BGP Selfstudy :: Guide Version 4.0

Nachfolgend sind die wichtigsten Eigenschaften von BG nochmals zusammen gefasst:

- BGP gibt es in vier Versionen; aktuell ist V4 Industriestandard.
- BGP ist in RFC 1771 abgebildet. Es dient zum Routing in via AS strukturierten Netzen.
- BGP ist ein path-vector protocol, da eine Pfadfolge als Abfolge von AS-Nummern dargestellt wird.
- BGP verwendet TCP Port 179 (für Updates). Derzeit verwendet nur BGP TCP.
- Router mit einer BGP Konfiguration werden typischer Weise BGP Speaker bezeichnet; BGP Router die eine TCP Session formen, werden dann als BGP peers oder BGP neighbors bezeichnet.
- BGP Nachbarn tauschen zunächst die volle Routingtabelle aus, danach nur noch partielle und triggered updates.
- Nachbarn senden periodisch keepalives.
- Jeder BGP Router hat seine „eigene“ BGP Tabelle. Jedes Netzwerk muss zunächst in die BGP Tabelle – und dann erst in den Routingprozess.

BGP verwendet folgende message-types:

- **Open messages—** These messages are used when establishing BGP peers.
- **Keepalives—** These messages are sent periodically to ensure that connections are still active or established.
- **Update messages—** Any change that occurs, such as a loss of network availability, results in an update message.
- **Notification—** These messages are used only to notify BGP peers of receiving errors.

The capability of BGP4 to guarantee routing delivery and the complexity of the routing decision process

BGP Attribute

Die Routingentscheidung wird in BGP unter anderem durch sogenannte Attribute getroffen. Diese Attribute werden allerdings nicht immer von allen Plattformen unterstützt.

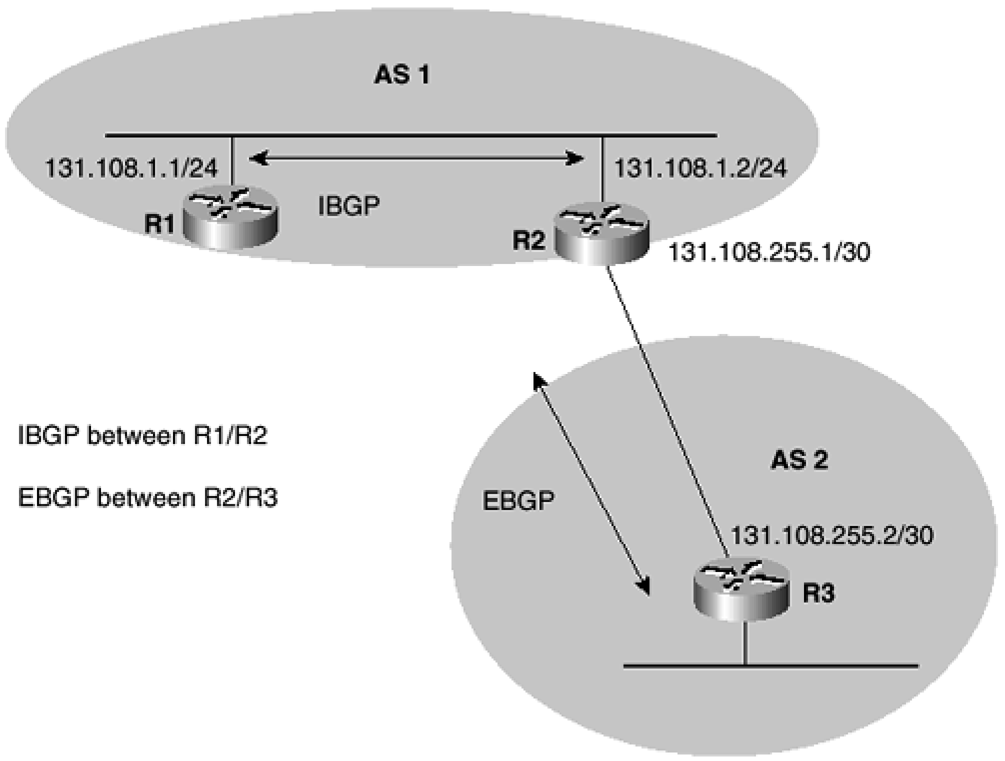
Der Wert dieser Attribute kann vom Administrator bestimmt warden – er wird in jedem Uptade eingetragen.

Origin	This attribute is mandatory and defines the origin of the path and can have three different values
AS_Path	This attribute describes the sequence of autonomous systems that the packet has traversed.
Next Hop	This attribute describes the next hop address taken to a remote path, typically the BGP peer
Local Preference	This attribute indicates to the AS the preferred path to exit the AS. A higher local preference is always preferred
MED	Multiexit Discriminator informs BGP peers in other autonomous systems which path to take to a remote network. A lower MED is always preferred.

Weight	This Cisco-only attribute is used in local router selection. Weight is not sent to other BGP peers, and a higher weight value is always preferred. The weight value is between 0–294967295.
Atomic	This attribute advises BGP routers that aggregation has taken place and is not used in the router-selection process
Aggregator	This is the router ID responsible for aggregation and is not used in the router-selection process.
Community	Communities allow routes to be tagged for use with a group of routers sharing the same characteristics.
Originator-ID	This attribute is used to prevent routing loops. This information is not used for router selection.
Cluster-List	This attribute is used in route-reflector environments. This information is not used for router selection.

Grundsätzlich werden in BGP zwei Beziehungen unterschieden:

- *Internal BGP (IBGP)* (beide Router im gleichen AS)
- *External BGP (EBGP)* (beide Router in unterschiedlichen AS)



BGP Peers stellen sicher, dass es zu keinen Routingloops kommen kann; dies wird dadurch realisiert, dass BGP nur Routen weitergibt, die von einem IGP gelernt wurden. Um also sicher zu stellen, dass Routen erst dann an ein anderes AS weitergegeben werden, wenn im lokalen AS Router diese Route kennen, wartet BGP darauf, dass diese Routen vom IGRP propagiert wurden. Dieses Feature wird mit „*synchronization*“ bezeichnet und kann mittels „*no synchronizaton*“ deaktiviert werden.

Der BGP Routingprozess ist im Vergleich zu IGP Protokollen sehr komplex und baut auf die zuvor dargestellten Attribute auf. Ein Cisco-Router befolgt bei der Weiterleitung folgende Regeln:

1) Wenn die next-hop IP erreich bar ist, ist diese zu verwenden.
2) Es wird die Route mit dem größten „weight“ Attribut angewendet.
3) Anwenden der Route mit größtem „LOCAL_REF“ Attribut. (Default 100, ansonsten mit bgp default local-preference konfigurierbar).
4) Anwenden des Pfades, der im lokalen network Befehl angegeben wurde, oder lokal durch Redistribution gelernt wurde.
5) Der Pfad mit geringstem „AS-PATH“ wird angewendet.
6) Pfad mit geringstem „origin type“ (IGP ist kleiner als EGP)
7) Pfad mit geringstem „multi-exit descriminator MED“.
8) Bevorzugung von eBGP gegenüber iBGP Pfaden.
9) Bevorzugung der Route des Routers mit kleinerer Router-ID.

BGP Konfiguration

- Initialisierung des Routingprozesses: **router bgp** *autonomous system number*
- Bekanntzugebende Netze: **network** *network-number* **mask** *network-mask*

Achtung: der Netzwerkbefehl hat nicht die gleiche Funktion wie in IGP Protokollen, es werden hier nur die Netze bekannt gegeben.

- Bekanntgabe von BGP Peers: **neighbor** *ip-address* **|** *peer-group name* **remote-as** *autonomous system number*

Achtung: durch übereinstimmende oder unterschiedliche AS-Nummern entsteht eine iBGP oder eBGP Beziehung.

Fallbeispiel iBGP	R1(config)#**router bgp 1** R1(config-router)#**neighbor 131.108.1.2 remote 1** R1(config-router)#**neighbor 131.208.1.2 remote 1** R1(config-router)#**no synchronization**
Fallbeispiel eBGP	R2(config)#**router bgp 1** R2(config-router)#**neighbor 131.108.1.1 remote-as 1** R2(config-router)#**neighbor 131.108.255.2 remote-as 2** R1(config-router)#**no synchronization**

Zu diesem Zeitpunkt sind zwar Adjazenzen geformt, aber noch keine Routen bekannt gegeben:

```
R1(config)#interface loopback 0
R1(config-if)#ip address 131.108.2.1 255.255.255.0
R1(config-if)#interface loopback 1
R1(config-if)#ip address 131.108.3.1 255.255.255.0
```

```
R1(config-if)#interface loopback 2
R1(config-if)#ip address 131.108.4.1 255.255.255.0
R1(config)#router bgp 1
R1(config-router)#network 131.108.2.0 mask 255.255.255.0
R1(config-router)#network 131.108.3.0 mask 255.255.255.0
R1(config-router)#network 131.108.4.0 mask 255.255.255.0
```

In der Routingtabelle sollten nun BGP Routen sichtbar sein:

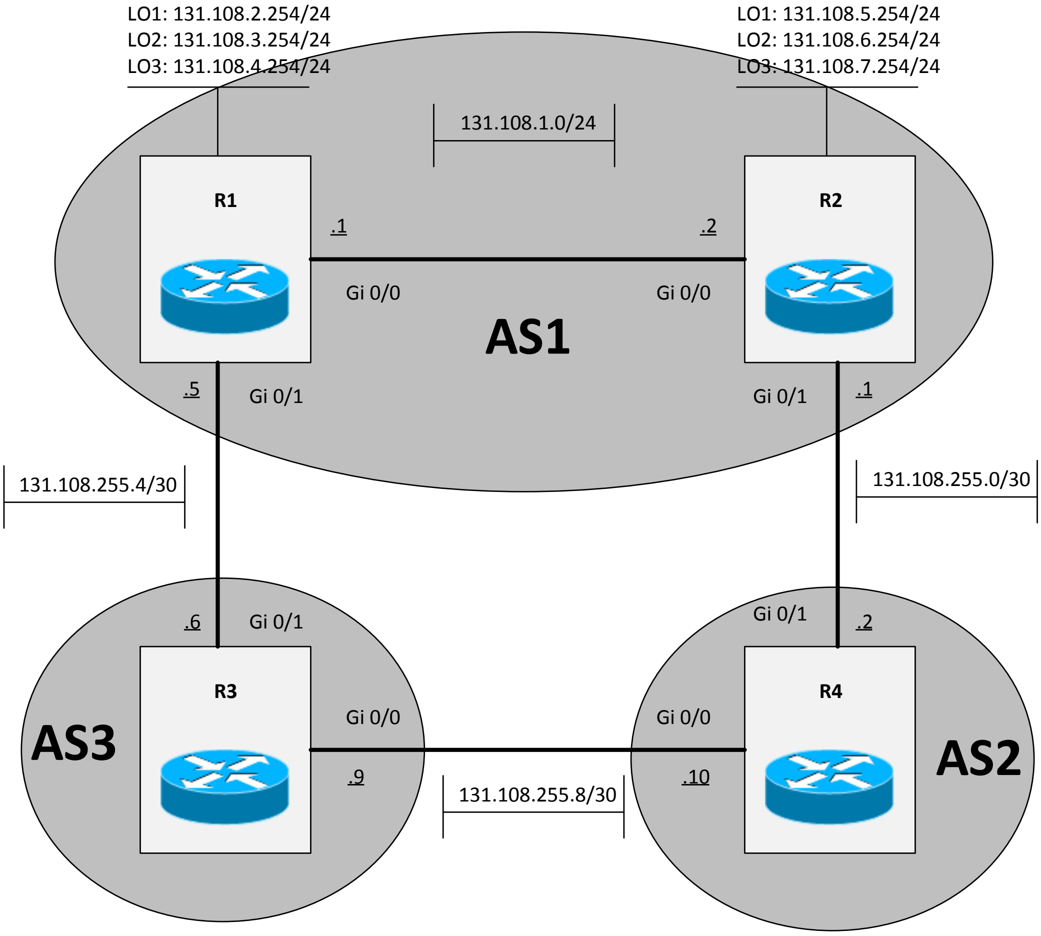
```
R1#show ip bgp
BGP table version is 4, local router ID is 131.108.1.1
Status codes: s suppressed, d damped, h history, * valid, > best, i - internal
Origin codes: i - IGP, e - EGP, ? - incomplete

   Network          Next Hop            Metric LocPrf Weight Path
*> 131.108.2.0/24   0.0.0.0                  0         32768 i
*> 131.108.3.0/24   0.0.0.0                  0         32768 i
*> 131.108.4.0/24   0.0.0.0                  0         32768 i
```

In den nachfolgenden Abschnitten werden nun einige BGP Fallbeispiele näher vorgestellt.

Fallbeispiel 1 :: EBGP and IBGP

In diesem Fallbeispiel sollen die Router für eine iBGP und eine eBGP Beziehung konfiguriert werden; OSPF fungiert als IGP zwischen R1 und R2. ***Synchronization wird NICHT*** deaktiviert, da dieses Netzwerk eine Schleife enthält!

Ziel: die Loopbacks 131.108.2.0-131-108.5.0 und 131.108.5.0-131.108.7.0 sind von R3 aus erreichbar.



OSPF – Konfiguration (auf R1 und R2 werden jeweils alle Loopback-Interfaces bekannt gegeben) :

```
R1(config)#router ospf 1
R1(config-router)# network 131.108.1.0 0.0.0.255 area 0
R1(config-router)# network 131.108.2.0 0.0.0.255 area 0
R1(config-router)# network 131.108.3.0 0.0.0.255 area 0
R1(config-router)# network 131.108.4.0 0.0.0.255 area 0
```

```
R1(config)#router ospf 1
R1(config-router)# network 131.108.1.0 0.0.0.255 area 0
R1(config-router)# network 131.108.5.0 0.0.0.255 area 0
R1(config-router)# network 131.108.6.0 0.0.0.255 area 0
R1(config-router)# network 131.108.7.0 0.0.0.255 area 0
```

Die OSPF Nachbarn auf R1:

```
R1_(9)#sh ip ospf neighbor
Neighbor ID     Pri   State           Dead Time   Address         Interface
```

```
131.108.7.254     1   FULL/BDR       00:00:31    131.108.1.2     GigabitEthernet0/0
```

Nachdem nun das IGP konfiguriert wurde, folgt BGP mit I- BGP und E-BGP:

```
R1(config)#router bgp 1
R1(config-router)# neighbor 131.108.1.2 remote-as 1
R1(config-router)# neighbor 131.108.255.6 remote-as 3
R1(config-router)# network 131.108.1.0 mask 255.255.255.0

R2(config)#router bgp 1
R2(config-router)# neighbor 131.108.1.1 remote-as 1
R2(config-router)# neighbor 131.108.255.2 remote-as 2
R2(config-router)# network 131.108.1.0 mask 255.255.255.0
R2(config-router)# network 131.108.255.0 mask 255.255.255.252

R4(config)#router bgp 2
R4(config-router)# neighbor 131.108.255.1 remote-as 1
R4(config-router)# network 131.108.255.0 mask 255.255.255.252
```

Folgende Routingkonfigurationen sind nun aktiv:

- OSPF auf Router R1 und R2 (im OSPF Prozess sind alle Loopback-interfaces von R1 und R2 bekannt)
- I-BGP zwischen R1 und R2
- E-BGP zwischen
- Auf R3 keine BGP Konfiguration

Betrachten wir nun den output von show ip bgp auf R1:

```
R1#sh ip bgp
BGP table version is 3, local router ID is 131.108.4.254
Status codes: s suppressed, d damped, h history, * valid, > best, i
- internal,r RIB-failure, S Stale, m multipath, b backup-path, f RT-
Filter,x best-external, a additional-path, c RIB-compressed,
Origin codes: i - IGP, e - EGP, ? - incomplete
RPKI validation codes: V valid, I invalid, N Not found

     Network          Next Hop            Metric LocPrf Weight Path
 * i 131.108.1.0/24   131.108.1.2              0    100      0 i
 *>                   0.0.0.0                  0         32768 i
 *>i 131.108.255.0/30 131.108.1.2              0    100      0 i
```

Der BGP Prozess von R1 hat keine Informationen über die lokalen Loopbackinterfaces. Damit diese ebenfalls am BGP Prozess teilnehmen, müssen diese im BGP-network Befehl includiert werden:

```
R1(config)#router bgp 1
```

R1(config-router)# **network 131.108.2.0 mask 255.255.255.0**

R1(config-router)# **network 131.108.3.0 mask 255.255.255.0**

R1(config-router)# **network 131.108.47.0 mask 255.255.255.0**

R2(config)#**router bgp 1**

R2(config-router)# **network 131.108.5.0 mask 255.255.255.0**

R2(config-router)# **network 131.108.6.0 mask 255.255.255.0**

R2(config-router)# **network 131.108.7.0 mask 255.255.255.0**

Anmerkung: Nach Veränderungen am BGP sollte immer **clear ip bgp *** ausgeführt werden! Dies kann auch nur für einen neighbor durchgeführt werden: **clear ip bgp 131.108.1.2.**

Die BGP-Routingtabelle auf R1 lautet nun:

R1#**sh ip bgp**

```
BGP table version is 9, local router ID is 131.108.4.254
Status codes: s suppressed, d damped, h history, * valid, > best, i
- internal,
              r RIB-failure, S Stale, m multipath, b backup-path, f
RT-Filter,
              x best-external, a additional-path, c RIB-compressed,
Origin codes: i - IGP, e - EGP, ? - incomplete
RPKI validation codes: V valid, I invalid, N Not found

     Network          Next Hop            Metric LocPrf Weight Path
 * i 131.108.1.0/24   131.108.1.2              0    100      0 i
 *>                   0.0.0.0                  0         32768 i
 *>  131.108.2.0/24   0.0.0.0                  0         32768 i
 *>  131.108.3.0/24   0.0.0.0                  0         32768 i
 *>  131.108.4.0/24   0.0.0.0                  0         32768 i
 *>i 131.108.5.0/24   131.108.1.2              0    100      0 i
 *>i 131.108.6.0/24   131.108.1.2              0    100      0 i
 *>i 131.108.7.0/24   131.108.1.2              0    100      0 i
 *>i 131.108.255.0/30 131.108.1.2              0    100      0 i
```

R1 sieht somit die drei lokalen Loopbackinterfaces und die drei Looobackinterfaces von R2 (via 131.108.1.2).

Die „default weight“ ist 32768 für lokale Netzwerke. Die „local preference“ ist 100 für entfernte Netze.

Defaultmäßig ist Routen-Summary in BGP aktiviert; für unser Beispiel werden wir es deaktivieren:

R1(config)#**router bgp 1**

R1(config-router)# **no auto-summary**

R2(config)#**router bgp 1**

R2(config-router)# **no auto-summary**

Einer der wichtigsten Befehle für BGP Troubleshooting ist das Anzeigen der Nachbarn:

```
R1#sh ip bgp neighbors
GP neighbor is 131.108.1.2,  remote AS 1, internal link
  BGP version 4, remote router ID 131.108.7.254
  BGP state = Established, up for 00:51:26
  Last  read  00:00:50,  last  write  00:00:00,  hold  time  is  180,
keepalive interval is 60 seconds
  Neighbor sessions:
    1 active, is not multisession capable (disabled)
  Neighbor capabilities:
    Route refresh: advertised and received(new)
    Four-octets ASN Capability: advertised and received
    Address family IPv4 Unicast: advertised and received
    Enhanced Refresh Capability: advertised and received
    Multisession Capability:
    Stateful switchover support enabled: NO for session 1
…. unterdrückt
```

Im Outout von show bgp neighbor muss für den Status des Nachbarn „Established“ eingetragen sein; jeder anderer Wert würde einen Fehler darstellen. Folgende Statis sind möglich:

- **Connect—** BGP is waiting for the TCP connection to be completed.
- **Active—** BGP is trying to acquire a remote peer by initiating a new TCP connection.
- **OpenSent—** BGP is waiting for an open message from the remote peer.
- **OpenConfirm—** BGP is waiting for a keepalive message.
- **Established—** After a keepalive message is sent, this is the final stage of BGP peer negotiation during which both peers exchange their BGP tables.

Effizienter können Nachbarn mit show ip bgp summary betrachtet werden:

```
R1#sh ip bgp summary
BGP router identifier 131.108.4.254, local AS number 1
BGP table version is 9, main routing table version 9
8 network entries using 1152 bytes of memory
9 path entries using 720 bytes of memory
2/2 BGP path/bestpath attribute entries using 320 bytes of memory
0 BGP route-map cache entries using 0 bytes of memory
0 BGP filter-list cache entries using 0 bytes of memory
BGP using 2192 total bytes of memory
BGP activity 8/0 prefixes, 10/1 paths, scan interval 60 secs

Neighbor        V           AS MsgRcvd MsgSent   TblVer  InQ OutQ Up/Down  State/PfxRcd
131.108.1.2     4            1      69      70        9    0    0 00:58:22        5
131.108.255.6   4            3       2       7        9    0    0 00:00:50        0
```

Die Tabelle der Nachbarn in obigen Befehlsoutput enthält folgende Werte:

Field	Description
BGP router identifier	In order of precedence and availability, router identifier specified by the bgp router-id command, loopback address, or lowest IP address. For Example, in Example 6-26, the router ID of R4 is 151.108.1.1/24.

Field	Description
BGP table version	Internal version number of BGP database.
main routing table version	Last version of BGP database injected into main routing table.
Neighbor	IP address of a neighbor.
V	BGP version number spoken to that neighbor. Typically you see only version 4.
AS	Peer autonomous system.
MsgRcvd	BGP messages received from that neighbor.
MsgSent	BGP messages sent to that neighbor.
TblVer	Last version of the BGP database sent to that neighbor.
InQ	Number of messages from that neighbor waiting to be processed.
OutQ	Number of messages waiting to be sent to that neighbor.
Up/Down	The length of time that the BGP session has been in the Established state, or the current state, if the state is not Established.
State/PfxRcd	Current state of the BGP session/the number of prefixes the router has received from a neighbor or peer group. When the maximum number (as set by the neighbor maximum-prefix command) is reached, the string, PfxRcd, appears in the entry, the neighbor is shut down, and the connection is idle. No information below the state indicates an active peer, as displayed in Example 6-26.

Betrachten wir nun die Routingtabelle auf R3:

```
R3#sh ip route
      131.108.0.0/16 is variably subnetted, 12 subnets, 3 masks
B        131.108.1.0/24 [20/0] via 131.108.255.5, 00:04:55
B        131.108.2.0/24 [20/0] via 131.108.255.5, 00:04:55
B        131.108.3.0/24 [20/0] via 131.108.255.5, 00:04:55
B        131.108.4.0/24 [20/0] via 131.108.255.5, 00:04:55
B        131.108.5.0/24 [20/0] via 131.108.255.5, 00:04:55
B        131.108.6.0/24 [20/0] via 131.108.255.5, 00:04:55
B        131.108.7.0/24 [20/0] via 131.108.255.5, 00:04:55
B        131.108.255.0/30 [20/0] via 131.108.255.5, 00:04:55
C        131.108.255.4/30 is directly connected, GigabitEthernet0/1
L        131.108.255.6/32 is directly connected, GigabitEthernet0/1
C        131.108.255.8/30 is directly connected, GigabitEthernet0/0
L        131.108.255.9/32 is directly connected, GigabitEthernet0/0
```

Zusätzlich betrachten wir noch show ip bgp auf Router R3:

```
R3#sh ip bgp
   Network          Next Hop            Metric LocPrf Weight Path
 *   131.108.1.0/24   131.108.255.10                       0 2 1 i
 *>                   131.108.255.5            0             0 1 i
 *   131.108.2.0/24   131.108.255.10                       0 2 1 i
 *>                   131.108.255.5            0             0 1 i
 *   131.108.3.0/24   131.108.255.10                       0 2 1 i
 *>                   131.108.255.5            0             0 1 i
 *   131.108.4.0/24   131.108.255.10                       0 2 1 i
 *>                   131.108.255.5            0             0 1 i
 *   131.108.5.0/24   131.108.255.10                       0 2 1 i
 *>                   131.108.255.5                          0 1 i
 *   131.108.6.0/24   131.108.255.10                       0 2 1 i
 *>                   131.108.255.5                          0 1 i
 *   131.108.7.0/24   131.108.255.10                       0 2 1 i
 *>                   131.108.255.5                          0 1 i
     Network          Next Hop            Metric LocPrf Weight Path
 *   131.108.255.0/30 131.108.255.10           0             0 2 i
 *>                   131.108.255.5                          0 1 i
```

Nun sind einige Informationen zu betrachten:

Die Route zu 131.108.1.0/24 ist in der Routingtabelle einmal vorkommend, in der BGP Table allerdings als Dualpath, hier ist 131.108.255.5 bevorzugt. BGP verwendet defaultmäßig kein loadbalancing – und somit gibt es auch nur den bevorzugten Router in der Routingtabelle. Warum wird R1 gegenüber R4 bevorzugt. Die Entscheidung dafür liegt in den zuvor dargestellten 10 Parametern; die ersten vier (next hop reachable, weigth equal, local preference the same, not originated by local router) davon sind gleich. Der Nächste Parameter stellt die path-länge. Die AS-Länge über R1 ist 1 AS, die über R4 sind zwei AS!.

Um beispielsweise nun R4 gegenüber R1 zu bevorzugen kann das höher gewichtige Attribut „preference“ gesetzt werden:

Nachfolgend ist dargestellt, wie alle Updates eines Nachbarn mit dem Gewicht 1 in die BGP Tabelle eingetragen werden (nicht vergessen – clear ip bgp *):

```
R3(config)#router bgp 3
R3(config-router)# neighbor 131.108.255.10 weight 1
R3(config-router)#exit
R3(config)# clear ip bgp *
```

Sicherheitshalber sind nachfolgend nun die Running-configs der Geräte auszugsweise angegeben:

R1	R2
hostname R1 interface Loopback1 ip address 131.108.2.254 255.255.255.0 interface Loopback2 ip address 131.108.3.254 255.255.255.0 interface Loopback3 ip address 131.108.4.254 255.255.255.0 interface GigabitEthernet0/0 description to_R2 ip address 131.108.1.1 255.255.255.0 interface GigabitEthernet0/1	hostname R2 interface Loopback1 ip address 131.108.5.254 255.255.255.0 interface Loopback2 ip address 131.108.6.254 255.255.255.0 interface Loopback3 ip address 131.108.7.254 255.255.255.0 interface GigabitEthernet0/0 description to_R1 ip address 131.108.1.2 255.255.255.0 interface GigabitEthernet0/1

```
 description to_R3
 ip address 131.108.255.5 255.255.255.252
router ospf 1
 network 131.108.1.0 0.0.0.255 area 0
 network 131.108.2.0 0.0.0.255 area 0
 network 131.108.3.0 0.0.0.255 area 0
 network 131.108.4.0 0.0.0.255 area 0
router bgp 1
 bgp log-neighbor-changes
 network 131.108.1.0 mask 255.255.255.0
 network 131.108.2.0 mask 255.255.255.0
 network 131.108.3.0 mask 255.255.255.0
 network 131.108.4.0 mask 255.255.255.0
 neighbor 131.108.1.2 remote-as 1
 neighbor 131.108.255.6 remote-as 3
```

```
 description to_R4
 ip address 131.108.255.1 255.255.255.252
router ospf 1
 network 131.108.1.0 0.0.0.255 area 0
 network 131.108.5.0 0.0.0.255 area 0
 network 131.108.6.0 0.0.0.255 area 0
 network 131.108.7.0 0.0.0.255 area 0
router bgp 1
 bgp log-neighbor-changes
 network 131.108.1.0 mask 255.255.255.0
 network 131.108.5.0 mask 255.255.255.0
 network 131.108.6.0 mask 255.255.255.0
 network 131.108.7.0 mask 255.255.255.0
 network 131.108.255.0 mask 255.255.255.252
 neighbor 131.108.1.1 remote-as 1
 neighbor 131.108.255.2 remote-as 2
```

R3

```
hostname R3
interface GigabitEthernet0/0
 description to_R4
 ip address 131.108.255.9 255.255.255.252
interface GigabitEthernet0/1
 description to_R1
 ip address 131.108.255.6 255.255.255.252
router bgp 3
 bgp log-neighbor-changes
 neighbor 131.108.255.5 remote-as 1
 neighbor 131.108.255.10 remote-as 2
 neighbor 131.108.255.10 weight 1
```

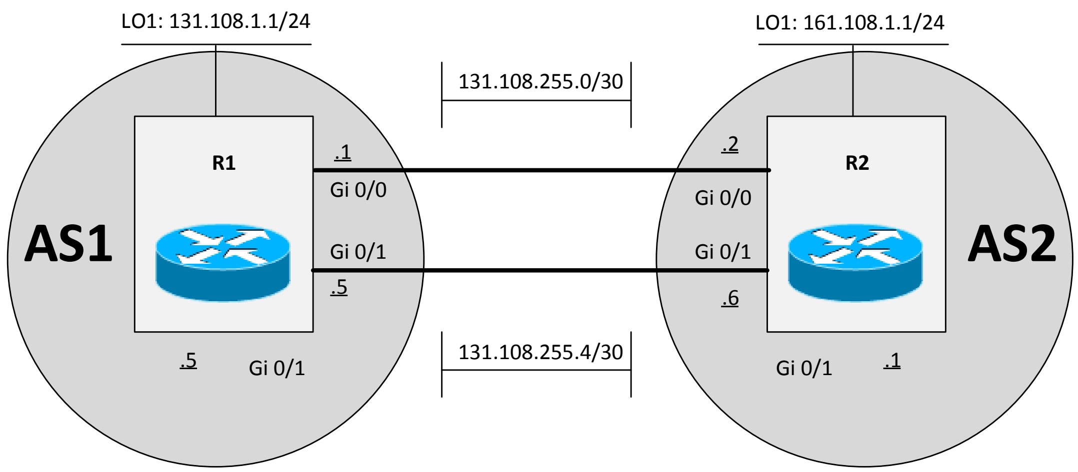
R4

```
hostname R4
interface GigabitEthernet0/0
 description to_R3
 ip address 131.108.255.10 255.255.255.252
interface GigabitEthernet0/1
 description to_R4
 ip address 131.108.255.2 255.255.255.252
router bgp 2
 bgp log-neighbor-changes
 network 131.108.255.0 mask 255.255.255.252
 neighbor 131.108.255.1 remote-as 1
 neighbor 131.108.255.9 remote-as 3
```

Fallbeispiel 2 :: BGP und statische Routen

Mit Hilfe von statischen Routen wird Loadbalancing zwischen zwei E-BGP Routern dargestellt.

Da BGP standardmäßig nur eine Route zum Ziel bevorzugt, muss mit Hilfe von statischen Routen ein Loadbalancing realisiert werden.



In diesem Fallbeispiel spielt Synchronisierung keine Rolle. Für das peering werden jeweils die gegenüberliegenden Loopbackinterfaces verwendet. Da das Loopback nicht directly connected ist, muss auch ebgp-multihop konfiguriert werden. Als update source wird ebenfalls das Loopbackinterface angenommen.

Die BGP- Konfigurationen lauten:

```
R1(config)# router bgp 1
R1(config-router)# no auto-summary
R1(config-router)# neighbor 161.108.1.1 remote-as 2
R1(config-router)# neighbor 161.108.1.1 ebgp-multihop
R1(config-router)# neighbor 161.108.1.1 update-source lo 1
R1(config-router)# network 131.108.1.0 mask 255.255.255.0
```

```
R1(config)# router bgp 2
R1(config-router)# no auto-summary
R1(config-router)# neighbor 131.108.1.1 remote-as 1
R1(config-router)# neighbor 131.108.1.1 ebgp-multihop
R1(config-router)# neighbor 131.108.1.1 update-source lo 1
R1(config-router)# network 161.108.1.0 mask 255.255.255.0
```

Betrachten wir nun auf R1 die Nachbarn:

```
R1#sh ip bgp neighbors 161.108.1.1
BGP neighbor is 161.108.1.1,  remote AS 2, external link
  BGP version 4, remote router ID 0.0.0.0
  BGP state = Idle
  Neighbor sessions:
    0 active, is not multisession capable (disabled)
    Stateful switchover support enabled: NO
  Do log neighbor state changes (via global configuration)
```

R2 ist mir R1 noch nicht adjazent, da ja R1 keine Route zum Nachbarn (161.108.1.1) hat; gleiches gilt auch für R2. Nachfolgend ist die statische Route für R1 dargestellt:

```
R1(config)# ip route 161.108.1.0 255.255.255.0 131.108.255.2
R1(config)# ip route 161.108.1.0 255.255.255.0 131.108.255.6
```

Um das erfolgreiche Loadbalancing zu verifizieren, wir mit Hilfe des debug Befehls der ICMP Debug-Output analysiert:

```
R1(config)# debug ip packet
R1(config)# #ping 161.108.1.1
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 161.108.1.1, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 1/1/4 ms
R1#
*Dec 16 22:12:56.291: IP: s=131.108.1.1 (local), d=161.108.1.1 (GigabitEthernet0/0), len 59, sending
*Dec 16 22:12:56.799: IP: s=131.108.255.1 (local), d=161.108.1.1 (GigabitEthernet0/1), len 100, sending
*Dec 16 22:12:57.255: IP: s=131.108.1.1 (local), d=161.108.1.1 (GigabitEthernet0/0), len 40, sending
```

Wie man sieht, funktioniert Loadbalancing. Allerdings gilt es zu beachten, dass BGP immer noch nur einen Pfad zum Ziel R2 verwendet, dieser aber aufgrund eines rekursiven Routinglookups dann via Loadbalancing gesendet wird!

Zur Sicherheit wieder die Auszüge aus den running-configs:

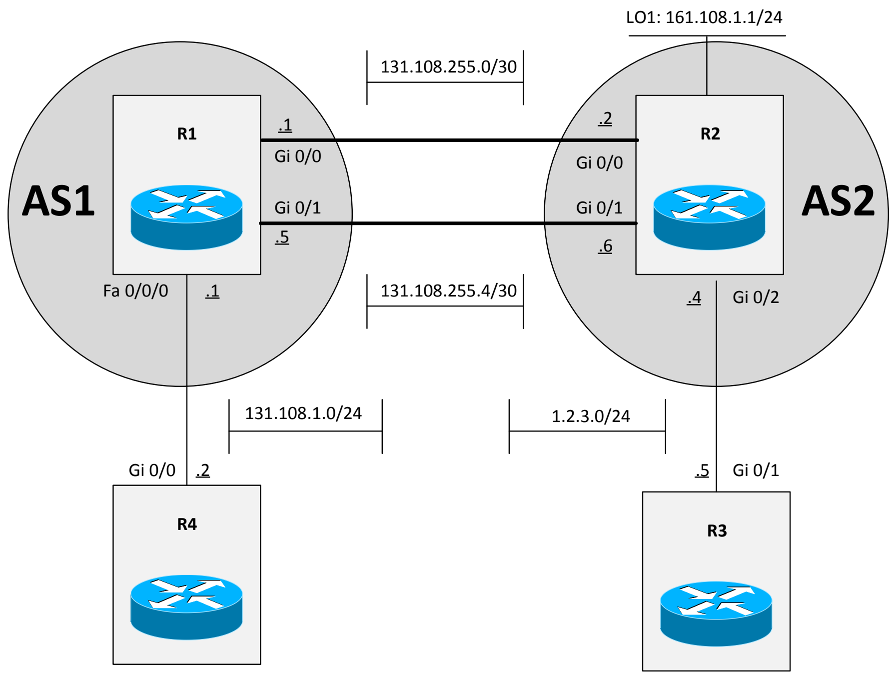
R1		R2
hostname R1 interface Loopback1 ip address 131.108.1.1 255.255.255.0 interface GigabitEthernet0/0 description to_R2 ip address 131.108.255.1 255.255.255.252 interface GigabitEthernet0/1 description to_R2 ip address 131.108.255.5 255.255.255.252 router bgp 1 bgp log-neighbor-changes network 131.108.1.0 mask 255.255.255.0 neighbor 161.108.1.1 remote-as 2 neighbor 161.108.1.1 ebgp-multihop 255 neighbor 161.108.1.1 update-source Loopback1 ip route 161.108.1.0 255.255.255.0 131.108.255.2 ip route 161.108.1.0 255.255.255.0 131.108.255.6		hostname R2 interface Loopback1 ip address 161.108.1.1 255.255.255.0 interface GigabitEthernet0/0 description to_R1 ip address 131.108.255.2 255.255.255.252 interface GigabitEthernet0/1 description to_R1 ip address 131.108.255.6 255.255.255.252 router bgp 2 bgp log-neighbor-changes network 161.108.1.0 mask 255.255.255.0 neighbor 131.108.1.1 remote-as 1 neighbor 131.108.1.1 ebgp-multihop 255 neighbor 131.108.1.1 update-source Loopback1 ip route 131.108.1.0 255.255.255.0 131.108.255.1 ip route 131.108.1.0 255.255.255.0 131.108.255.5

Fallbeispiel 3 :: BGP und Policy-Based Routing

In diesem Fallbeispiel wird die Kombination von PBR und BGP gezeigt. Zur Erinnerung; Policy-Based Routing wird in folgenden Szenarien verwendet:

- Source- oder Destination based traffic flow
- Unterschiedlicher next hop in Abhängigkeit eines Kriteriums

Das Szenario entspricht dem des vorherigen Beispiels, nur dass nun zwei E-BGP Sessions konfiguriert werden:



Zunächst werden die beiden E-BGP Sessions geformt. Das Mulithop-Attribut wird nicht benötigt, da die directly connected Interfaces zur Konfiguration verwendet werden.

```
R1(config)# router bgp 1
R1(config-router)# no auto-summary
R1(config-router)# neighbor 131.108.255.1 remote-as 2
R1(config-router)# neighbor 131.108.255.5 remote-as 2
R1(config-router)# network 131.108.1.0 mask 255.255.255.0
```

```
R1(config)# router bgp 2
R1(config-router)# no auto-summary
R1(config-router)# neighbor 131.108.255.1 remote-as 1
R1(config-router)# neighbor 131.108.255.5 remote-as 1
R1(config-router)# network 131.108.1.0 mask 255.255.255.0
```

```
R1(config)# show ip bgp

     Network          Next Hop            Metric LocPrf Weight Path

*>   131.108.1.0/24   0.0.0.0                  0         32768 i

*    161.108.1.0/24   131.108.255.6            0             0 2 i

*>                    131.108.255.2            0             0 2 i
```

Zur Erinnerung: BGP macht kein LoadBalancing! Als next hop wird 131.108.255.2 gewählt, da die kleinste IP Adresse zieht (die anderen Parameter sind gleich).

Via BGP und PBR soll nun folgendes implementiert werden:

- Der gesamte Traffic von 131.108.1.0/24 nach 161.108.1.0/24 geht via 131.108.255.2
- Der „restliche“ Traffic geht via 131.108.255.4

Poliy-Based Routing benötigt dazu Route.maps. Mit einer Route-map kann der next hop verändert werden:

Im ersten Schritt soll R2 eine Defaultroute an R1 propagieren (R2 hat eine Defaultroute auf 1.2.3.5):

```
R2(config)# router bgp 2
R2(config-router)# neighbor 131.108.255.1 default-originate
R2(config-router)# neighbor 131.108.255.5 default-originate
```

Die Defaultroute wird an R1 via BGP übergeben:

```
R1(config)# show ip bgp
    Network          Next Hop            Metric LocPrf Weight Path
*   0.0.0.0          131.108.255.6                         0 2 i
*>                   131.108.255.2                         0 2 i
*>  131.108.1.0/24   0.0.0.0                  0        32768 i
*   161.108.1.0/24   131.108.255.6            0            0 2 i

*>                   131.108.255.2            0            0 2 i
```

Für eine PBR werden folgende Konfigurationsschritte benötigt:

- Route-map, die an das entsprechende Interface angebunden wird
- eine Access-list mit der Condition für die Route-map
- Action – in diesem Fall der next hop

```
R1(config)# interface fa 0/0/0
R1(config-if)# ip policy route-map nondefault
R1(config-if)# exit
R1(config)# route-map nondefault permit 10
R1(config-route-map)# match ip address 100
R1(config-route-map)# set ip next-hop 131.108.252.2
R1(config-route-map)# exit
R1(config)# route-map nondefault permit 20
R1(config-route-map)# match ip address 101
R1(config-route-map)# set ip next-hop 131.108.252.6
R1(config-route-map)# exit
R1(config)# access-list 100 permit icmp 131.108.1.0 0.0.0.255 161.108.1.0 0.0.0.255
R1(config)# access-list 101 permit ip 131.108.1.0 0.0.0.255 any
```

Die Überprüfung der Funktionsweise erfolgt mit debug ip policy: (für Bedingung 1)

```
R1# debug ip policy
R4# ping 161.108.1.1
```

```
*Dec 17 21:20:29.147: IP: s=131.108.1.2 (FastEthernet0/0/0), d=161.108.1.1, len 100, FIB
policy match
*Dec 17 21:20:29.147: IP: s=131.108.1.2 (FastEthernet0/0/0), d=161.108.1.1, len 100, PBR
Counted
*Dec 17 21:20:29.147: IP: s=131.108.1.2 (FastEthernet0/0/0), d=161.108.1.1, g=131.108.255.2,
len 100, FIB policy routed
*Dec 17 21:20:29.151: IP: s=131.108.1.2 (FastEthernet0/0/0), d=161.108.1.1, len 100, FIB
policy match
*Dec 17 21:20:29.151: IP: s=131.108.1.2 (FastEthernet0/0/0), d=161.108.1.1, len 100,
```

Die Überprüfung für Bedingung 2:

R1#**debug ip policy**

R4# **ping 1.2.3.5**

```
*Dec 17 21:30:20.167: IP: s=131.108.1.2 (FastEthernet0/0/0), d=1.2.3.5, len 100, PBR
Counted
*Dec 17 21:30:20.167: IP: s=131.108.1.2 (FastEthernet0/0/0), d=1.2.3.5,
g=131.108.255.6, len 100, FIB policy routed
*Dec 17 21:30:20.167: IP: s=131.108.1.2 (FastEthernet0/0/0), d=1.2.3.5, len 100, FIB
policy match
*Dec 17 21:30:20.167: IP: s=131.108.1.2 (FastEthernet0/0/0), d=1.2.3.5, len 100, PBR
Counted
*Dec 17 21:30:20.167: IP: s=131.108.1.2 (FastEthernet0/0/0), d=1.2.3.5,
g=131.108.255.6, len 100,
```

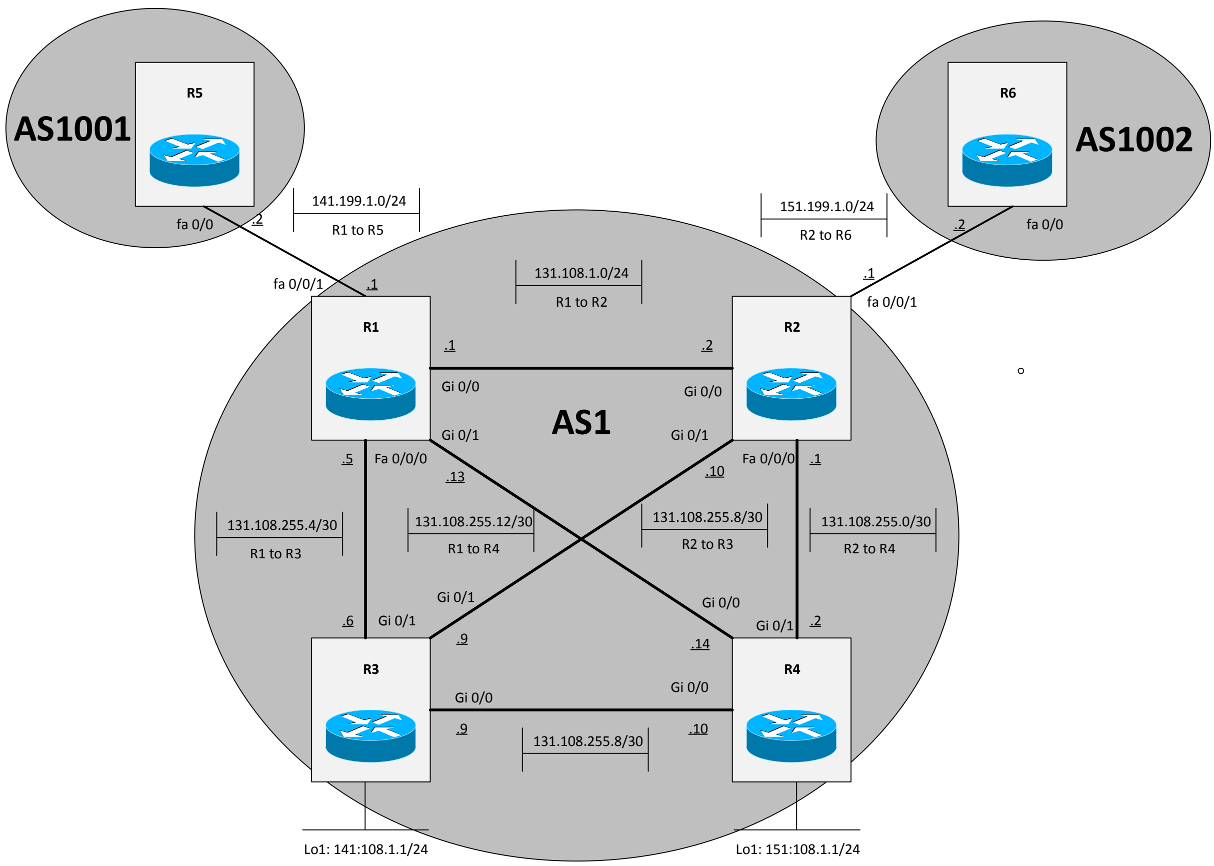
Zum Abschluss wieder die Auszüge aus der Running-config:

<table>
<tr><td>R1</td><td></td><td>R2</td></tr>
<tr><td>hostname R1
interface GigabitEthernet0/0
 description to_R2
 ip address 131.108.255.1 255.255.255.252
interface GigabitEthernet0/1
 description to_R2
 ip address 131.108.255.5 255.255.255.252
interface FastEthernet0/0/0
 ip address 131.108.1.1 255.255.255.0
 ip policy route-map nondefault
router bgp 1
 bgp log-neighbor-changes
 network 131.108.1.0 mask 255.255.255.0
 neighbor 131.108.255.2 remote-as 2
 neighbor 131.108.255.6 remote-as 2
route-map nondefault permit 10
 match ip address 100
 set ip next-hop 131.108.255.2
route-map nondefault permit 20
 match ip address 101
 set ip next-hop 131.108.255.6
access-list 100 permit icmp 131.108.1.0 0.0.0.255 161.108.1.0 0.0.0.255
access-list 101 permit icmp any any</td><td></td><td>hostname R2
interface Loopback1
 ip address 161.108.1.1 255.255.255.0
interface GigabitEthernet0/0
 description to_R1
 ip address 131.108.255.2 255.255.255.252
interface GigabitEthernet0/1
 description to_R1
 ip address 131.108.255.6 255.255.255.252
interface Vlan1
 ip address 1.2.3.4 255.255.255.0
router bgp 2
 bgp log-neighbor-changes
 network 161.108.1.0 mask 255.255.255.0
 neighbor 131.108.255.1 remote-as 1
 neighbor 131.108.255.1 default-originate
 neighbor 131.108.255.5 remote-as 1
 neighbor 131.108.255.5 default-originate
ip route 0.0.0.0 0.0.0.0 1.2.3.5</td></tr>
<tr><td>R3</td><td></td><td>R4</td></tr>
<tr><td>hostname R3
interface GigabitEthernet0/0
 ip address 1.2.3.5 255.255.255.0
 duplex auto
 speed auto
ip route 0.0.0.0 0.0.0.0 1.2.3.4</td><td></td><td>hostname R4
interface GigabitEthernet0/0
 ip address 131.108.1.2 255.255.255.0
ip route 0.0.0.0 0.0.0.0 131.108.1.1</td></tr>
</table>

Fallbeispiel 4 :: BGP mit Peer Groups

BGP bietet für das Peering mit vielen BGP-Peers mehrere Lösungen an. In diesem Fallbeispiel werden dazu Peer Groups verwendet. Eine Peer Group ist eine Gruppe von Routern, die die gleiche Update-Policy verwenden.

Anmerkung: Für die Konfiguration der Community für die Peer Group können Werte von 1 bis 4294967200 verwendet werden. Mit Hilfe des commands set community …. wird dies konfiguriert. Einige well-known community Attribute wie no-export (keine Updates an peer) oder no-advertise (die entsprechende Route wird an keinen peer bekannt gegeben) können an Stelle der community-number verwendet werden.



R1 wird als E-BGP mit dem Remote-Peer 141.199.1.2 konfiguriert - also dem „Gateway zum Internet".

Zwei Bedingungen werden für diese E-BGP Beziehung gefordert:

1. Das „Internet" – also R5 darf keine Attribute von R1 erhalten
2. R1 darf nur die „Kundennetze" 141.108.1.1 und 151.108.1.1 weitergeben, keine anderen via BGP gelernten Netze.

Ad1: Es ist aber gewünscht, dass R5 keine Attribute von AS1 erhält. Somit muss die „send community" (sonst würden in der community die Attribute nicht übertragen werden) und eine Route-map konfiguriert werden,

Ad2: via Disribution-List (access-list 2) werden in den Updates nur die Netze 141.108.1.0/24 und 131.108.1.0/24 bekannt geben.

R1(config)# **router bgp 1**

```
R1(config-router)# neighbor 141.199.1.2 remote-as 1001
R1(config-router)# neighbor 141.199.1.2 send-community
R1(config-router)# neighbor 141.199.1.2 route-map setcommunity out
R1(config-router)# neighbor 141.199.1.2 distribution-list 2 out
R1(config)# route-map setcommunity
R1(config-rout-map)# set community no-export
R1(config)# access-list 2 permit 141.108.1.0
R1(config)# access-list 2 permit 151.108.1.0
```

Als nächstes werden die I-BGP Sessions am Router R1 für die Router R2 – R4 konfiguriert; alle Router sollen die gleiche Policy haben.

Vom Netzwerkdesigner wurde die Annahme getroffen, dass R1 keine Defaultrouten von R2,R3 und R4 beziehen dar. Weiters soll auch next-hop-self gesetzt werden.

Um die Konfiguration effiizient zu gestalten, werden die Attribute nur auf R1 als community konfiguriert und dann in der community an R2 bis R4 „vererbt“ (die Einträge der community gelten dann aber nur auf R1 !).

```
R1(config)# router bgp 1
R1(config-router)# neighbor internal peer-group
R1(config-router)# neighbor internal distribute-list 1 in
R1(config-router)# neighbor internal next-hop-self
R1(config-router)# neighbor internal remote-as 1
R1(config-router)# neighbor internal route-map setattributes in
R1(config)# route-map setattributes
R1(config-rout-map)# set community 2000
R1(config-rout-map)# ip address 2
R1(config-rout-map)# set weight 1000
```

Die anderen Router müssen nun als I-BGP Beziehung angelegt warden:

```
R1(config-router)#  neighbor 131.106.1.2 peer-group internal
R1(config-router)# neighbor 131.108.255.6 peer-group internal
R1(config-router)# neighbor 131.108.255.14 peer-group internal
R1(config-router)# network 131.108.255.4 mask 255.255.255.252
R1(config-router)# network 131.108.255.12 mask 255.255.255.252
R1(config-router)# network 131.106.1.0 mask 255.255.255.0
```

Auf den anderen Routern wird BGP wie in den vorherigen Beispielen konfiguriert (siehe Gesamtkonfiguration am Ende dieses Kapitels).

Überprüfen wir nun die Routingtabellen auf R5 (hier dürfen in der Routingtabelle nur die Netze 141.105.1.0/24 und 151.108.1.0/24 aufscheinen):

```
R5# sh ip route
```



```
     141.199.0.0/24 is subnetted, 1 subnets
C       141.199.1.0 is directly connected, FastEthernet0/0
     141.108.0.0/24 is subnetted, 1 subnets
B       141.108.1.0 [20/0] via 141.199.1.1, 00:12:50
     151.108.0.0/24 is subnetted, 1 subnets
B       151.108.1.0 [20/0] via 141.199.1.1, 00:12:50
```

Auch auf R1 dürfen nur diese beiden Netze in der Routingtabelle aufscheinen:

```
R1# sh ip route
      131.106.0.0/16 is variably subnetted, 2 subnets, 2 masks
C        131.106.1.0/30 is directly connected, GigabitEthernet0/0
L        131.106.1.1/32 is directly connected, GigabitEthernet0/0
      131.108.0.0/16 is variably subnetted, 4 subnets, 2 masks
C        131.108.255.4/30 is directly connected, FastEthernet0/0/0
L        131.108.255.5/32 is directly connected, FastEthernet0/0/0
C        131.108.255.12/30 is directly connected, GigabitEthernet0/1
L        131.108.255.13/32 is directly connected, GigabitEthernet0/1
      141.108.0.0/24 is subnetted, 1 subnets
B        141.108.1.0 [200/0] via 131.108.255.6, 00:45:38
      141.199.0.0/16 is variably subnetted, 2 subnets, 2 masks
C        141.199.1.0/24 is directly connected, FastEthernet0/0/1
L        141.199.1.1/32 is directly connected, FastEthernet0/0/1
      151.108.0.0/24 is subnetted, 1 subnets
B        151.108.1.0 [200/0] via 131.108.255.14, 00:30:25
```

Betrachten wir nun die RT von R2:

```
R2# sh ip route
      131.106.0.0/16 is variably subnetted, 2 subnets, 2 masks
C        131.106.1.0/30 is directly connected, GigabitEthernet0/0
L        131.106.1.2/32 is directly connected, GigabitEthernet0/0
      131.108.0.0/16 is variably subnetted, 6 subnets, 2 masks
C        131.108.255.0/30 is directly connected, Vlan10
L        131.108.255.1/32 is directly connected, Vlan10
B        131.108.255.4/30 [200/0] via 131.108.255.9, 00:40:28
C        131.108.255.8/30 is directly connected, GigabitEthernet0/1
L        131.108.255.10/32 is directly connected, GigabitEthernet0/1
B        131.108.255.12/30 [200/0] via 131.106.1.1, 00:40:28
      141.108.0.0/24 is subnetted, 1 subnets
B        141.108.1.0 [200/0] via 131.108.255.9, 00:40:28
      151.108.0.0/24 is subnetted, 1 subnets
```

```
B        151.108.1.0 [200/0] via 131.108.255.2, 00:31:27
      151.199.0.0/16 is variably subnetted, 2 subnets, 2 masks
C        151.199.1.0/24 is directly connected, Vlan20
L        151.199.1.1/32 is directly connected, Vlan20
```

Die Konfigurationsauszüge lauten:

R1		R2
hostname R1 interface GigabitEthernet0/0 description to_R2 ip address 131.106.1.1 255.255.255.252 interface GigabitEthernet0/1 description to_R4 ip address 131.108.255.13 255.255.255.252 interface FastEthernet0/0/0 description to_R3 ip address 131.108.255.5 255.255.255.252 interface FastEthernet0/0/1 description to_R5 ip address 141.199.1.1 255.255.255.0 router bgp 1 bgp log-neighbor-changes network 131.106.1.0 mask 255.255.255.0 network 131.108.255.4 mask 255.255.255.252 network 131.108.255.12 mask 255.255.255.252 neighbor internal peer-group neighbor internal remote-as 1 neighbor internal next-hop-self neighbor internal distribute-list 1 in neighbor internal route-map setattributes in neighbor 131.106.1.2 peer-group internal neighbor 131.108.255.6 peer-group internal neighbor 131.108.255.14 peer-group internal neighbor 141.199.1.2 remote-as 1001 neighbor 141.199.1.2 send-community neighbor 141.199.1.2 distribute-list 1 out neighbor 141.199.1.2 route-map setcommunity out route-map setcommunity permit 10 set community no-export route-map setattributes permit 10 match ip address 2 set weight 1000 set community 2000 access-list 1 permit 141.108.1.0 access-list 1 permit 151.108.1.0 access-list 2 permit any		hostname R2 interface GigabitEthernet0/0 description to_R1 ip address 131.106.1.2 255.255.255.252 interface GigabitEthernet0/1 description to_R3 ip address 131.108.255.10 255.255.255.252 interface GigabitEthernet0/0/0 switchport access vlan 10 no ip address interface GigabitEthernet0/0/1 switchport access vlan 20 interface Vlan10 description to_R4 ip address 131.108.255.1 255.255.255.252 interface Vlan20 description to_R6 ip address 151.199.1.1 255.255.255.0 ! router bgp 1 bgp log-neighbor-changes network 131.106.1.0 mask 255.255.255.0 network 131.108.255.0 mask 255.255.255.252 network 131.108.255.8 mask 255.255.255.252 neighbor 131.106.1.1 remote-as 1 neighbor 131.108.255.2 remote-as 1 neighbor 131.108.255.9 remote-as 1 neighbor 151.100.1.1 remote-as 1002 neighbor 151.100.1.1 send-community neighbor 151.100.1.1 route-map setcommunity out route-map setcommunity permit 10 set community no-export
R3		R4
hostname R3 interface Loopback1 ip address 141.108.1.1 255.255.255.0 interface GigabitEthernet0/0 description to_R1 ip address 131.108.255.6 255.255.255.252 interface GigabitEthernet0/1 ip address 131.108.255.9 255.255.255.252 router bgp 1 bgp log-neighbor-changes network 131.108.255.4 mask 255.255.255.252		hostname R4 interface Loopback1 ip address 151.108.1.1 255.255.255.0 interface GigabitEthernet0/0 description to_R1 ip address 131.108.255.14 255.255.255.252 interface GigabitEthernet0/1 ip address 131.108.255.2 255.255.255.252 router bgp 1 bgp log-neighbor-changes network 131.108.255.0 mask 255.255.255.252

network 131.108.255.8 mask 255.255.255.252 network 141.108.1.0 mask 255.255.255.0 neighbor 131.108.255.5 remote-as 1 neighbor 131.108.255.10 remote-as 1	--More-- network 131.108.255.12 mask 255.255.255.252 network 151.108.1.0 mask 255.255.255.0 neighbor 131.108.255.1 remote-as 1 neighbor 131.108.255.13 remote-as 1
R5	R6
hostname R5 interface FastEthernet0/0 ip address 141.199.1.2 255.255.255.0 router bgp 1001 no synchronization bgp log-neighbor-changes neighbor 141.199.1.1 remote-as 1 no auto-summary	hostname R6 interface FastEthernet0/0 ip address 151.199.1.2 255.255.255.0 router bgp 1002 no synchronization bgp log-neighbor-changes neighbor 151.199.1.1 remote-as 1 no auto-summary

Fallbeispiel 5 :: Route Reflector

In BGP ist es notwendig, dass alle adjazenten Router auch eine "direkte Verbindung" zueinander haben - als full meshed sind. Dies würde aber n(n-1)/2 Links benötigen.

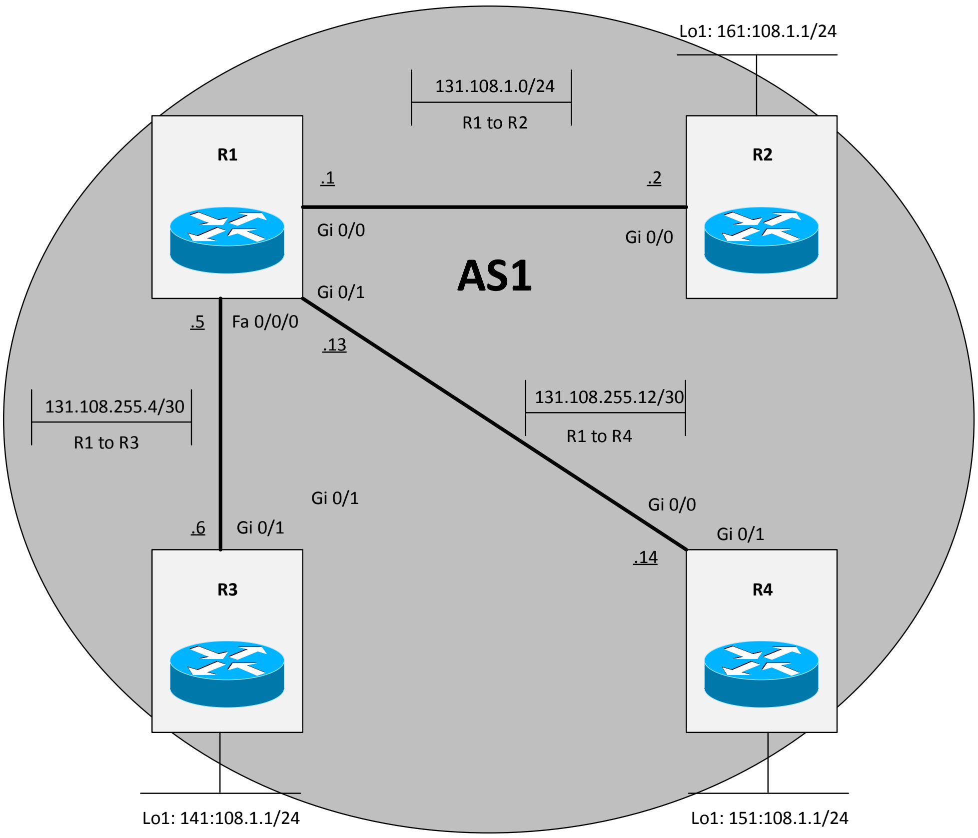
Zur Lösung dieses Problems gibt es zwei Ansätze:

1. Route Reflector
2. Confederations (erweiterte Route Reflectors, beyond thees chapters)

Route Reflectors werden nur in I-BGP Sessions eingesetzt. Sie funktionieren ähnlich der Designated Router in OSPF.

Route Reflector mit den Clients R2 – R4 einen Cluster. Der Route Reflector hat dabei folgende Eigenschaften:

- Die Route Reflector Konfiguration wird nur am RF selbst konfiguriert; Clients werden „normal konfiguriert“
- Route Reflectoren erhalten alle BGP Attribute.
- Der Route Reflector sendet updates an alle Clients.
- Clients empfangen Updates nur vom Route Reflector.
- Es muss mindestens einen Route Reflector pro Cluster geben.
- Der Route Reflector ignoriert Updates, die von ihm selbst ausgesendet wurden.



In obigem Beispiel soll R1 als Route Reflector für die Router R2 – R4 (als Clients bezeichnet) fungieren.

Die Konfiguration von R1 als Route Reflector lautet:

```
R1(config)# router bgp 1
R1(config-router)# no synchronization
R1(config-router)# network 131.106.1.0 mask 255.255.255.0
R1(config-router)# network 131.108.255.4 mask 255.255.255.252
R1(config-router)# network 131.108.255.12 mask 255.255.255.252
R1(config-router)# neighbor 131.106.1.2 remote-as 1
R1(config-router)# neighbor 131.106.1.2 route-reflector-client
R1(config-router)# neighbor 131.108.255.6 remote-as 1
R1(config-router)# neighbor 131.108.255.6 route-reflector-client
R1(config-router)# neighbor 131.108.255.14 remote-as 1
R1(config-router)# neighbor 131.108.255.14 route-reflector-client
```

Die Router R2 – R4 werden "normal" konfiguriert.

Betrachten wir nun die Routingtabelle auf R1:

```
R1(config)# show ip route
     131.106.0.0/16 is variably subnetted, 2 subnets, 2 masks
C       131.106.1.0/24 is directly connected, GigabitEthernet0/0
```

```
L        131.106.1.1/32 is directly connected, GigabitEthernet0/0
      131.108.0.0/16 is variably subnetted, 4 subnets, 2 masks
C        131.108.255.4/30 is directly connected, FastEthernet0/0/0
L        131.108.255.5/32 is directly connected, FastEthernet0/0/0
C        131.108.255.12/30 is directly connected, GigabitEthernet0/1
L        131.108.255.13/32 is directly connected, GigabitEthernet0/1
      141.108.0.0/24 is subnetted, 1 subnets
B        141.108.1.0 [200/0] via 131.108.255.6, 00:03:15
      151.108.0.0/24 is subnetted, 1 subnets
B        151.108.1.0 [200/0] via 131.108.255.14, 00:00:35
      161.108.0.0/24 is subnetted, 1 subnets
B        161.108.1.0 [200/0] via 131.106.1.2, 00:03:15
```

Betrachten wir nun die Routingtabelle auf R3:

```
R3(config)# show ip route
   131.106.0.0/24 is subnetted, 1 subnets
B        131.106.1.0 [200/0] via 131.108.255.5, 00:03:52
      131.108.0.0/16 is variably subnetted, 3 subnets, 2 masks
C        131.108.255.4/30 is directly connected, GigabitEthernet0/0
L        131.108.255.6/32 is directly connected, GigabitEthernet0/0
B        131.108.255.12/30 [200/0] via 131.108.255.5, 00:03:52
      141.108.0.0/16 is variably subnetted, 2 subnets, 2 masks
C        141.108.1.0/24 is directly connected, Loopback1
L        141.108.1.1/32 is directly connected, Loopback1
      151.108.0.0/24 is subnetted, 1 subnets
B        151.108.1.0 [200/0] via 131.108.255.14, 00:01:29
      161.108.0.0/24 is subnetted, 1 subnets
B        161.108.1.0 [200/0] via 131.106.1.2, 00:03:47
```

Abschließend wieder die gesamte Konfiguration:

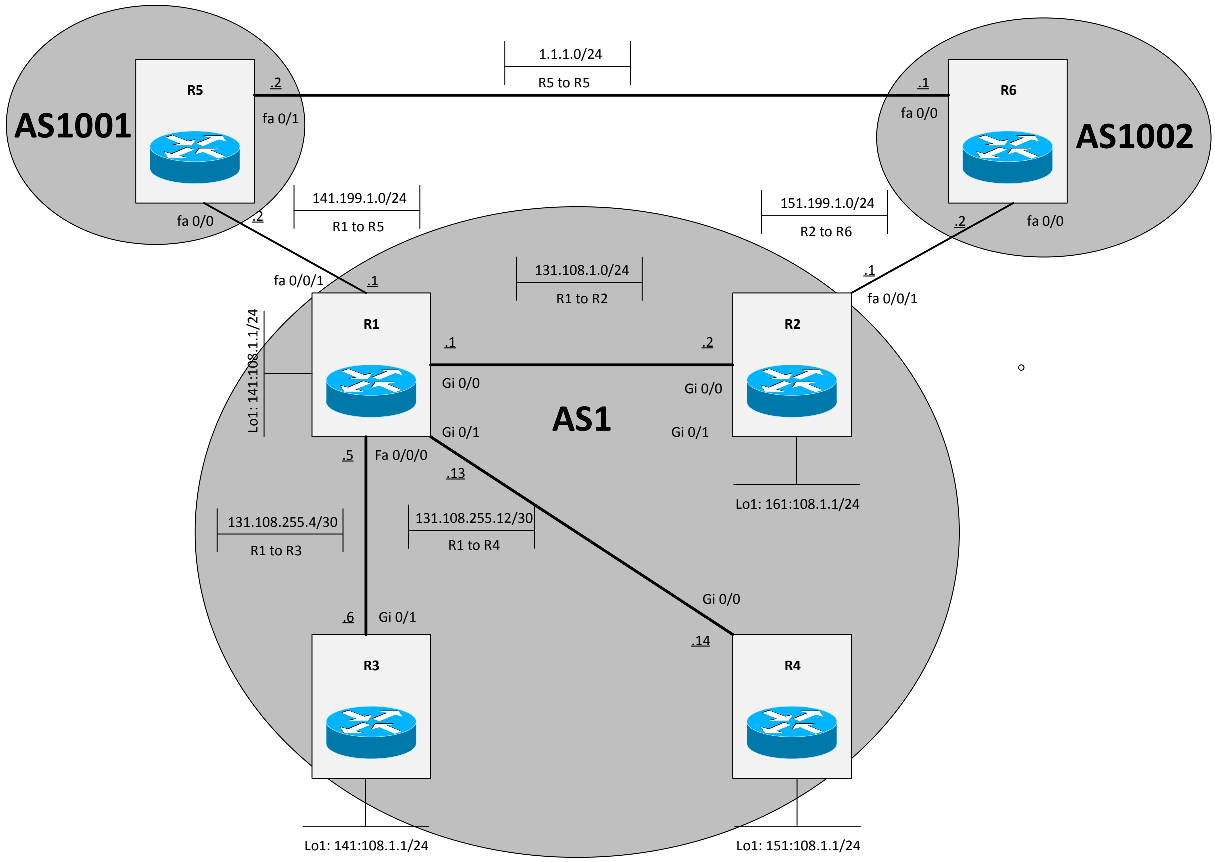
R1		R2
hostname R1 interface GigabitEthernet0/0 description to_R2 ip address 131.106.1.1 255.255.255.0 interface GigabitEthernet0/1 description to_R4 ip address 131.108.255.13 255.255.255.252 interface FastEthernet0/0/0 description to_R3 ip address 131.108.255.5 255.255.255.252 router bgp 1 bgp log-neighbor-changes network 131.106.1.0 mask 255.255.255.0 network 131.108.255.4 mask 255.255.255.252		hostname R2 interface Loopback1 ip address 161.108.1.1 255.255.255.0 interface GigabitEthernet0/0 description to_R1 ip address 131.106.1.2 255.255.255.0 interface GigabitEthernet0/1 no ip address shutdown interface GigabitEthernet0/0/0 no ip address router bgp 1 bgp log-neighbor-changes network 131.106.1.0 mask 255.255.255.0

network 131.108.255.12 mask 255.255.255.252 neighbor 131.106.1.2 remote-as 1 neighbor 131.106.1.2 route-reflector-client neighbor 131.108.255.6 remote-as 1 neighbor 131.108.255.6 route-reflector-client neighbor 131.108.255.14 remote-as 1 neighbor 131.108.255.14 route-reflector-client	network 161.108.1.0 mask 255.255.255.0 neighbor 131.106.1.1 remote-as 1
R3	R4
hostname R3 interface Loopback1 ip address 141.108.1.1 255.255.255.0 interface GigabitEthernet0/0 description to_R1 ip address 131.108.255.6 255.255.255.252 interface GigabitEthernet0/1 no ip address router bgp 1 bgp log-neighbor-changes network 131.108.255.4 mask 255.255.255.252 network 141.108.1.0 mask 255.255.255.0 neighbor 131.108.255.5 remote-as 1	hostname R4 interface Loopback1 ip address 151.108.1.1 255.255.255.0 interface GigabitEthernet0/0 description to_R1 ip address 131.108.255.14 255.255.255.252 interface GigabitEthernet0/1 no ip address shutdown router bgp 1 bgp log-neighbor-changes network 131.108.255.12 mask 255.255.255.252 network 151.108.1.0 mask 255.255.255.0 neighbor 131.108.255.13 remote-as 1

Fallbeispiel 6 :: Advanced Route Reflectors – Dual Homing ISP

R3 und R4 sind Borderrouter, sie sind via R5 und R6 an das „Internet" angebunden. R1 und R2 fungieren somit wieder als Route Reflector. Falls R1 ausfällt, soll R2 ebenfalls als Route Reflector konfiguriert und fungiert dann als Backuprouter für R1.

In diesem Fallbeispiel wird OSPF als IGP verwendet. Weiters werden die BGP Router mit Loopback Interfaces konfiguriert.



R1 und R2 propagieren via BGP die Defaultrouten von ihren ISP-Routern.

Die Konfiguration auf ISP-R5 lautet:

Example 7-36. EBGP on ISP1

```
ISP-R1(config)# router bgp 1001
ISP-R1(config-router)# neighbor 141.199.1.1 remote-as 1
ISP-R1(config-router)# network 141.199.1.1 defult-originate
```

R1 wird als Route Reflector konfiguriert (Achtung: update-source nicht vergessen):

```
R1(config)# router bgp 1
R1(config-router)# no synchronization
R1(config-router)# neighbor 141.199.1.2 remote-as 1001
R1(config-router)# neighbor 161.108.1.1 remote-as 1
R1(config-router)# neighbor 161.108.1.1 route-reflector-client
R1(config-router)# neighbor 161.108.1.1 update-source Loopback 1
R1(config-router)# neighbor 151.108.1.1 remote-as 1
R1(config-router)#  neighbor 151.108.1.1 route-reflector-client
R1(config-router)#  neighbor 151.108.1.1 update-source Loopback 1
R1(config-router)#  neighbor 141.108.1.1 remote-as 1
R1(config-router)#  neighbor 141.108.1.1 route-reflector-client
R1(config-router)#  neighbor 141.108.1.1 update-source Loopback 1
```

```
R1(config-router)#  network 131.16.1.0 mask 255.255.255.0
R1(config-router)#  network 131.108.255.4 mask 255.255.255.252
R1(config-router)#  network 131.108.255.12 mask 255.255.255.252
```

R2 wird ebenfalls als Route Reflector konfiguriert, R3 und R4 “normal“ (Sie Konfigauszüge am Ende dieses Kapitels).

In der bisherigen Konfiguration erhalten R1 die Defaultroute von ISP-R5, R2 die Defaultroute von ISP-R6. Es gibt also 2 Defaultrouten im System; welche soll an die Borderrouter distributiert werden?

Somit wird angenommen, dass der Defaultpath via ISP-R5 geht; somit soll auch R2 diese Route als Defaultroute propagieren. Dies kann mit Hilfe des MED Attributes erreicht werden (geringere MED Werte werden bevorzugt).

```
R2(config)# router bgp 1
R2(config-router)# neighbor 151.199.1.2 route-map setmedisp2 in
R2(config-router)# neighbor 131.108.1.1 route-map setmedr1 in
R2(config-router)# route-map setmedr1
R2(config-router)# match ip address 1
R2(config-router)# set metric 100
R2(config-router)# exit
R2(config-router)# route-map setmedisp2
R2(config-router)# match ip address 2
R2(config-router)# set metric 200
R2(config-router)# exit
R2(config-router)# access-list 1 permit 0.0.0.0
R2(config-router)# access-list 2 permit 0.0.0.0
```

Betrachten wir nun den BGP-Prozess auf R2:

```
R2(config-router)# sh ip bgp
    Network          Next Hop            Metric LocPrf Weight Path
 *>  0.0.0.0          151.199.1.2            200             0 1002 i
 * i                  141.199.1.2            100    100      0 1001 i
 r>i 131.108.255.4/30 141.108.1.1              0    100      0 i
 r>i 131.108.255.12/30
                       151.108.1.1              0    100      0 i
```

Betrachten wir die Routingtabelle auf R2:

```
R2(config-router)# sh ip route
B*    0.0.0.0/0 [20/200] via 151.199.1.2, 00:01:55
      131.106.0.0/16 is variably subnetted, 2 subnets, 2 masks
C        131.106.1.0/24 is directly connected, GigabitEthernet0/0
```

```
L        131.106.1.2/32 is directly connected, GigabitEthernet0/0
      131.108.0.0/16 is variably subnetted, 3 subnets, 2 masks
O        131.108.1.1/32 [110/2] via 131.106.1.1, 01:09:50, GigabitEthernet0/0
O        131.108.255.4/30
           [110/2] via 131.106.1.1, 01:14:41, GigabitEthernet0/0
O        131.108.255.12/30
           [110/2] via 131.106.1.1, 01:11:08, GigabitEthernet0/0
      141.108.0.0/32 is subnetted, 1 subnets
O        141.108.1.1 [110/3] via 131.106.1.1, 01:10:40, GigabitEthernet0/0
      151.108.0.0/32 is subnetted, 1 subnets
O        151.108.1.1 [110/3] via 131.106.1.1, 01:10:58, GigabitEthernet0/0
      151.199.0.0/16 is variably subnetted, 2 subnets, 2 masks
C        151.199.1.0/24 is directly connected, Vlan10
L        151.199.1.1/32 is directly connected, Vlan10
      161.108.0.0/16 is variably subnetted, 2 subnets, 2 masks
C        161.108.1.0/24 is directly connected, Loopback1
L        161.108.1.1/32 is directly connected, Loopback1
```

Wie man sieht, ist nun die Defaultroute via ISP-R5 (allerdings auch mit dessen IP, eigentlich sollte dies aber die IP von R1 sein). Deshalb muss R1 als Routenherkunft eingetragen werden (next-hop self):

R1(config)# **router bgp 1**

R1(config-router)# **neighbor 161.108.1.1 next-hop-self**

Nun lautet die Routingtabelle auf R2 (mit der korrekten Defaultroute via R1):

R2(config)# **show ip route**

```
B*    0.0.0.0/0 [200/100] via 131.108.1.1, 00:00:30
      131.106.0.0/16 is variably subnetted, 2 subnets, 2 masks
C        131.106.1.0/24 is directly connected, GigabitEthernet0/0
L        131.106.1.2/32 is directly connected, GigabitEthernet0/0
      131.108.0.0/16 is variably subnetted, 3 subnets, 2 masks
O       131.108.1.1/32 [110/2] via 131.106.1.1, 01:20:25, GigabitEthernet0/0
O        131.108.255.4/30
           [110/2] via 131.106.1.1, 01:25:16, GigabitEthernet0/0
O        131.108.255.12/30
           [110/2] via 131.106.1.1, 01:21:43, GigabitEthernet0/0
      141.108.0.0/32 is subnetted, 1 subnets
O        141.108.1.1 [110/3] via 131.106.1.1, 01:21:15, GigabitEthernet0/0
      151.108.0.0/32 is subnetted, 1 subnets
O        151.108.1.1 [110/3] via 131.106.1.1, 01:21:33, GigabitEthernet0/0
      151.199.0.0/16 is variably subnetted, 2 subnets, 2 masks
C        151.199.1.0/24 is directly connected, Vlan10
L        151.199.1.1/32 is directly connected, Vlan10
```

```
      161.108.0.0/16 is variably subnetted, 2 subnets, 2 masks
C        161.108.1.0/24 is directly connected, Loopback1
L        161.108.1.1/32 is directly connected, Loopback1
```

Da die MED-Attribute nur innerhalb eines AS verglichen werden, aber in diesem Beispiel die ISP-Router in einem anderen AS sind, muss der MED Vergleich erzwungen werden.

Betrachten wir nun, ob auch R3 die Defaultroute über R1 eingetragen hat:

```
R3(config)# show ip route
 B*     0.0.0.0/0 [200/0] via 131.108.1.1, 00:00:24
      131.106.0.0/24 is subnetted, 1 subnets
O        131.106.1.0 [110/2] via 131.108.255.5, 01:35:19, GigabitEthernet0/0
      131.108.0.0/16 is variably subnetted, 4 subnets, 2 masks
O        131.108.1.1/32
           [110/2] via 131.108.255.5, 01:30:28, GigabitEthernet0/0
C        131.108.255.4/30 is directly connected, GigabitEthernet0/0
L        131.108.255.6/32 is directly connected, GigabitEthernet0/0
O        131.108.255.12/30
           [110/2] via 131.108.255.5, 01:31:46, GigabitEthernet0/0
      141.108.0.0/16 is variably subnetted, 2 subnets, 2 masks
C        141.108.1.0/24 is directly connected, Loopback1
L        141.108.1.1/32 is directly connected, Loopback1
      151.108.0.0/32 is subnetted, 1 subnets
O        151.108.1.1 [110/3] via 131.108.255.5, 01:31:36, GigabitEthernet0/0
      161.108.0.0/32 is subnetted, 1 subnets
O        161.108.1.1 [110/3] via 131.108.255.5, 01:30:51, GigabitEthernet0/0
```

Nun müssen noch zwei Sicherheitspunkte realisiert werden:

1. Vom ISP dürfen nur Defaultrouten bezogen werden!
2. Es muss sichergestellt werden, dass unser AS1 kein transport-AS ist!

Ersters kann mit einer Filter-List erreicht werden, zweites mit einer Route Map.

```
R1(config)# router bgp 1
R1(config-router)# neighbor 141.199.1.2 filter-list 1 in
R1(config-router)# neighbor 141.199.1.2 send-community
R1(config-router)# neighbor 141.199.1.2 route-map noexport out
R1(config)# access-list 1 permit 0.0.0.0 ! nur Defaultroute
R1(config)# route-map noexport
R1(config-route-map)# set community no-export
```

Abschließend wieder die Konfigurationsauszüge:

R1		R2
hostname R1		hostname R2

```
interface Loopback1
 ip address 131.108.1.1 255.255.255.0
interface GigabitEthernet0/0
 description to_R2
 ip address 131.106.1.1 255.255.255.0
interface GigabitEthernet0/1
 description to_R4
 ip address 131.108.255.13 255.255.255.252
interface FastEthernet0/0/0
 description to_R3
 ip address 131.108.255.5 255.255.255.252
interface FastEthernet0/0/1
 ip address 141.199.1.1 255.255.255.0
router ospf 1
 network 131.106.1.0 0.0.0.255 area 1
 network 131.108.1.0 0.0.0.255 area 1
 network 131.108.255.4 0.0.0.3 area 1
 network 131.108.255.12 0.0.0.3 area 1
router bgp 1
 bgp always-compare-med
 bgp log-neighbor-changes
 network 131.16.1.0 mask 255.255.255.0
 network 131.108.255.4 mask 255.255.255.252
 network 131.108.255.12 mask 255.255.255.252
 neighbor 141.108.1.1 remote-as 1
 neighbor 141.108.1.1 update-source Loopback1
 neighbor 141.108.1.1 route-reflector-client
 neighbor 141.108.1.1 next-hop-self
 neighbor 141.199.1.2 remote-as 1001
 neighbor 141.199.1.2 send-community
 neighbor 141.199.1.2 route-map noexport out
 neighbor 141.199.1.2 filter-list 1 in
 neighbor 151.108.1.1 remote-as 1
 neighbor 151.108.1.1 update-source Loopback1
 neighbor 151.108.1.1 route-reflector-client
 neighbor 151.108.1.1 next-hop-self
 neighbor 161.108.1.1 remote-as 1
 neighbor 161.108.1.1 update-source Loopback1
 neighbor 161.108.1.1 route-reflector-client
 neighbor 161.108.1.1 next-hop-self

route-map noexport permit 10
 set community no-export
access-list 1 permit 0.0.0.0
```

```
interface Loopback1
 ip address 161.108.1.1 255.255.255.0
interface GigabitEthernet0/0
 description to_R1
 ip address 131.106.1.2 255.255.255.0
interface GigabitEthernet0/0/1
 switchport access vlan 10
 no ip address
interface Vlan10
 ip address 151.199.1.1 255.255.255.0
router ospf 1
 network 131.106.1.0 0.0.0.255 area 1
 network 161.108.1.0 0.0.0.255 area 1
router bgp 1
 bgp always-compare-med
 bgp log-neighbor-changes
 network 131.108.1.0 mask 255.255.255.0
 neighbor 131.108.1.1 remote-as 1
 neighbor 131.108.1.1 update-source Loopback1
 neighbor 131.108.1.1 route-reflector-client
 neighbor 131.108.1.1 route-map setmedr1 in
 neighbor 141.108.1.1 remote-as 1
 neighbor 141.108.1.1 update-source Loopback1
 neighbor 141.108.1.1 route-reflector-client
 neighbor 151.108.1.1 remote-as 1
 neighbor 151.108.1.1 update-source Loopback1
 neighbor 151.108.1.1 route-reflector-client
 neighbor 151.199.1.2 remote-as 1002
 neighbor 151.199.1.2 route-map setmedisp2 in
!
access-list 1 permit 0.0.0.0
access-list 2 permit 0.0.0.0
route-map setmedr1 permit 10
 match ip address 1
 set metric 100
route-map setmedisp2 permit 10
 match ip address 2
 set metric 200
```

R3

```
hostname R3
interface Loopback1
 ip address 141.108.1.1 255.255.255.0
interface GigabitEthernet0/0
 description to_R1
 ip address 131.108.255.6 255.255.255.252
router ospf 1
 network 131.108.255.4 0.0.0.3 area 1
 network 141.108.1.0 0.0.0.255 area 1
router bgp 1
 bgp log-neighbor-changes
 network 131.108.255.4 mask 255.255.255.252
 neighbor 131.108.1.1 remote-as 1
 neighbor 131.108.1.1 update-source Loopback1
 neighbor 161.108.1.1 remote-as 1
 neighbor 161.108.1.1 update-source Loopback1
```

R4

```
hostname R4
interface Loopback1
 ip address 151.108.1.1 255.255.255.0
interface GigabitEthernet0/0
 description to_R1
 ip address 131.108.255.14 255.255.255.252

router ospf 1
 network 131.108.255.12 0.0.0.3 area 1
 network 151.108.1.0 0.0.0.255 area 1
router bgp 1
 bgp log-neighbor-changes
 network 131.108.255.12 mask 255.255.255.252
 neighbor 131.108.1.1 remote-as 1
 neighbor 131.108.1.1 update-source Loopback1
 neighbor 161.108.1.1 remote-as 1
 neighbor 161.108.1.1 update-source Loopback1
```

R5

```
hostname ISP_R5
interface FastEthernet0/0
```

R6

```
hostname ISP_R6
interface FastEthernet0/0
```

```
 ip address 141.199.1.2 255.255.255.0
 no shut
interface FastEthernet0/1
 description to-R6
 ip address 1.1.1.2 255.255.255.0
router bgp 1001
 no synchronization
 bgp log-neighbor-changes
 neighbor 141.199.1.1 remote-as 1
 neighbor 141.199.1.1 default-originate
 no auto-summary

ip route 0.0.0.0 0.0.0.0 1.1.1.1
```

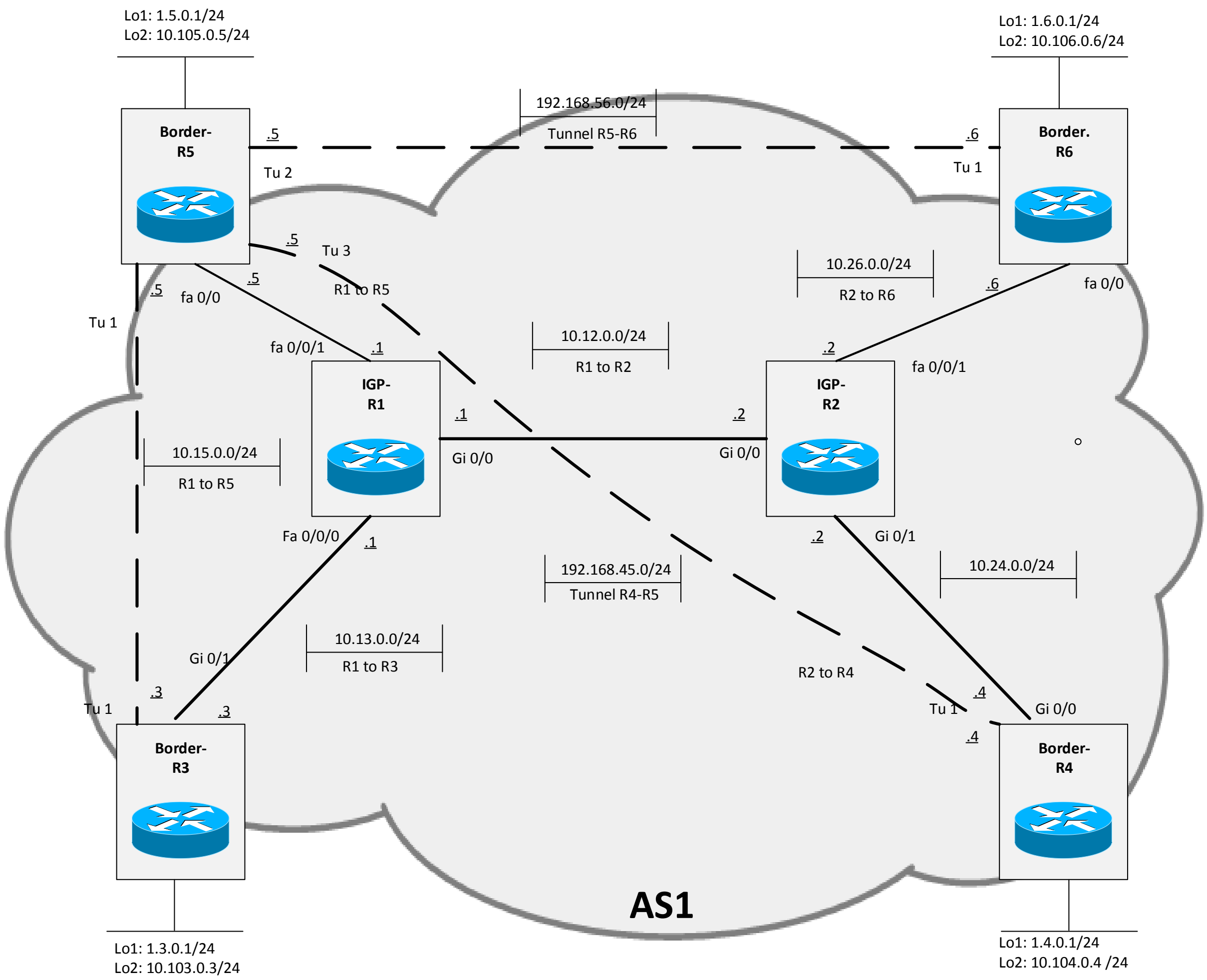
```
 ip address 151.199.1.2 255.255.255.0
interface FastEthernet0/1
 ip address 1.1.1.1 255.255.255.0
router bgp 1002
 no synchronization
 bgp log-neighbor-changes
 neighbor 151.199.1.1 remote-as 1
 neighbor 151.199.1.1 default-originate
 no auto-summary

ip route 0.0.0.0 0.0.0.0 1.1.1.2
```

Fallbeispiel 7 :: BGP und MPLS (Prüfungsbeispiel)

In diesem Fallbeispiel wird das Zusammenwirken von BGP und MPLS dargestellt.

Folgende Anforderungen werden konfiguriert:

1. In diesem Fallbeispiel gibt es einen Carier, bestehend aus den Routen R1 und R2. Dieser versorgt einen ISP mit vier Boderroutern (R3,R4,R5 und R6).
2. Im Carrier wird mit OSPF geroutet.
3. Router 5 wird als Router Reflector ausgeführt
4. R5 hat zu den anderen Borderroutern einen GRE-Tunnel.
5. In den Tunneln wird mit EIGRP geroutet.
6. Die Border haben ein LO als Router-ID für BGP.



Nachfolgend die Auszüge aus den Konfigurationen:

R1	R2
hostname IGP-R1 ip host R2 10.12.0.2 ip host R5 10.15.0.5 ip host R3 10.13.0.3 interface GigabitEthernet0/0 description to_R2 ip address 10.12.0.1 255.255.255.0 interface FastEthernet0/0/0 description to_R3 ip address 10.13.0.1 255.255.255.0 interface FastEthernet0/0/1 description to_R5 ip address 10.15.0.1 255.255.255.0 router ospf 1 network 10.12.0.0 0.0.0.255 area 1 network 10.13.0.0 0.0.0.255 area 1 network 10.15.0.0 0.0.0.255 area 1	hostname IGP-R2 ip host R6 10.26.0.6 ip host R4 10.24.0.4 ip host R1 10.12.0.1 interface GigabitEthernet0/0 description to_R1 ip address 10.12.0.2 255.255.255.0 interface GigabitEthernet0/0/0 description to_R4 switchport access vlan 20 no ip address interface Vlan10 description to_R6 ip address 10.26.0.2 255.255.255.0 interface Vlan20 description to_R4 ip address 10.24.0.2 255.255.255.0 router ospf 1 network 10.12.0.0 0.0.0.255 area 1 network 10.24.0.0 0.0.0.255 area 1 network 10.26.0.0 0.0.0.255 area 1
R3	**R4**
hostname Border-R3 interface Loopback1 ip address 1.3.0.1 255.255.255.0 interface Loopback2 ip address 10.103.0.3 255.255.255.0	hostname Border-R4 interface Loopback1 ip address 1.4.0.1 255.255.255.0 interface Loopback2 ip address 10.104.0.4 255.255.255.0

```
interface Tunnel1
 ip address 192.168.35.3 255.255.255.0
 tunnel source GigabitEthernet0/0
 tunnel destination 10.15.0.5
interface GigabitEthernet0/0
 description to_R1
 ip address 10.13.0.3 255.255.255.0
router eigrp 1
 network 10.103.0.0 0.0.0.255
 network 192.168.35.0
router ospf 1
 network 10.13.0.0 0.0.0.255 area 1
router bgp 1
 bgp log-neighbor-changes
 network 1.3.0.0 mask 255.255.255.0
 network 192.168.35.0
 neighbor 10.105.0.5 remote-as 1
 neighbor 10.105.0.5 update-source Loopback2
```

```
interface Tunnel1
 ip address 192.168.45.4 255.255.255.0
 tunnel source GigabitEthernet0/1
 tunnel destination 10.15.0.5
interface GigabitEthernet0/1
 description to_R2
 ip address 10.24.0.4 255.255.255.0
router eigrp 1
 network 10.104.0.0 0.0.0.255
 network 192.168.45.0
router ospf 1
 network 10.24.0.0 0.0.0.255 area 1
router bgp 1
 bgp log-neighbor-changes
 network 1.4.0.0 mask 255.255.255.0
 network 192.168.45.0
 neighbor 10.105.0.5 remote-as 1
 neighbor 10.105.0.5 update-source Loopback2
```

R5

```
hostname Border-R5
interface Loopback1
 ip address 1.5.0.1 255.255.255.0
interface Loopback2
 ip address 10.105.0.5 255.255.255.0
interface Tunnel1
 ip address 192.168.35.5 255.255.255.0
 tunnel source FastEthernet0/0
 tunnel destination 10.13.0.3
interface Tunnel2
 ip address 192.168.56.5 255.255.255.0
 tunnel source FastEthernet0/0
 tunnel destination 10.26.0.6
interface Tunnel3
 ip address 192.168.45.5 255.255.255.0
 tunnel source FastEthernet0/0
 tunnel destination 10.24.0.4
interface FastEthernet0/0
 description to_R2
 ip address 10.15.0.5 255.255.255.0
router eigrp 1
 network 10.105.0.0 0.0.0.255
 network 192.168.35.0
 network 192.168.45.0
 network 192.168.56.0
 no auto-summary
router ospf 1
 log-adjacency-changes
 network 10.15.0.0 0.0.0.255 area 1
router bgp 1
 no synchronization
 bgp log-neighbor-changes
 network 1.5.0.0 mask 255.255.255.0
 network 192.168.35.0
 network 192.168.45.0
 network 192.168.56.0
 neighbor 10.103.0.3 remote-as 1
 neighbor 10.103.0.3 update-source Loopback2
 neighbor 10.103.0.3 route-reflector-client
 neighbor 10.104.0.4 remote-as 1
 neighbor 10.104.0.4 update-source Loopback2
 neighbor 10.104.0.4 route-reflector-client
 neighbor 10.106.0.6 remote-as 1
 neighbor 10.106.0.6 update-source Loopback2
 neighbor 10.106.0.6 route-reflector-client
 no auto-summary
```

R6

```
hostname Border-R6
interface Loopback1
 ip address 1.6.0.1 255.255.255.0
interface Loopback2
 ip address 10.106.0.6 255.255.255.0
interface Tunnel1
 ip address 192.168.56.6 255.255.255.0
 tunnel source FastEthernet0/0
 tunnel destination 10.15.0.5
interface FastEthernet0/0
 description to_R2
 ip address 10.26.0.6 255.255.255.0
 duplex auto
 speed auto
router eigrp 1
 network 10.106.0.0 0.0.0.255
 network 192.168.56.0
 no auto-summary
router ospf 1
 log-adjacency-changes
 network 10.26.0.0 0.0.0.255 area 1
router bgp 1
 no synchronization
 bgp log-neighbor-changes
 network 1.6.0.0 mask 255.255.255.0
 network 192.168.56.0
 neighbor 10.105.0.5 remote-as 1
 neighbor 10.105.0.5 update-source Loopback2
 no auto-summary
```

Betrachten wir nun beispielsweise die Routingtabelle auf R3:

```
R3(config)# show ip route
D     192.168.45.0/24 [90/28160000] via 192.168.35.5, 01:03:42, Tunne      1.0.0.0/8
is variably subnetted, 5 subnets, 2 masks
C        1.3.0.0/24 is directly connected, Loopback1
L        1.3.0.1/32 is directly connected, Loopback1
B        1.4.0.0/24 [200/0] via 10.104.0.4, 00:45:18
B        1.5.0.0/24 [200/0] via 10.105.0.5, 00:34:32
B        1.6.0.0/24 [200/0] via 10.106.0.6, 00:36:38
      10.0.0.0/8 is variably subnetted, 11 subnets, 2 masks
O        10.12.0.0/24 [110/2] via 10.13.0.1, 22:16:11, GigabitEthernet0/0
C        10.13.0.0/24 is directly connected, GigabitEthernet0/0
L        10.13.0.3/32 is directly connected, GigabitEthernet0/0
O        10.15.0.0/24 [110/2] via 10.13.0.1, 22:16:11, GigabitEthernet0/0
O        10.24.0.0/24 [110/3] via 10.13.0.1, 22:16:11, GigabitEthernet0/0
O        10.26.0.0/24 [110/3] via 10.13.0.1, 22:16:11, GigabitEthernet0/0
C        10.103.0.0/24 is directly connected, Loopback2
L        10.103.0.3/32 is directly connected, Loopback2
D        10.104.0.0/24 [90/28288000] via 192.168.35.5, 00:59:16, Tunnel1
D        10.105.0.0/24 [90/27008000] via 192.168.35.5, 01:03:42, Tunnel1
D        10.106.0.0/24 [90/28288000] via 192.168.35.5, 01:01:10, Tunnel1
      192.168.35.0/24 is variably subnetted, 2 subnets, 2 masks
C        192.168.35.0/24 is directly connected, Tunnel1
L        192.168.35.3/32 is directly connected, Tunnel1
D     192.168.56.0/24 [90/28160000] via 192.168.35.5, 01:03:42, Tunnel1
```

Betrachten wir nun einen Trace von R3 auf R6 – man erkennt, dass hier die Tunnel zur Anwendung kommen:

```
R3(config)# raceroute 1.6.0.1
  1 192.168.35.5 0 msec 0 msec 0 msec
  2 192.168.56.6 4 msec 0 msec *
```

Nun werden die GRE-Tunnel durch mpls im Carrier ersetzt.

Fallbeispiel 8 :: BGP und MPLS

In dieser Konfiguration übernimmt MPLS die dynamische „Verwaltung" der logischen Verbindungen durch den Carrier:

Nachfolgend exemplarisch die Konfiguration von R5:

```
R5(config)# ip cef
R5(config-if)# int fa 0/1
R5(config-if)#des to_R1
R5(config-if)#ip add 10.15.0.5 255.255.255.0
```

```
R5(config-if)#mpls ip
R5(config-if)#no shut
R5(config)#int lo1
R5(config-if)#ip address 1.5.0.1 255.255.255.0
R5(config-if)#int lo2
R5(config-if)#ip address 10.105.0.5 255.255.255.0
R5(config-if)#exit
R5(config)#router ospf 1
R5(config-router)#network 10.15.0.0 0.0.0.255 area 1
R5(config-router)#network 10.105.0.0 0.0.0.255 area 1
R5(config-router)#exit
R5(config-if)#router bgp 1
R5(config-router)#  neighbor 10.103.0.3 remote-as 1
R5(config-router)#    neighbor 10.103.0.3 update-source lo 2
R5(config-router)#    neighbor 10.103.0.3 route-reflector-client
R5(config-router)#    neighbor 10.104.0.4 remote-as 1
R5(config-router)#    neighbor 10.104.0.4 update-source lo 2
R5(config-router)#    neighbor 10.104.0.4 route-reflector-client
R5(config-router)#    neighbor 10.106.0.6 remote-as 1
R5(config-router)#    neighbor 10.106.0.6 update-source lo 2
R5(config-router)#    neighbor 10.106.0.6 route-reflector-client
R5(config-router)#    network 1.5.0.0 mask 255.255.255.0
```

R5 ist wieder als Route Reflector konfiguriert, CEF ist global aktiviert und MPLS auf dem Interface aktiviert.

Eine beispielhafte Konfiguration von R1 lautet:

```
R5(config)# ip cef
R5(config-if)# int gi 0/0
R5(config-if)# des to_R3
R5(config-if)# ip address 10.13.0.1 255.255.255.0
R5(config-if)# mpls ip
R5(config-if)# no sh
R5(config-if)# exit
R5(config)# int vlan 10
R5(config-if)# des to_R2
R5(config-if)# ip address 10.12.0.1 255.255.255.0
R5(config-if)# mpls ip
R5(config-if)# no shutdown
```

```
R5(config-if)# exit
R5(config-)# int gi 0/0/0
R5(config-if)# des to_R2
R5(config-if)# switchport access vlan 10
R5(config-if)# mpls ip
R5(config-if)# no shut
R5(config-if)# exit
R5(config)# int gi 0/1
R5(config-if)# des to_R5
R5(config-if)# ip address 10.15.0.1 255.255.255.0
R5(config-if)# mpls ip
R5(config-if)# no sh
R5(config-if)# exit
R5(config)# router ospf 1
R5(config-router)# network 10.15.0.0 0.0.0.255 area 1
R5(config-router)# network 10.12.0.0 0.0.0.255 area 1
R5(config-router)# network 10.13.0.0 0.0.0.255 area 1
R5(config-router)# exit
```

Auch auf R1 muss CEF aktiviert sein, sowie auf allen Interfaces (bzw. dem VLAN) MPLS aktiviert werden. Man beachte, daß in OSPF nur die lokalen Netze verwaltet werden.

Betrachten wir nun die Routingtabelle von R1:

```
R5(config)# sh ip route
      10.0.0.0/8 is variably subnetted, 12 subnets, 2 masks
C        10.12.0.0/24 is directly connected, Vlan10
L        10.12.0.1/32 is directly connected, Vlan10
C        10.13.0.0/24 is directly connected, GigabitEthernet0/0
L        10.13.0.1/32 is directly connected, GigabitEthernet0/0
C        10.15.0.0/24 is directly connected, GigabitEthernet0/1
L        10.15.0.1/32 is directly connected, GigabitEthernet0/1
O        10.24.0.0/24 [110/2] via 10.12.0.2, 00:27:47, Vlan10
O        10.26.0.0/24 [110/2] via 10.12.0.2, 00:51:38, Vlan10
O        10.103.0.3/32 [110/2] via 10.13.0.3, 00:23:42, GigabitEthernet0/0
O        10.104.0.4/32 [110/3] via 10.12.0.2, 00:25:51, Vlan10
O        10.105.0.5/32 [110/2] via 10.15.0.5, 00:34:37, GigabitEthernet0/1
O        10.106.0.6/32 [110/3] via 10.12.0.2, 00:31:19, Vlan10
```

Wie aus der Routingtabelle ersichtlich, sind nur private Adressen erkennbar – und KEINE Border-IP's.

Betrachten wir nun die Routingtabelle auf R5:

R5(config)# **sh ip route**
```
     1.0.0.0/24 is subnetted, 4 subnets
B       1.3.0.0 [200/0] via 10.103.0.3, 00:23:31
C       1.5.0.0 is directly connected, Loopback1
B       1.4.0.0 [200/0] via 10.104.0.4, 00:19:34
B       1.6.0.0 [200/0] via 10.106.0.6, 00:20:06
     10.0.0.0/8 is variably subnetted, 9 subnets, 2 masks
C       10.15.0.0/24 is directly connected, FastEthernet0/1
O       10.12.0.0/24 [110/2] via 10.15.0.1, 00:39:37, FastEthernet0/1
O       10.13.0.0/24 [110/2] via 10.15.0.1, 00:28:41, FastEthernet0/1
O       10.26.0.0/24 [110/3] via 10.15.0.1, 00:39:38, FastEthernet0/1
O       10.24.0.0/24 [110/3] via 10.15.0.1, 00:32:47, FastEthernet0/1
C       10.105.0.0/24 is directly connected, Loopback2
O       10.106.0.6/32 [110/4] via 10.15.0.1, 00:36:19, FastEthernet0/1
O       10.104.0.4/32 [110/4] via 10.15.0.1, 00:30:52, FastEthernet0/1
O       10.103.0.3/32 [110/3] via 10.15.0.1, 00:28:32, FastEthernet0/1
```

Beziehungsweise genauer:

R5(config)# **sh ip route**
```
B       1.3.0.0 [200/0] via 10.103.0.3, 00:24:04
B       1.4.0.0 [200/0] via 10.104.0.4, 00:20:07
B       1.6.0.0 [200/0] via 10.106.0.6, 00:20:39
```

Somit sind die Bordernetze auf R5 sichtbar – und auch erreichbar, obwohl diese Netze auf R1 und R2 unbekannt sind:

R5(config)# **sh ip route**
```
Sending 5, 100-byte ICMP Echos to 1.4.0.1, timeout is 2 seconds:
!!!!!
```

Betrachten wir dazu nun die MPLS Forwardingbase auf R5:

```
Border-R5#sh mpls ip  binding
  1.5.0.0/24
        in label:     imp-null
  10.12.0.0/24
        in label:     17
        out label:    imp-null  lsr: 10.12.0.1:0      inuse
  10.13.0.0/24
        in label:     21
        out label:    imp-null  lsr: 10.12.0.1:0      inuse
```

```
  10.15.0.0/24
        in label:     imp-null
        out label:    imp-null  lsr: 10.12.0.1:0
  10.24.0.0/24
        in label:     19
        out label:    19        lsr: 10.12.0.1:0      inuse
  10.26.0.0/24
        in label:     16
        out label:    16        lsr: 10.12.0.1:0      inuse
  10.103.0.3/32
        in label:     22
        out label:    21        lsr: 10.12.0.1:0      inuse
  10.104.0.4/32
        in label:     20
        out label:    20        lsr: 10.12.0.1:0      inuse
  10.105.0.0/24
        in label:     imp-null
  10.105.0.5/32
        out label:    17        lsr: 10.12.0.1:0
  10.106.0.6/32
        in label:     18
        out label:    18        lsr: 10.12.0.1:0      inuse
Border-R5#sh mpls ldp neighbor
    Peer LDP Ident: 10.12.0.1:0; Local LDP Ident 10.15.0.5:0
        TCP connection: 10.12.0.1.646 - 10.15.0.5.26324
        State: Oper; Msgs sent/rcvd: 63/64; Downstream
        Up time: 00:45:36
        LDP discovery sources:
          FastEthernet0/1, Src IP addr: 10.15.0.1
        Addresses bound to peer LDP Ident:
          10.12.0.1       10.15.0.1       10.13.0.1
Border-R5#
Border-R5#sh mpls ldp bindings
```

```
 lib entry: 1.5.0.0/24, rev 4
       local binding:  label: imp-null
 lib entry: 10.12.0.0/24, rev 10
       local binding:  label: 17
       remote binding: lsr: 10.12.0.1:0, label: imp-null
 lib entry: 10.13.0.0/24, rev 19
       local binding:  label: 21
       remote binding: lsr: 10.12.0.1:0, label: imp-null
 lib entry: 10.15.0.0/24, rev 2
       local binding:  label: imp-null
       remote binding: lsr: 10.12.0.1:0, label: imp-null
 lib entry: 10.24.0.0/24, rev 15
       local binding:  label: 19
       remote binding: lsr: 10.12.0.1:0, label: 19
 lib entry: 10.26.0.0/24, rev 8
       local binding:  label: 16
       remote binding: lsr: 10.12.0.1:0, label: 16
 lib entry: 10.103.0.3/32, rev 21
       local binding:  label: 22
       remote binding: lsr: 10.12.0.1:0, label: 21
 lib entry: 10.104.0.4/32, rev 17
       local binding:  label: 20
       remote binding: lsr: 10.12.0.1:0, label: 20
 lib entry: 10.105.0.0/24, rev 6
       local binding:  label: imp-null
 lib entry: 10.105.0.5/32, rev 11
       remote binding: lsr: 10.12.0.1:0, label: 17
 lib entry: 10.106.0.6/32, rev 13
       local binding:  label: 18
       remote binding: lsr: 10.12.0.1:0, label: 18
Border-R5#sh mpls forwarding-table
Local  Outgoing      Prefix            Bytes Label   Outgoing   Next Hop
Label  Label or VC   or Tunnel Id      Switched      interface
```

```
16    16          10.26.0.0/24     0         Fa0/1     10.15.0.1
17    Pop Label   10.12.0.0/24     0         Fa0/1     10.15.0.1
18    18          10.106.0.6/32    0         Fa0/1     10.15.0.1
19    19          10.24.0.0/24     0         Fa0/1     10.15.0.1
20    20          10.104.0.4/32    0         Fa0/1     10.15.0.1
21    Pop Label   10.13.0.0/24     0         Fa0/1     10.15.0.1
22    21          10.103.0.3/32    0         Fa0/1     10.15.0.1
```

R1!!

```
IGP-R1#show mpls ip binding
  1.3.0.0/24
        out label:    imp-null  lsr: 10.103.0.3:0
  1.5.0.0/24
        out label:    imp-null  lsr: 10.15.0.5:0
  10.12.0.0/24
        in label:     imp-null
        out label:    imp-null  lsr: 10.12.0.2:0
        out label:    17        lsr: 10.15.0.5:0
        out label:    22        lsr: 10.103.0.3:0
  10.13.0.0/24
        in label:     imp-null
        out label:    21        lsr: 10.15.0.5:0
        out label:    20        lsr: 10.12.0.2:0
        out label:    imp-null  lsr: 10.103.0.3:0
  10.15.0.0/24
        in label:     imp-null
        out label:    16        lsr: 10.12.0.2:0
        out label:    imp-null  lsr: 10.15.0.5:0
        out label:    21        lsr: 10.103.0.3:0
  10.24.0.0/24
        in label:     19
        out label:    imp-null  lsr: 10.12.0.2:0      inuse
        out label:    19        lsr: 10.15.0.5:0
```

```
        out label:    20        lsr: 10.103.0.3:0
  10.26.0.0/24
        in label:     16
        out label:    imp-null  lsr: 10.12.0.2:0      inuse
        out label:    16        lsr: 10.15.0.5:0
        out label:    19        lsr: 10.103.0.3:0
  10.103.0.0/24
        out label:    imp-null  lsr: 10.103.0.3:0
  10.103.0.3/32
        in label:     21
        out label:    21        lsr: 10.12.0.2:0
        out label:    22        lsr: 10.15.0.5:0
  10.104.0.4/32
        in label:     20
        out label:    19        lsr: 10.12.0.2:0      inuse
        out label:    20        lsr: 10.15.0.5:0
        out label:    18        lsr: 10.103.0.3:0
  10.105.0.0/24
        out label:    imp-null  lsr: 10.15.0.5:0
  10.105.0.5/32
        in label:     17
        out label:    17        lsr: 10.12.0.2:0
        out label:    17        lsr: 10.103.0.3:0
  10.106.0.6/32
        in label:     18
        out label:    18        lsr: 10.12.0.2:0      inuse
        out label:    18        lsr: 10.15.0.5:0
        out label:    16        lsr: 10.103.0.3:0
IGP-R1#
GP-R1#sh mpls ldp neighbor
    Peer LDP Ident: 10.12.0.2:0; Local LDP Ident 10.12.0.1:0
        TCP connection: 10.12.0.2.33865 - 10.12.0.1.646
        State: Oper; Msgs sent/rcvd: 70/69; Downstream
```

```
        Up time: 00:49:52
        LDP discovery sources:
          Vlan10, Src IP addr: 10.12.0.2
        Addresses bound to peer LDP Ident:
          10.12.0.2       10.26.0.2       10.24.0.2
    Peer LDP Ident: 10.15.0.5:0; Local LDP Ident 10.12.0.1:0
        TCP connection: 10.15.0.5.26324 - 10.12.0.1.646
        State: Oper; Msgs sent/rcvd: 68/67; Downstream
        Up time: 00:48:34
        LDP discovery sources:
          GigabitEthernet0/1, Src IP addr: 10.15.0.5
        Addresses bound to peer LDP Ident:
          10.15.0.5       1.5.0.1         10.105.0.5
    Peer LDP Ident: 10.103.0.3:0; Local LDP Ident 10.12.0.1:0
        TCP connection: 10.103.0.3.53175 - 10.12.0.1.646
        State: Oper; Msgs sent/rcvd: 55/56; Downstream
        Up time: 00:37:38
        LDP discovery sources:
          GigabitEthernet0/0, Src IP addr: 10.13.0.3
        Addresses bound to peer LDP Ident:
          10.13.0.3       1.3.0.1         10.103.0.3
IGP-R1#sh mpls ldp bindings
  lib entry: 1.3.0.0/24, rev 24
        remote binding: lsr: 10.103.0.3:0, label: imp-null
  lib entry: 1.5.0.0/24, rev 10
        remote binding: lsr: 10.15.0.5:0, label: imp-null
  lib entry: 10.12.0.0/24, rev 6
        local binding:  label: imp-null
        remote binding: lsr: 10.12.0.2:0, label: imp-null
        remote binding: lsr: 10.15.0.5:0, label: 17
        remote binding: lsr: 10.103.0.3:0, label: 22
  lib entry: 10.13.0.0/24, rev 21
        local binding:  label: imp-null
```

```
        remote binding: lsr: 10.15.0.5:0, label: 21
        remote binding: lsr: 10.12.0.2:0, label: 20
        remote binding: lsr: 10.103.0.3:0, label: imp-null
  lib entry: 10.15.0.0/24, rev 4
        local binding:  label: imp-null
        remote binding: lsr: 10.12.0.2:0, label: 16
        remote binding: lsr: 10.15.0.5:0, label: imp-null
        remote binding: lsr: 10.103.0.3:0, label: 21
  lib entry: 10.24.0.0/24, rev 17
        local binding:  label: 19
        remote binding: lsr: 10.12.0.2:0, label: imp-null
        remote binding: lsr: 10.15.0.5:0, label: 19
        remote binding: lsr: 10.103.0.3:0, label: 20
  lib entry: 10.26.0.0/24, rev 8
        local binding:  label: 16
        remote binding: lsr: 10.12.0.2:0, label: imp-null
        remote binding: lsr: 10.15.0.5:0, label: 16
        remote binding: lsr: 10.103.0.3:0, label: 19
  lib entry: 10.103.0.0/24, rev 25
        remote binding: lsr: 10.103.0.3:0, label: imp-null
  lib entry: 10.103.0.3/32, rev 23
        local binding:  label: 21
        remote binding: lsr: 10.12.0.2:0, label: 21
        remote binding: lsr: 10.15.0.5:0, label: 22
  lib entry: 10.104.0.4/32, rev 19
        local binding:  label: 20
        remote binding: lsr: 10.12.0.2:0, label: 19
        remote binding: lsr: 10.15.0.5:0, label: 20
        remote binding: lsr: 10.103.0.3:0, label: 18
  lib entry: 10.105.0.0/24, rev 11
        remote binding: lsr: 10.15.0.5:0, label: imp-null
  lib entry: 10.105.0.5/32, rev 13
        local binding:  label: 17
```



```
        remote binding: lsr: 10.12.0.2:0, label: 17
        remote binding: lsr: 10.103.0.3:0, label: 17
  lib entry: 10.106.0.6/32, rev 15
        local binding:  label: 18
        remote binding: lsr: 10.12.0.2:0, label: 18
        remote binding: lsr: 10.15.0.5:0, label: 18
        remote binding: lsr: 10.103.0.3:0, label: 16
IGP-R1#
IGP-R1#sh mpls forwarding-table
Local      Outgoing   Prefix           Bytes Label   Outgoing   Next Hop
Label      Label      or Tunnel Id     Switched      interface
16         Pop Label  10.26.0.0/24     0             Vl10       10.12.0.2
17         No Label   10.105.0.5/32    16530         Gi0/1      10.15.0.5
18         18         10.106.0.6/32    6502          Vl10       10.12.0.2
19         Pop Label  10.24.0.0/24     1140          Vl10       10.12.0.2
20         19         10.104.0.4/32    7146          Vl10       10.12.0.2
21         No Label   10.103.0.3/32    6780          Gi0/0      10.13.0.3
Border-R3#show mpls ip binding
  1.3.0.0/24
        in label:     imp-null
  10.12.0.0/24
        in label:     22
        out label:    imp-null  lsr: 10.12.0.1:0      inuse
  10.13.0.0/24
        in label:     imp-null
        out label:    imp-null  lsr: 10.12.0.1:0
  10.15.0.0/24
        in label:     21
        out label:    imp-null  lsr: 10.12.0.1:0      inuse
  10.24.0.0/24
        in label:     20
        out label:    19        lsr: 10.12.0.1:0      inuse
  10.26.0.0/24
```

```
        in label:     19
        out label:    16        lsr: 10.12.0.1:0       inuse
  10.103.0.0/24
        in label:     imp-null
  10.103.0.3/32
        out label:    21        lsr: 10.12.0.1:0
  10.104.0.4/32
        in label:     18
        out label:    20        lsr: 10.12.0.1:0       inuse
  10.105.0.5/32
        in label:     17
        out label:    17        lsr: 10.12.0.1:0       inuse
  10.106.0.6/32
        in label:     16
        out label:    18        lsr: 10.12.0.1:0       inuse
Border-R3#sh mpls ldp neighbor
    Peer LDP Ident: 10.12.0.1:0; Local LDP Ident 10.103.0.3:0
        TCP connection: 10.12.0.1.646 - 10.103.0.3.53175
        State: Oper; Msgs sent/rcvd: 57/56; Downstream
        Up time: 00:39:10
        LDP discovery sources:
          FastEthernet0/0, Src IP addr: 10.13.0.1
        Addresses bound to peer LDP Ident:
          10.12.0.1       10.15.0.1       10.13.0.1
Border-R3#sh mpls ldp bindings
  lib entry: 1.3.0.0/24, rev 2
        local binding:  label: imp-null
  lib entry: 10.12.0.0/24, rev 20
        local binding:  label: 22
        remote binding: lsr: 10.12.0.1:0, label: imp-null
  lib entry: 10.13.0.0/24, rev 6
        local binding:  label: imp-null
        remote binding: lsr: 10.12.0.1:0, label: imp-null
```

```
  lib entry: 10.15.0.0/24, rev 18
        local binding:  label: 21
        remote binding: lsr: 10.12.0.1:0, label: imp-null
  lib entry: 10.24.0.0/24, rev 16
        local binding:  label: 20
        remote binding: lsr: 10.12.0.1:0, label: 19
  lib entry: 10.26.0.0/24, rev 14
        local binding:  label: 19
        remote binding: lsr: 10.12.0.1:0, label: 16
  lib entry: 10.103.0.0/24, rev 4
        local binding:  label: imp-null
  lib entry: 10.103.0.3/32, rev 21
        remote binding: lsr: 10.12.0.1:0, label: 21
  lib entry: 10.104.0.4/32, rev 12
        local binding:  label: 18
        remote binding: lsr: 10.12.0.1:0, label: 20
  lib entry: 10.105.0.5/32, rev 10
        local binding:  label: 17
        remote binding: lsr: 10.12.0.1:0, label: 17
  lib entry: 10.106.0.6/32, rev 8
        local binding:  label: 16
        remote binding: lsr: 10.12.0.1:0, label: 18
Border-R3#sh mpls forwarding-table
Local  Outgoing      Prefix            Bytes Label   Outgoing   Next Hop
Label  Label or VC   or Tunnel Id      Switched      interface
16     18            10.106.0.6/32     0             Fa0/0      10.13.0.1
17     17            10.105.0.5/32     0             Fa0/0      10.13.0.1
18     20            10.104.0.4/32     0             Fa0/0      10.13.0.1
19     16            10.26.0.0/24      0             Fa0/0      10.13.0.1
20     19            10.24.0.0/24      0             Fa0/0      10.13.0.1
21     Pop Label     10.15.0.0/24      0             Fa0/0      10.13.0.1
22     Pop Label     10.12.0.0/24      0             Fa0/0      10.13.0.1
R6!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
```

```
Border-R6#show mpls ip binding
  1.6.0.0/24
        in label:     imp-null
  10.12.0.0/24
        in label:     18
        out label:    imp-null  lsr: 10.12.0.2:0      inuse
  10.13.0.0/24
        in label:     21
        out label:    20        lsr: 10.12.0.2:0      inuse
  10.15.0.0/24
        in label:     17
        out label:    16        lsr: 10.12.0.2:0      inuse
  10.24.0.0/24
        in label:     19
        out label:    imp-null  lsr: 10.12.0.2:0      inuse
  10.26.0.0/24
        in label:     imp-null
        out label:    imp-null  lsr: 10.12.0.2:0
  10.103.0.3/32
        in label:     22
        out label:    21        lsr: 10.12.0.2:0      inuse
  10.104.0.4/32
        in label:     20
        out label:    19        lsr: 10.12.0.2:0      inuse
  10.105.0.5/32
        in label:     16
        out label:    17        lsr: 10.12.0.2:0      inuse
  10.106.0.0/24
        in label:     imp-null
  10.106.0.6/32
        out label:    18        lsr: 10.12.0.2:0
Border-R6#sh mpls ldp neighbor
    Peer LDP Ident: 10.12.0.2:0; Local LDP Ident 10.26.0.6:0
```

```
    TCP connection: 10.12.0.2.646 - 10.26.0.6.61794
    State: Oper; Msgs sent/rcvd: 68/69; Downstream
    Up time: 00:48:07
    LDP discovery sources:
      FastEthernet0/1, Src IP addr: 10.26.0.2
    Addresses bound to peer LDP Ident:
      10.12.0.2       10.26.0.2       10.24.0.2
Border-R6# sh mpls ldp bindings
  lib entry: 1.6.0.0/24, rev 4
        local binding:  label: imp-null
  lib entry: 10.12.0.0/24, rev 12
        local binding:  label: 18
        remote binding: lsr: 10.12.0.2:0, label: imp-null
  lib entry: 10.13.0.0/24, rev 19
        local binding:  label: 21
        remote binding: lsr: 10.12.0.2:0, label: 20
  lib entry: 10.15.0.0/24, rev 10
        local binding:  label: 17
        remote binding: lsr: 10.12.0.2:0, label: 16
  lib entry: 10.24.0.0/24, rev 15
        local binding:  label: 19
        remote binding: lsr: 10.12.0.2:0, label: imp-null
  lib entry: 10.26.0.0/24, rev 2
        local binding:  label: imp-null
        remote binding: lsr: 10.12.0.2:0, label: imp-null
  lib entry: 10.103.0.3/32, rev 21
        local binding:  label: 22
        remote binding: lsr: 10.12.0.2:0, label: 21
  lib entry: 10.104.0.4/32, rev 17
        local binding:  label: 20
        remote binding: lsr: 10.12.0.2:0, label: 19
  lib entry: 10.105.0.5/32, rev 8
        local binding:  label: 16
```

remote binding: lsr: 10.12.0.2:0, label: 17

lib entry: 10.106.0.0/24, rev 6

local binding: label: imp-null

lib entry: 10.106.0.6/32, rev 13

remote binding: lsr: 10.12.0.2:0, label: 18

Border-R6#sh mpls forwarding-table

Local Label	Outgoing Label or VC	Prefix or Tunnel Id	Bytes Label Switched	Outgoing interface	Next Hop
16	17	10.105.0.5/32	0	Fa0/1	10.26.0.2
17	16	10.15.0.0/24	0	Fa0/1	10.26.0.2
18	Pop Label	10.12.0.0/24	0	Fa0/1	10.26.0.2
19	Pop Label	10.24.0.0/24	0	Fa0/1	10.26.0.2
20	19	10.104.0.4/32	0	Fa0/1	10.26.0.2
21	20	10.13.0.0/24	0	Fa0/1	10.26.0.2
22	21	10.103.0.3/32	0	Fa0/1	10.26.0.2

R2!!! GP-R2#show mpls ip binding

1.4.0.0/24

out label: imp-null lsr: 10.104.0.4:0

1.6.0.0/24

out label: imp-null lsr: 10.26.0.6:0

10.12.0.0/24

in label: imp-null

out label: imp-null lsr: 10.12.0.1:0

out label: 18 lsr: 10.26.0.6:0

out label: 20 lsr: 10.104.0.4:0

10.13.0.0/24

in label: 20

out label: imp-null lsr: 10.12.0.1:0 inuse

out label: 21 lsr: 10.26.0.6:0

out label: 21 lsr: 10.104.0.4:0

10.15.0.0/24

in label: 16

out label: imp-null lsr: 10.12.0.1:0 inuse

```
        out label:    17        lsr: 10.26.0.6:0
        out label:    18        lsr: 10.104.0.4:0
  10.24.0.0/24
        in label:     imp-null
        out label:    19        lsr: 10.12.0.1:0
        out label:    19        lsr: 10.26.0.6:0
        out label:    imp-null  lsr: 10.104.0.4:0
  10.26.0.0/24
        in label:     imp-null
        out label:    16        lsr: 10.12.0.1:0
        out label:    imp-null  lsr: 10.26.0.6:0
        out label:    19        lsr: 10.104.0.4:0
  10.103.0.3/32
        in label:     21
        out label:    21        lsr: 10.12.0.1:0     inuse
        out label:    22        lsr: 10.26.0.6:0
        out label:    22        lsr: 10.104.0.4:0
  10.104.0.0/24
        out label:    imp-null  lsr: 10.104.0.4:0
  10.104.0.4/32
        in label:     19
        out label:    20        lsr: 10.12.0.1:0
        out label:    20        lsr: 10.26.0.6:0
  10.105.0.5/32
        in label:     17
        out label:    17        lsr: 10.12.0.1:0     inuse
        out label:    16        lsr: 10.26.0.6:0
        out label:    17        lsr: 10.104.0.4:0
  10.106.0.0/24
        out label:    imp-null  lsr: 10.26.0.6:0
  10.106.0.6/32
        in label:     18
        out label:    18        lsr: 10.12.0.1:0
```

```
        out label:    16        lsr: 10.104.0.4:0
IGP-R2#
IGP-R2#sh mpls ldp neighbor
    Peer LDP Ident: 10.12.0.1:0; Local LDP Ident 10.12.0.2:0
        TCP connection: 10.12.0.1.646 - 10.12.0.2.33865
        State: Oper; Msgs sent/rcvd: 74/74; Downstream
        Up time: 00:53:57
        LDP discovery sources:
          FastEthernet0/0/0, Src IP addr: 10.12.0.1
        Addresses bound to peer LDP Ident:
          10.12.0.1       10.15.0.1       10.13.0.1
    Peer LDP Ident: 10.26.0.6:0; Local LDP Ident 10.12.0.2:0
        TCP connection: 10.26.0.6.61794 - 10.12.0.2.646
        State: Oper; Msgs sent/rcvd: 70/69; Downstream
        Up time: 00:49:28
        LDP discovery sources:
          GigabitEthernet0/1, Src IP addr: 10.26.0.6
        Addresses bound to peer LDP Ident:
          10.26.0.6       1.6.0.1         10.106.0.6
    Peer LDP Ident: 10.104.0.4:0; Local LDP Ident 10.12.0.2:0
        TCP connection: 10.104.0.4.28427 - 10.12.0.2.646
        State: Oper; Msgs sent/rcvd: 62/63; Downstream
        Up time: 00:44:00
        LDP discovery sources:
          GigabitEthernet0/0, Src IP addr: 10.24.0.4
        Addresses bound to peer LDP Ident:
          10.24.0.4       1.4.0.1         10.104.0.4
GP-R2#sh mpls ldp bindings
  lib entry: 1.4.0.0/24, rev 20
        remote binding: lsr: 10.104.0.4:0, label: imp-null
  lib entry: 1.6.0.0/24, rev 14
        remote binding: lsr: 10.26.0.6:0, label: imp-null
  lib entry: 10.12.0.0/24, rev 2
```



```
        local binding:  label: imp-null
        remote binding: lsr: 10.12.0.1:0, label: imp-null
        remote binding: lsr: 10.26.0.6:0, label: 18
        remote binding: lsr: 10.104.0.4:0, label: 20
  lib entry: 10.13.0.0/24, rev 23
        local binding:  label: 20
        remote binding: lsr: 10.12.0.1:0, label: imp-null
        remote binding: lsr: 10.26.0.6:0, label: 21
        remote binding: lsr: 10.104.0.4:0, label: 21
  lib entry: 10.15.0.0/24, rev 6
        local binding:  label: 16
        remote binding: lsr: 10.12.0.1:0, label: imp-null
        remote binding: lsr: 10.26.0.6:0, label: 17
        remote binding: lsr: 10.104.0.4:0, label: 18
  lib entry: 10.24.0.0/24, rev 17
        local binding:  label: imp-null
        remote binding: lsr: 10.12.0.1:0, label: 19
        remote binding: lsr: 10.26.0.6:0, label: 19
        remote binding: lsr: 10.104.0.4:0, label: imp-null
  lib entry: 10.26.0.0/24, rev 4
        local binding:  label: imp-null
        remote binding: lsr: 10.12.0.1:0, label: 16
        remote binding: lsr: 10.26.0.6:0, label: imp-null
        remote binding: lsr: 10.104.0.4:0, label: 19
  lib entry: 10.103.0.3/32, rev 25
        local binding:  label: 21
        remote binding: lsr: 10.12.0.1:0, label: 21
        remote binding: lsr: 10.26.0.6:0, label: 22
        remote binding: lsr: 10.104.0.4:0, label: 22
  lib entry: 10.104.0.0/24, rev 21
        remote binding: lsr: 10.104.0.4:0, label: imp-null
  lib entry: 10.104.0.4/32, rev 19
        local binding:  label: 19
```

```
        remote binding: lsr: 10.12.0.1:0, label: 20
        remote binding: lsr: 10.26.0.6:0, label: 20
  lib entry: 10.105.0.5/32, rev 11
        local binding:  label: 17
        remote binding: lsr: 10.12.0.1:0, label: 17
        remote binding: lsr: 10.26.0.6:0, label: 16
        remote binding: lsr: 10.104.0.4:0, label: 17
  lib entry: 10.106.0.0/24, rev 15
        remote binding: lsr: 10.26.0.6:0, label: imp-null
  lib entry: 10.106.0.6/32, rev 13
        local binding:  label: 18
        remote binding: lsr: 10.12.0.1:0, label: 18
        remote binding: lsr: 10.104.0.4:0, label: 16
IGP-R2#sh mpls forwarding-table
Local      Outgoing   Prefix           Bytes Label   Outgoing   Next Hop
Label      Label      or Tunnel Id     Switched      interface
16         Pop Label  10.15.0.0/24     1710          Fa0/0/0    10.12.0.1
17         17         10.105.0.5/32    12972         Fa0/0/0    10.12.0.1
18         No Label   10.106.0.6/32    7164          Gi0/1      10.26.0.6
19         No Label   10.104.0.4/32    7222          Gi0/0      10.24.0.4
20         Pop Label  10.13.0.0/24     0             Fa0/0/0    10.12.0.1
21         21         10.103.0.3/32    590           Fa0/0/0    10.12.0.1
R4!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
Border-R4#show mpls ip binding
  1.4.0.0/24
        in label:     imp-null
  10.12.0.0/24
        in label:     20
        out label:    imp-null  lsr: 10.12.0.2:0      inuse
  10.13.0.0/24
        in label:     21
        out label:    20        lsr: 10.12.0.2:0      inuse
  10.15.0.0/24
```



```
        in label:     18
        out label:    16        lsr: 10.12.0.2:0      inuse
  10.24.0.0/24
        in label:     imp-null
        out label:    imp-null  lsr: 10.12.0.2:0
  10.26.0.0/24
        in label:     19
        out label:    imp-null  lsr: 10.12.0.2:0      inuse
  10.103.0.3/32
        in label:     22
        out label:    21        lsr: 10.12.0.2:0      inuse
  10.104.0.0/24
        in label:     imp-null
  10.104.0.4/32
        out label:    19        lsr: 10.12.0.2:0
  10.105.0.5/32
        in label:     17
        out label:    17        lsr: 10.12.0.2:0      inuse
  10.106.0.6/32
        in label:     16
        out label:    18        lsr: 10.12.0.2:0      inuse
Border-R4#sh mpls ldp neighbor
    Peer LDP Ident: 10.12.0.2:0; Local LDP Ident 10.104.0.4:0
        TCP connection: 10.12.0.2.646 - 10.104.0.4.28427
        State: Oper; Msgs sent/rcvd: 64/64; Downstream
        Up time: 00:45:38
        LDP discovery sources:
          FastEthernet0/0, Src IP addr: 10.24.0.2
        Addresses bound to peer LDP Ident:
          10.12.0.2       10.26.0.2       10.24.0.2
Border-R4#sh mpls ldp bindings
  lib entry: 1.4.0.0/24, rev 2
        local binding:  label: imp-null
```

```
  lib entry: 10.12.0.0/24, rev 16
        local binding:  label: 20
        remote binding: lsr: 10.12.0.2:0, label: imp-null
  lib entry: 10.13.0.0/24, rev 19
        local binding:  label: 21
        remote binding: lsr: 10.12.0.2:0, label: 20
  lib entry: 10.15.0.0/24, rev 12
        local binding:  label: 18
        remote binding: lsr: 10.12.0.2:0, label: 16
  lib entry: 10.24.0.0/24, rev 4
        local binding:  label: imp-null
        remote binding: lsr: 10.12.0.2:0, label: imp-null
  lib entry: 10.26.0.0/24, rev 14
        local binding:  label: 19
        remote binding: lsr: 10.12.0.2:0, label: imp-null
  lib entry: 10.103.0.3/32, rev 21
        local binding:  label: 22
        remote binding: lsr: 10.12.0.2:0, label: 21
  lib entry: 10.104.0.0/24, rev 6
        local binding:  label: imp-null
  lib entry: 10.104.0.4/32, rev 17
        remote binding: lsr: 10.12.0.2:0, label: 19
  lib entry: 10.105.0.5/32, rev 10
        local binding:  label: 17
        remote binding: lsr: 10.12.0.2:0, label: 17
  lib entry: 10.106.0.6/32, rev 8
        local binding:  label: 16
        remote binding: lsr: 10.12.0.2:0, label: 18
Border-R4#sh mpls forwarding-table
Local  Outgoing      Prefix            Bytes Label   Outgoing   Next Hop
Label  Label or VC   or Tunnel Id      Switched      interface
16     18            10.106.0.6/32     0             Fa0/0      10.24.0.2
17     17            10.105.0.5/32     0             Fa0/0      10.24.0.2
```

18	16	10.15.0.0/24	0	Fa0/0	10.24.0.2
19	Pop Label	10.26.0.0/24	0	Fa0/0	10.24.0.2
20	Pop Label	10.12.0.0/24	0	Fa0/0	10.24.0.2
21	20	10.13.0.0/24	0	Fa0/0	10.24.0.2
22	21	10.103.0.3/32	0	Fa0/0	10.24.0.2