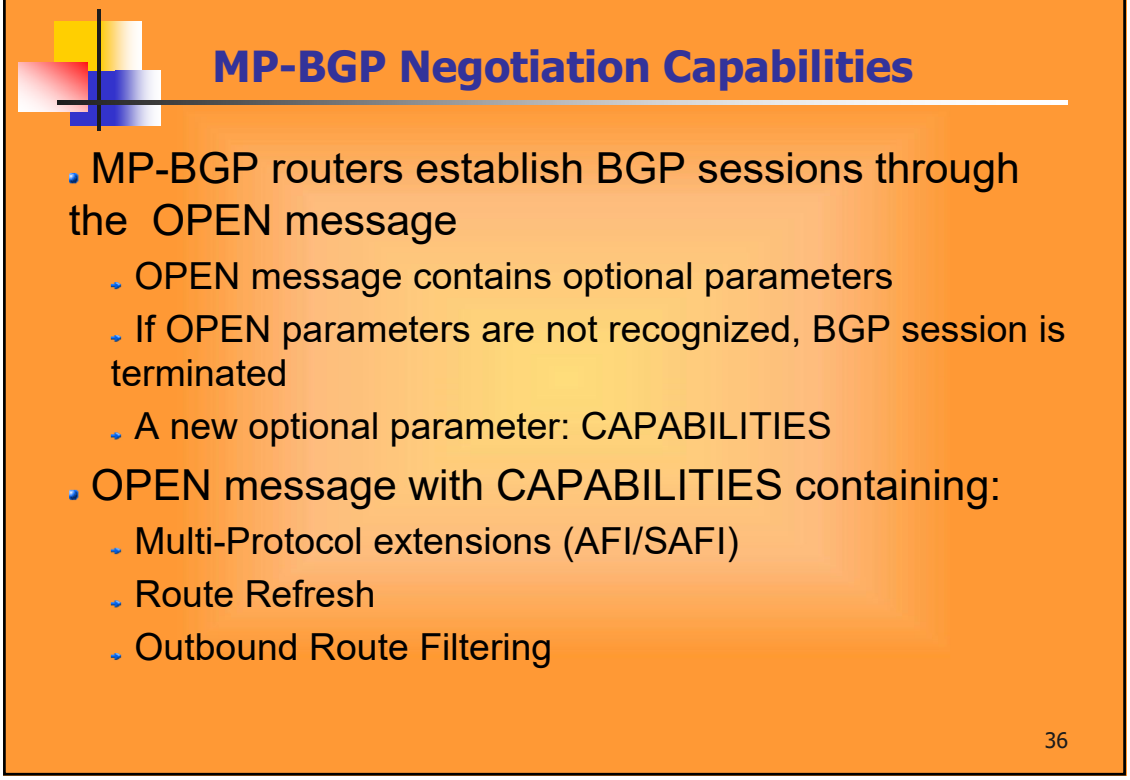
MP-BGP Negotiation Capabilities
MP-BGP routers establish BGP sessions through the OPEN message
OPEN message contains optional parameters
If OPEN parameters are not recognized, BGP session is terminated
A new optional parameter: CAPABILITIES
OPEN message with CAPABILITIES containing:
Multi-Protocol extensions (AFI/SAFI)
Route Refresh
Outbound Route Filtering
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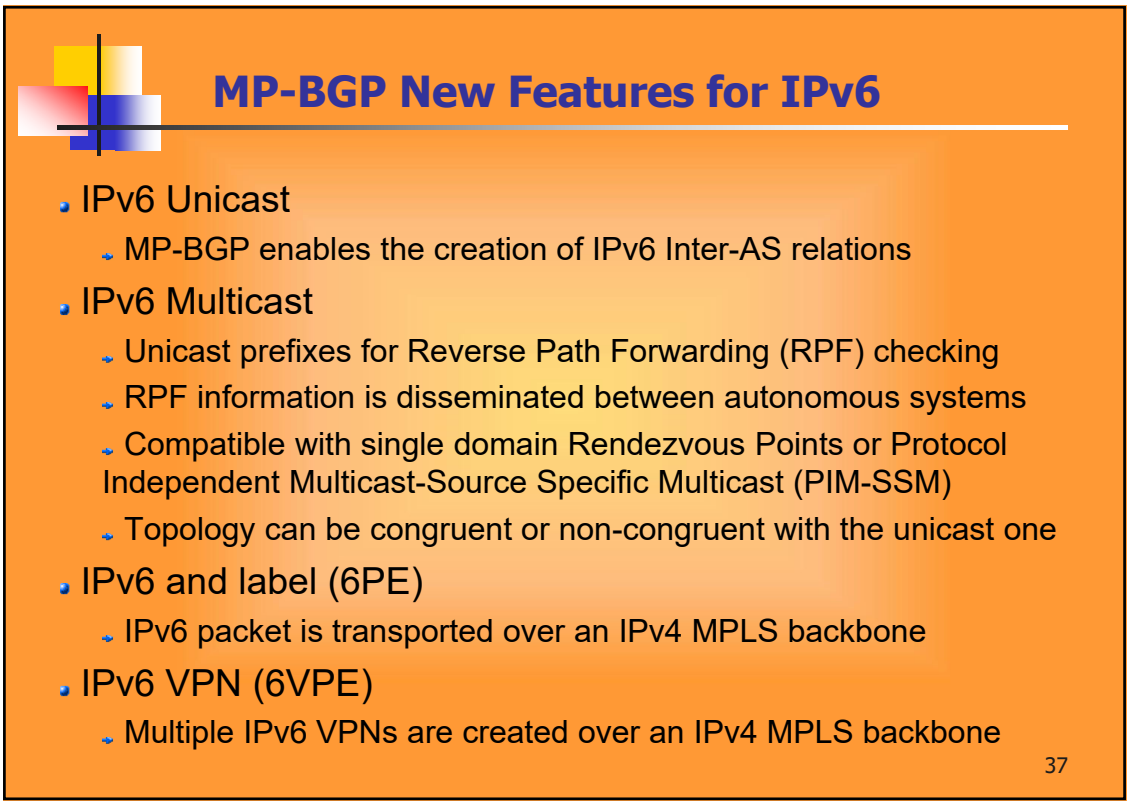
MP-BGP New Features for IPv6
IPv6 Unicast
MP-BGP enables the creation of IPv6 Inter-AS relations
IPv6 Multicast
Unicast prefixes for Reverse Path Forwarding (RPF) checking
RPF information is disseminated between autonomous systems
Compatible with single domain Rendezvous Points or Protocol Independent 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
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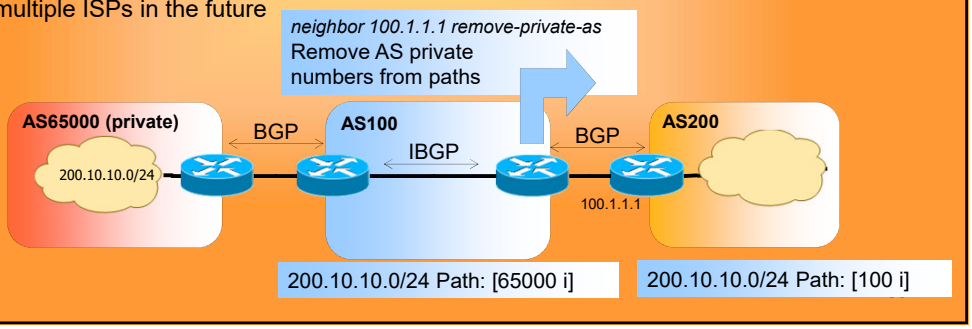
Advanced BGP

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
.....
```

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From RIPE database, http://www.db.ripe.net

Problem: 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.
  - This is a problem for large ISPs, with many ASBG
- BGP waits until IGP has propagated the route within the AS.
  - Then, BGP advertises the route to external peers.

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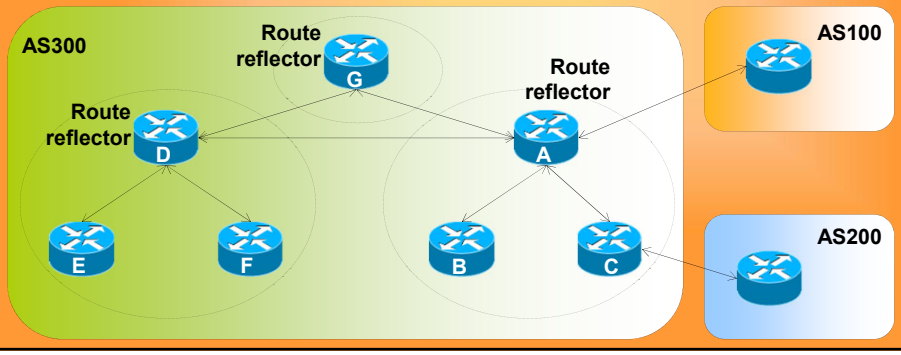
Solution: BGP Route Reflectors

- 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



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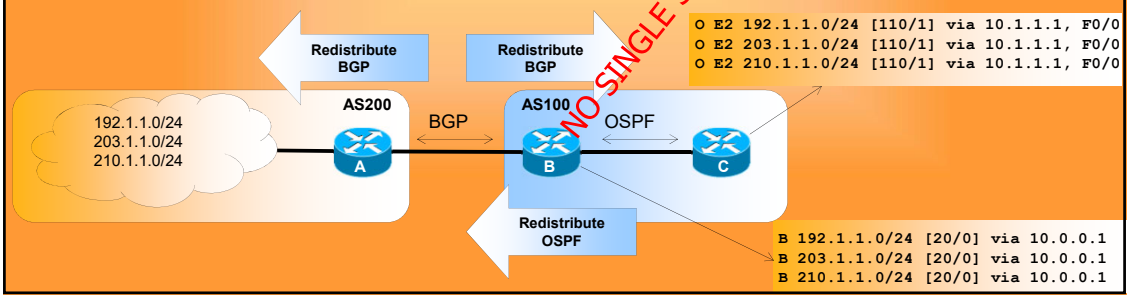
Potential Problem: Route Redistribution

A. Redistributing IGP routes by BGP will: FROM AS → Internet
- Simplify BGP configuration (advantage?)
- And BGP will announce only internal networks with connectivity (advantage?)

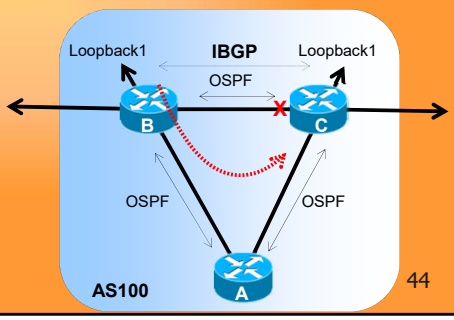
B. Redistributing BGP routes by IGP protocols will: FROM Internet → AS
- Make internal routers know all external routes (disadvantage/advantage?)
- Increase routing tables size in internal routers (disadvantage)
  - Decrease routing time, imposes memory requirements…
- Avoid the usage of internal default routes (disadvantage/advantage?)

NO SINGLE SOLUTION IS ADEQUATE EVERYWHERE



Problem: 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



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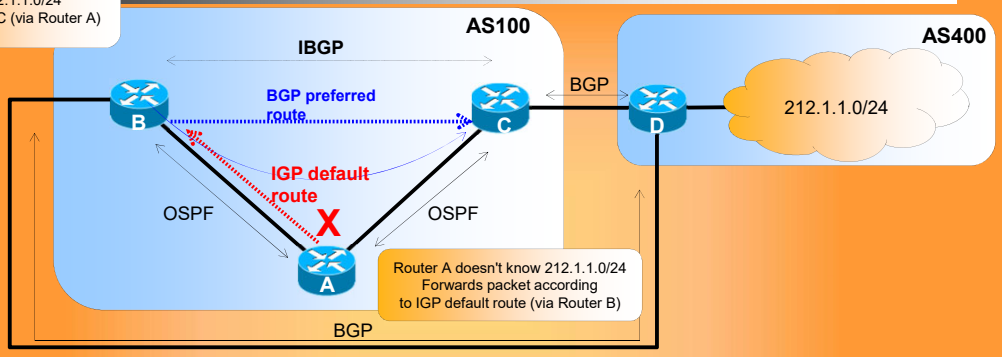
Problem: BGP and IGP conflicts

Router B forwards packets to 212.1.1.0/24 via Router C (via Router A)



- 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

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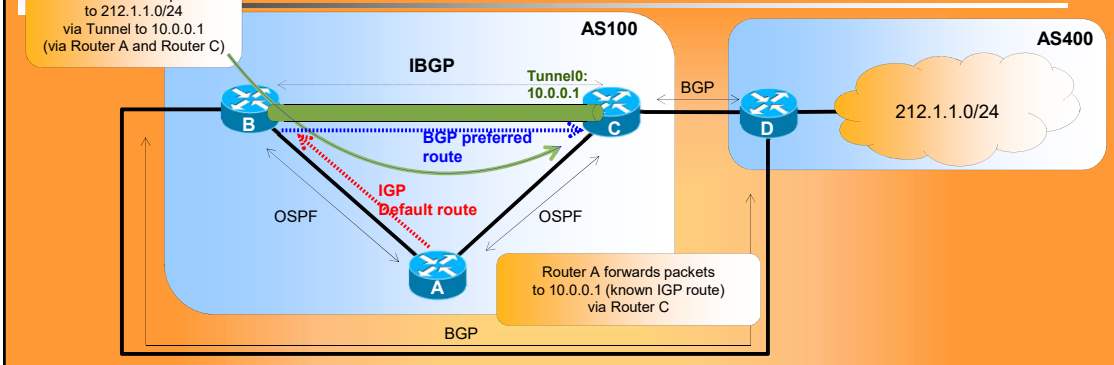
Solution: BGP over Tunnels (over IGP)



- 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)

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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

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BGP Case Studies

- Next slides highlight potential solutions to diferent sets of requirements in ISP- and corporation-oriented scenarios

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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
http://www.db.ripe.net

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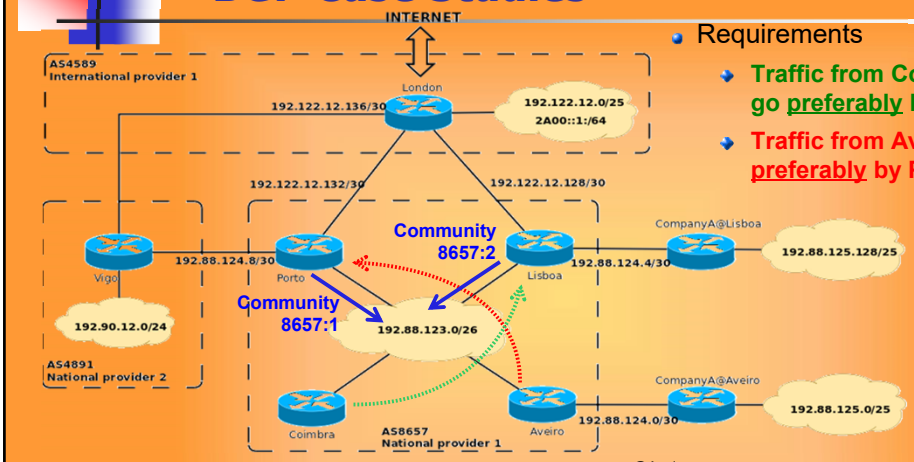
BGP Case Studies



- 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

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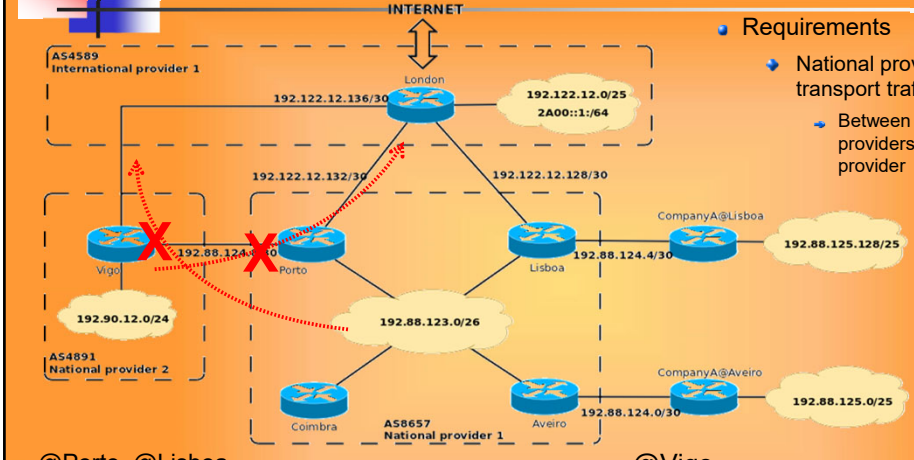
BGP Case Studies



- 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 "^$"

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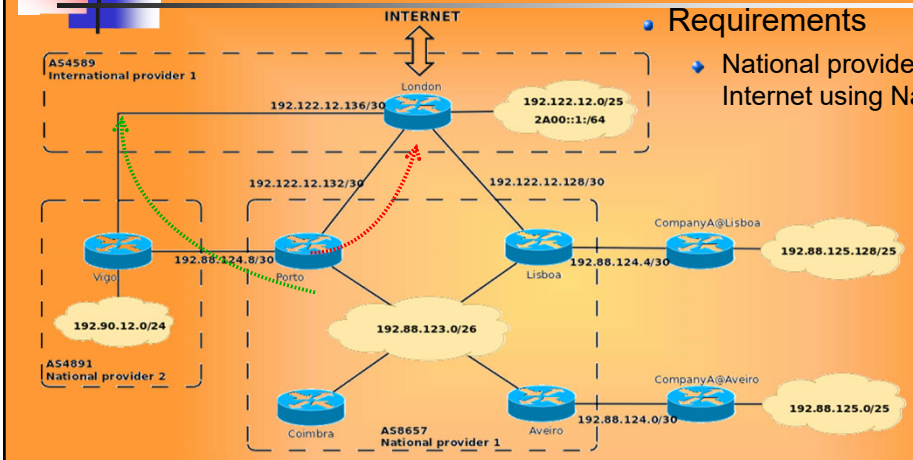
BGP Case Studies



- 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**

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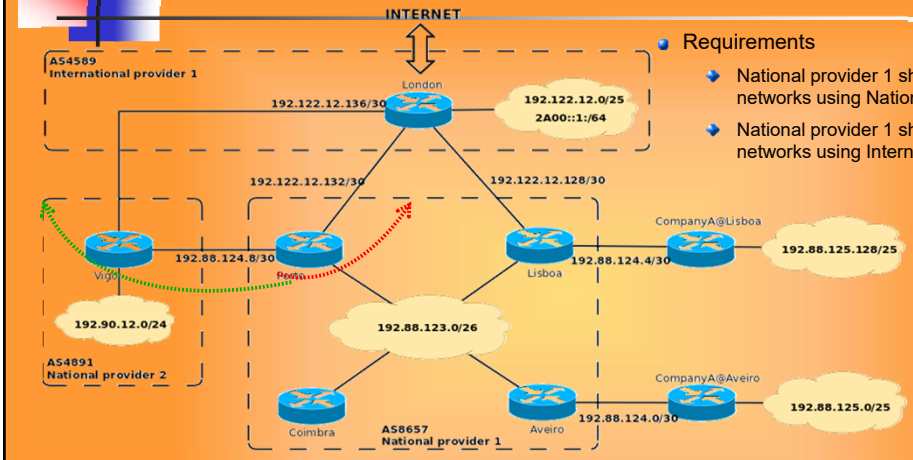
BGP Case Studies



- 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 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**
  - If Path ends in “4589$” → **Local-preference 100**

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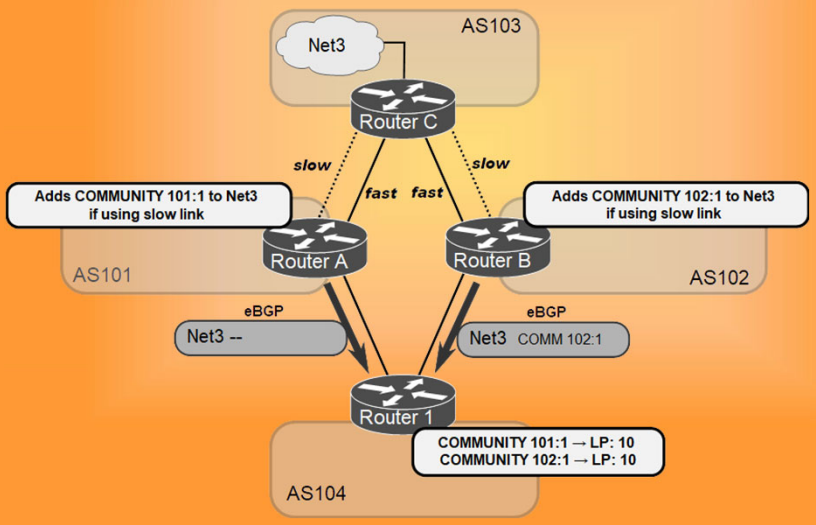
BGP Case Studies

- Requirements
  - AS104 wants to avoid paths to Net3 that use "slow" links.



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