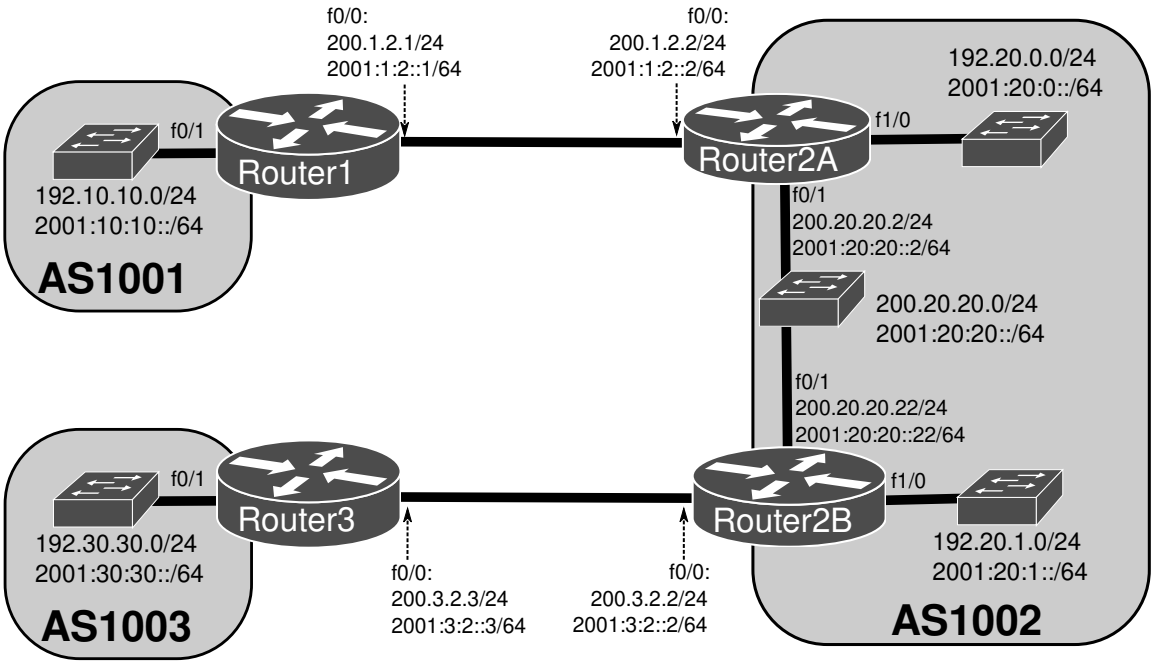
universidade de aveiro
theoria poiesis praxis

Arquitetura de Comunicações

Introduction to BGP



1. Assemble and configure (**only IPv4 addresses**) the above depicted network with three Autonomous Systems (AS). The internal routing protocol in AS1002 is OSPF (network 192.20.0.0/24 is not included in the process). The AS exchange routes using BGP. Using the following commands configure the BGP routing process:

```
Router1(config)# router bgp 1001
Router1(config-router)# neighbor 200.1.2.2 remote-as 1002
Router1(config-router)# network 192.10.10.0
---
Router2A(config)# interface f0/1
Router2A(config-if)# ip ospf 1 area 0
Router2A(config)# router bgp 1002
Router2A(config-router)# neighbor 200.1.2.1 remote-as 1001
Router2A(config-router)# neighbor 200.20.20.22 remote-as 1002
Router2A(config-router)# redistribute ospf 1
Router2A(config-router)# network 192.20.0.0        !Explicit inclusion. Not in OSPF 1.
---
Router2B(config)# interface f0/1
Router2B(config-if)# ip ospf 1 area 0
Router2B(config)# interface f1/0
Router2B(config-if)# ip ospf 1 area 0
Router2B(config)# router bgp 1002
Router2B(config-router)# neighbor 200.3.2.3 remote-as 1003
Router2B(config-router)# neighbor 200.20.20.2 remote-as 1002
Router2B(config-router)# redistribute ospf 1
---
Router3(config)# router bgp 1003
Router3(config-router)# neighbor 200.3.2.2 remote-as 1002
Router3(config-router)# network 192.30.30.0
```

Understand/explain the purpose of all commands. Using the following commands verify the state of the BGP routing processes:

```
Router1# show bgp summary
Router1# show ip route
Router1# show ip bgp          !Verify Network (valid * and best >), Next Hop and Path
```

>> What can you conclude about the connectivity obtained? All routers know all networks of all AS?

2. After analyzing the BGP process **in Routers 2A and 2B** (`show ip bgp`) and their routing table (`show ip route`).

>> Why routes to some networks are missing?

>> Why some routes are marked as valid in the BGP table, but not chosen as best and not placed on the routing table?

>> Identify the next-hop of all BGP routes, and explain why some routes cannot be activated.

>> How the BGP's **NEXT-HOP attribute** (from an external route) is propagated inside the AS?

Note: Inter-AS networks are commonly not included in any routing process, they are transit networks that only exist to provide connectivity between peers.

3. Override the way BGP's **NEXT-HOP attribute** is propagated inside the AS1002 by re-configuring the IBGP neighbor relations:

```
Router2A(config)# router bgp 1002
Router2A(config-router)# neighbor 200.20.20.22 next-hop-self
...
Router2B(config)# router bgp 1002
Router2B(config-router)# neighbor 200.20.20.2 next-hop-self
```

Reset the BGP routing processes (clear ip bgp *) and wait for the BGP processes reestablishment.

Verify and analyze the state of the routing process **in Routers 2A and 2B (**show ip route, show ip bgp**)**.
>> What can you conclude about the connectivity obtained and how the BGP's **NEXT-HOP attribute** is now propagated inside the AS?

>> Explain the differences of the administrative distance of networks learned via BGP.

>> Identify the path vector (**AS-PATH attribute**) of each route learned via BGP, namely, the AS number order.

Note: Inter-AS networks are commonly not included in any routing process, they only exist to provide connectivity between peers.

4. Start two packet captures on links Router1-Router2A and Router3-Router2B, reset the BGP routing processes (clear ip bgp *) and wait for the BGP processes reestablishment.

Analyze the content of the captured BGP packets (and associated TCP acknowledgments) and identify the BGP packet types, their purposes and periodicity.

>> What can you conclude about the established BGP neighbor relations are created and how BGP packets are exchanged?

>> Explain the purpose of **OPEN** and **KEEPALIVE** BGP messages.

>> Identify the exchanged **UPDATE** BGP messages and explain how are they exchanged.

>> Explain how IPv4 routes are announced to remote BGP peers by analyzing the **UPDATE** messages and the **NLRI** field of each one.

>> Identify and explain the purpose of the path attributes sent within **UPDATE** BGP messages with a **NLRI** field.

>> Identify the path attribute **NEXT-HOP** and explain their values.

>> Identify an **UPDATE** BGP message with a path attribute **AS-PATH** with more than one AS number and explain its purpose and the order of the AS numbers on the path.

>> Identify **UPDATE** BGP messages with path attributes **ORIGIN** with different values. Explain the reason for the IGP or INCOMPLETE values.

Note: routers may send an empty UPDATE BGP message (no NLRI and no Withdrawn Routes) to notify its peer that (at the moment) it has sent all known networks. It is known as End-of-RIB marker.

5. While capturing packets on link R1-R2A, disable Router 3's f0/1 interface (`shutdown`) to simulate a link failure. Wait a couple of minutes, and enable again the interface (`no shutdown`) .

Analyze the captured **UPDATE** BGP messages.

>> Explain how a network unreachability is announced to a BGP peer (check **Withdrawn Routes** field).

>> Explain also how a newly available network is announced to a BGP peer.

6. While capturing packets on link R1-R2A, change in Routers 2A and 2B BGP configurations in order that networks 192.20.0.0/24 and 192.20.1.0/24 are announced one as an aggregate:

```
Router2A(config)# router bgp 1002
Router2A(config-router)# aggregate-address 192.20.0.0 255.255.254.0 summary-only
...
Router2B(config)# router bgp 1002
Router2B(config-router)# aggregate-address 192.20.0.0 255.255.254.0 summary-only
```

Analyze the routing tables of all routers and the captured **UPDATE** BGP messages.

>> Explain how the network aggregate is announced to the the BGP peers (identify the relevant BGP attributes **AGGREGATTOR** and **ATOMIC_AGGREGATOR**).

>> Identify the main advantage of network aggregates.

Note: Routers 2A and 2B create a dummy routing table entry for the aggregated network (0.0.0.0 next-hop and Null output interface). This is required to allow its announcement via BGP.

7a. While capturing packets on link R1-R2A and with the networks aggregation active, disable Router 2B's f1/0 interface (`shutdown`) to simulate a link failure. Wait a couple of minutes.

Analyze the routing and BGP tables on Router2A to verify that network 192.20.1.0/24 is not known now. Also, analyze the routing and BGP tables on Router1.

>> Explain why no **UPDATE** BGP messages were captured and Router 1 does not know that network 192.20.1.0/20 is not accessible.

7b. While still capturing packets on link R1-R2A and with the networks aggregation active, disable now Router 2A's f1/0 interface (`shutdown`) to simulate a second link failure (network 192.20.0.0/24).

Analyze the routing and BGP tables on Router1.

>> Explain the captured **UPDATE** BGP messages.

>> Identify the main disadvantage of network aggregates.

Enable Router 2A's f1/0 interface and Router 2B's f1/0 interface (`no shutdown`) to restore the networks.

Introduction to MP-BGP

8. **Configure the network IPv6 addresses** and activate IPv6 routing (`ipv6 unicast-routing`). Delete the previous configured BGP processes and reconfigure new BGP processes to support simultaneously IPv4 and IPv6 network announcements (over IPv4 and IPv6, respectively) using MP-BGP address family specific configurations. AS1002 IPv6 internal routing protocol should be OSPFv3.

```
Router1(config)# no router bgp 1001
Router1(config)# router bgp 1001
Router1(config-router)# address-family ipv4 unicast
Router1(config-router-af)# neighbor 200.1.2.2 remote-as 1002
Router1(config-router-af)# network 192.10.10.0
Router1(config-router-af)# address-family ipv6 unicast
Router1(config-router-af)# neighbor 2001:1:2::2 remote-as 1002
Router1(config-router-af)# network 2001:10:10::/64
---
Router2A(config)# interface FastEthernet0/1
Router2A(config-if)# ipv6 ospf 1 area 0        !Activates OSPFv3 for this interface.
Router2A(config)# no router bgp 1002
Router2A(config)# router bgp 1002
Router2A(config-router)# address-family ipv4 unicast
Router2A(config-router-af)# neighbor 200.1.2.1 remote-as 1001
Router2A(config-router-af)# neighbor 200.20.20.22 remote-as 1002
Router2A(config-router-af)# neighbor 200.20.20.22 next-hop-self
Router2A(config-router-af)# redistribute ospf 1
Router2A(config-router-af)# network 192.20.0.0
Router2A(config-router-af)# address-family ipv6 unicast
Router2A(config-router-af)# neighbor 2001:1:2::1 remote-as 1001
Router2A(config-router-af)# neighbor 2001:20:20::22 remote-as 1002
Router2A(config-router-af)# neighbor 2001:20:20::22 next-hop-self
Router2A(config-router-af)# redistribute ospf 1
Router2A(config-router-af)# network 2001:20:0::/64      !Not in OSPF 1.
Router2A(config-router-af)# network 2001:20:20::/64     !Not added via the OSPF process
---
Router2B(config)# interface FastEthernet0/1
Router2B(config-if)# ipv6 ospf 1 area 0           !Activates OSPFv3 for this interface.
Router2B(config-if)# interface FastEthernet1/0
Router2B(config-if)# ipv6 ospf 1 area 0           !Activates OSPFv3 for this interface.
Router2B(config)# no router bgp 1002
Router2B(config)# router bgp 1002
Router2B(config-router)# address-family ipv4 unicast
Router2B(config-router-af)# neighbor 200.3.2.3 remote-as 1003
Router2B(config-router-af)# neighbor 200.20.20.2 remote-as 1002
Router2B(config-router-af)# neighbor 200.20.20.2 next-hop-self
Router2B(config-router-af)# redistribute ospf 1
Router2B(config-router)# address-family ipv6 unicast
Router2B(config-router-af)# neighbor 2001:3:2::3 remote-as 1003
Router2B(config-router-af)# neighbor 2001:20:20::2 remote-as 1002
Router2B(config-router-af)# neighbor 2001:20:20::2 next-hop-self
Router2B(config-router-af)# redistribute ospf 1
Router2B(config-router-af)# network 2001:20:1::/64      !Not added via the OSPF process
Router2B(config-router-af)# network 2001:20:20::/64     !Not added via the OSPF process
---
Router3(config)# no router bgp 1003
Router3(config)# router bgp 1003
Router3(config-router)# address-family ipv4 unicast
Router3(config-router-af)# neighbor 200.3.2.2 remote-as 1002
```

```
Router3(config-router-af)# network 192.30.30.0
Router3(config-router-af)# address-family ipv6 unicast
Router3(config-router-af)# neighbor 2001:3:2::2 remote-as 1002
Router3(config-router-af)# network 2001:30:30::/64
```

Analyze the IPv4 and IPv6 routing tables (`show ip route, show ipv6 route`) and BGP tables (`show ip bgp, show bgp ipv6 unicast`). Test the IPv4 and IPv6 connectivity.

Note: in BGP for address-family IPv6 the directly connect networks must always be added to the process explicitly (with the command `network`). In BGP for address-family IPv4 those networks are added by the OSPF process redistribution (if active on those networks).

9. Start two packet captures on links Router1-Router2A and Router3-Router2B, reset the BGP routing processes (clear ip bgp *) and wait for the BGP processes reestablishment. Analyze the content of the captured BGP packets (over IPv4 and IPv6) and identify the MP-BGP UPDATE messages over IPv4 and IPv6.

>> Verify that IPv4 routes announcement follow the same procedure as observed before.

>> Explain how IPv6 peering relations are established.

>> Explain how IPv6 routes are announced to BGP peers by analyzing the **UPDATE** messages and the new **MP_REACH_NLRI** attribute**.**

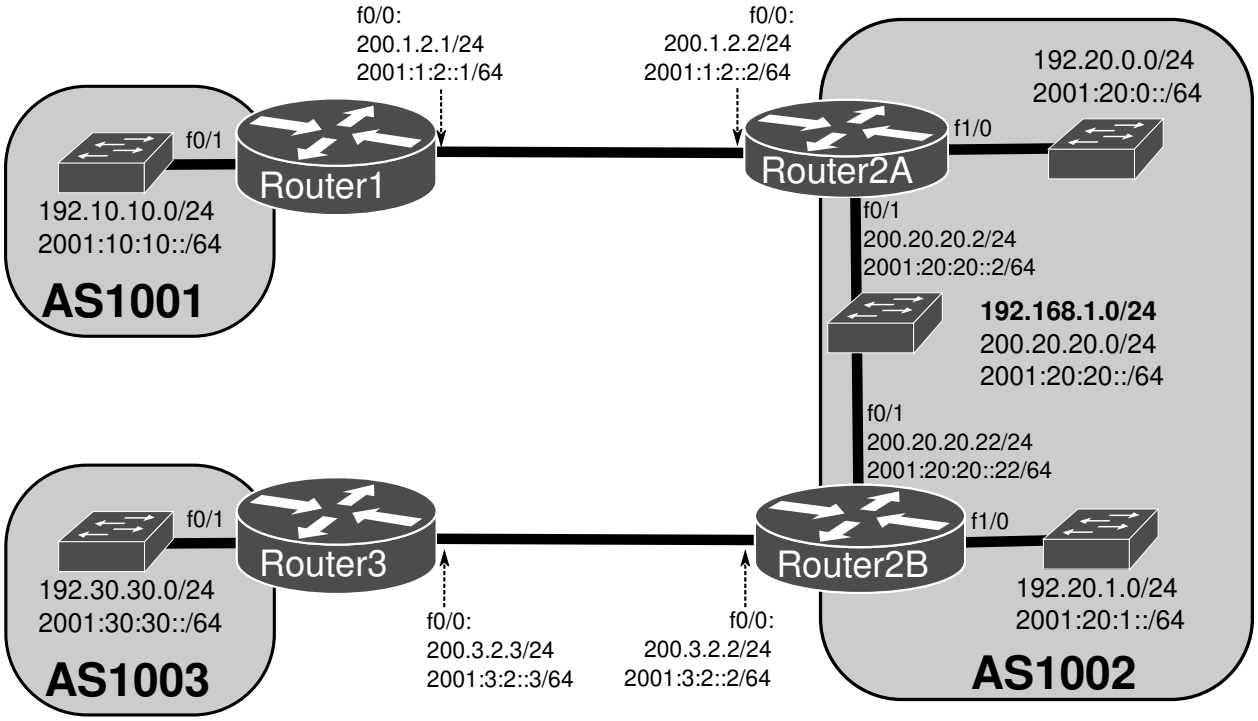
10. While capturing packets on link R1-R2A, disable Router 3's f0/1 interface (`shutdown`) to simulate a link failure. Wait a couple of minutes, and enable again the interface (`no shutdown`) .

Analyze the captured **UPDATE** IPv6 BGP messages.

>> Explain how an IPv6 network unreachability is announced to a BGP peer (check **MP_UNREACH_NLRI** attribute).

>> Explain also how a newly available network is announced to an IPv6 BGP peer.

MP-BGP IPv4 private routes propagation



11. To the network assembled and configured before, add an IPv4 private network on AS1002 to the LAN between Router 2A and Router 2B (and include it on OSPFv2 process 1):

```
Router2A(config)# interface FastEthernet 0/1
Router2A(config-if)# ip address 192.168.1.2 255.255.255.0 secondary
---
Router2B(config)# interface FastEthernet 0/1
Router2B(config-if)# ip address 192.168.1.22 255.255.255.0 secondary
```

Analyze the IPv4 routing table (`show ip route`) and BGP table (`show ip bgp`) in all routers.

>> What can be concluded about the propagation of the IPv4 private network from AS1002 to neighbors AS1001 and AS1003?

>> The announcement of IPv4 private networks to the other BGP peers (Internet) seams correct?

MP-BGP default route announcement and propagation

12. Configure Router 3 to announce IPv4 and IPv6 default routes to AS1002:

```
Router3(config)# router bgp 1003
Router3(config-router)# address-family ipv4 unicast
Router3(config-router-af)# neighbor 200.3.2.2 default-originate
Router3(config-router-af)# address-family ipv6 unicast
Router3(config-router-af)# neighbor 2001:3:2::2 default-originate
```

Analyze the IPv4 and IPv6 routing tables (`show ip route, show ipv6 route`) and BGP tables (`show ip bgp, show bgp ipv6 unicast`) in all routers.

>> What can be concluded about the propagation of the default routes to AS1002 and to AS1001 through AS1002?

>> What the announcement of a default route means for AS1001 and AS1002?

BGP Policies deployment

Policy 1

AS1002 should NOT:

- Announce any IPv4 private network to its neighbors (strict rule!).
- Announce the external IPv4 and IPv6 default route to its neighbors (routing policy rule).

13. Confirm the appearance of default routes (via AS1002) in AS1001, and the AS1002 IPv4 private network in AS1001 and AS1003.

To filter the announcement of private networks and default routes it is required to create a prefix list with all network to block (deny) and announce (permit). In both Routers 2A and 2B:

```
Router2*(config)# ip prefix-list pOut-priv-default seq 10 deny 10.0.0.0/8 le 32
Router2*(config)# ip prefix-list pOut-priv-default seq 12 deny 172.16.0.0/12 le 32
Router2*(config)# ip prefix-list pOut-priv-default seq 14 deny 192.168.0.0/16 le 32
Router2*(config)# ip prefix-list pOut-priv-default seq 16 deny 0.0.0.0/0       !default route
Router2*(config)# ip prefix-list pOut-priv-default seq 100 permit 0.0.0.0/0 le 32
                                                                              !All others
Router2*(config)# ipv6 prefix-list pOut-default seq 16 deny ::/0
Router2*(config)# ipv6 prefix-list pOut-default seq 100 permit ::/0 le 128     !All others
---
Router2A(config)#router bgp 1002
Router2A(config-router)# address-family ipv4 unicast
Router2A(config-router-af)# neighbor 200.1.2.1 prefix-list pOut-priv-default out
Router2A(config-router)# address-family ipv6 unicast
Router2A(config-router-af)# neighbor 2001:1:2::1 prefix-list pOut-default out
---
Router2B(config)#router bgp 1002
Router2B(config-router)# address-family ipv4 unicast
Router2B(config-router-af)# neighbor 200.3.2.3 prefix-list pOut-priv-default out
Router2B(config-router)# address-family ipv6 unicast
Router2B(config-router-af)# neighbor 2001:3:2::3 prefix-list pOut-default out
```

Reset the BGP relations of Router2A and 2B (`clear ip bgp *`). Analyze the IPv4 and IPv6 routing tables (`show ip route, show ipv6 route`) and BGP tables (`show ip bgp, show bgp ipv6 unicast`), and identify the filtering results in Router1 and Router3.

>> In terms of operational aspects explain the importance of not announcing private networks to AS1001 and AS1003.

>> In terms of operational **and commercial** aspects explain the importance of not announcing the default route to AS1001.

>> Explain the importance of controlling the default behavior of BGP of announcing all networks received from other BGP peers (or local routing processes).

Policy 2

AS1002 also should NOT accept the default route from AS1003 (routing policy rule).

14. To filter (at AS1002) the reception of default routes from AS1003:

```
Router2B(config)# ip prefix-list pIn-default seq 16 deny 0.0.0.0/0    !block default route
Router2B(config)# ip prefix-list pIn-default seq 100 permit 0.0.0.0/0 le 32
                                                                       !accept all others
Router2B(config)# ipv6 prefix-list pIn-default seq 16 deny ::/0       !block default route
Router2B(config)# ipv6 prefix-list pIn-default seq 100 permit ::/0 le 128
                                                                       !accept all others
---
Router2B(config)#router bgp 1002
Router2B(config-router)# address-family ipv4 unicast
Router2B(config-router-af)# neighbor 200.3.2.3 prefix-list pIn-default in
Router2B(config-router)# address-family ipv6 unicast
Router2B(config-router-af)# neighbor 2001:3:2::3 prefix-list pIn-default in
```

Reset the BGP relation between Router2B and Router3, analyze the IPv4 and IPv6 routing tables (`show ip route, show ipv6 route`) and BGP tables (`show ip bgp, show bgp ipv6 unicast`), and identify the filtering results in Routers 2A and 2B.

>> In terms of operational **and commercial** aspects explain the importance of not accepting the default route from AS1003.

>> Explain the importance of controlling the default behavior of BGP of accepting all network announcements from a peer.