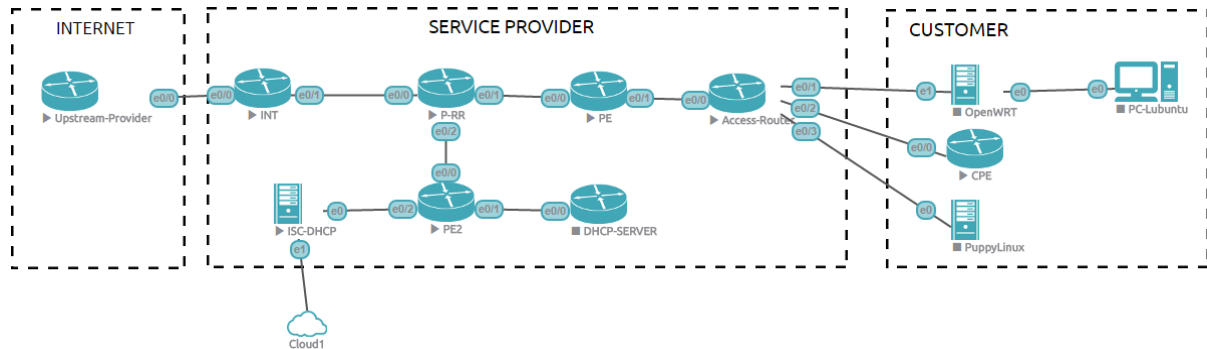


Guía del Tutorial Avanzado de IPv6:

Esquema:



Definiciones:

General:

- Para el direccionamiento, tanto de IPv4 como de IPv6, se utilizaron bloques reservados.
- En BGP se utilizaron ASNs privados.
- Se considera la base de un Backbone MPLS ya funcionando con IPv4.
- El servicio de INTERNET se transporta a través del Backbone MPLS sobre la VRF INTERNET.
- El IGP utilizado en el Backbone MPLS es OSPF.
- Se incluyen buenas prácticas de configuración como ser:
 - Contraseñas en sesiones de eBGP
 - Contraseñas en sesiones de iBGP
 - MD5 en OSPF
 - ACLs en interfaces de interconexión contra el Upstream Provider.
 - Filtros entrantes y salientes en sesiones BGP contra el Upstream Provider.
- El INT solo anuncia Rutas Default de IPv4 e IPv6 hacia el Backbone MPLS en VRF INTERNET.

Direccionamiento:

- Red Upstream-Provider: 192.0.2.0/24 (pública internacional)
- Red ISP: 198.51.100.0/24 (pública del ISP)
- Red Acceso: 203.0.113.0/24 (pública del ISP)
- Redes privadas:
 - Monitoria: 192.168.50.0/24 (privada de monitoria en el ISP)
 - Loopbacks Core: 192.168.25.0/24
 - Wanes Core: 192.168.26.0/24
 - Loopbacks Acceso: 192.168.27.0/24
 - Wanes Acceso: 192.168.28.0/24
- IPv6 Documentation Prefix: **2001:DB8::/32**
 - IPv6 Upstream-Provider: **2001:DB8::/34**
 - IPv6 Upstream-Provider: **2001:DB8:C000::/34**
 - IPv6 ISP: **2001:DB8:4000::/34**
 - IPV6 ISP - CORE: 2001:db8:4000::/38
 - IPV6 ISP - UPSTREAM-PROVIDER: 2001:db8:4000::/64
 - IPV6 ISP - ACCESO: 2001:db8:4400::/38
 - IPV6 ISP - WAN ACCESO: 2001:db8:4400::/38
 - IPV6 ISP - WAN ACCESO 1: 2001:db8:4400::/64
 - IPV6 ISP - WAN ACCESO 2: 2001:db8:4400:1::/64
 - IPV6 ISP - PD ACCESO-RESIDENCIAL: 2001:db8:4800::/38 (en /64s)
 - IPV6 ISP - PD ACCESO-CORPORATIVO: 2001:db8:4C00::/38 (en /48s)
 - IPv6 ISP: **2001:DB8:8000::/34**
- IPv6 ULA: **FC00::/7**
 - Acceso: **FC00::/40**
 - Loopbacks Acceso: FC00::/48
 - Loopbacks Acceso PE: fc00::/64
 - Loopbacks Acceso PE2: fc00:0:0:1::/64
 - WAN: FC00:0:1::/48
 - WAN PE → ACCESS-ROUTER: FC00:0:1::/64
 - Link-1: FC00:0:1::/126
 - Link-2: FC00:0:1::4/126
 - WAN PE → ACCESS-ROUTER-2: FC00:0:1:1::/64
 - Link-1: FC00:0:1:1::/126
 - WAN PE2 → ACCESS-ROUTER: FC00:0:1:1::/64
 - WAN Backend: **FC00:0:100::/40**
 - WAN PE2 → ISC-DHCP: FC00:0:100::/64

Seguridad:

- Password eBGP: UpstreamISP
- Password iBGP: iBGP_ISP
- MD5 OSPF Core: OSPF_Lacnic25
- MD5 OSPF Acceso: OspfIntLacnic25

Configuración 6VPE en Backbone MPLS:

INT:

```
ipv6 unicast-routing
```

```
ipv6 cef
```

```
!
```

```
vrf definition INTERNET
```

```
rd 192.168.25.1:1
```

```
route-target export 65001:1
```

```
route-target import 65001:1
```

```
!
```

```
address-family ipv4
```

```
exit-address-family
```

```
!
```

```
address-family ipv6
```

```
exit-address-family
```

```
!
```

```
router bgp 65001
```

```
address-family vpv6
```

```
neighbor 192.168.25.2 activate
```

```
neighbor 192.168.25.2 send-community both
```

```
exit-address-family
```

P-RR:

```
ipv6 unicast-routing
```

```
ipv6 cef
```

```
!
```

```
router bgp 65001
```

```
address-family vpv6
```

```
neighbor 192.168.25.1 activate
```

```
neighbor 192.168.25.1 send-community both
```

```
neighbor 192.168.25.1 route-reflector-client
```

```
neighbor 192.168.25.3 activate
```

```
neighbor 192.168.25.3 send-community both
```

```
neighbor 192.168.25.3 route-reflector-client
```

```
neighbor 192.168.25.4 activate
neighbor 192.168.25.4 send-community both
neighbor 192.168.25.4 route-reflector-client
exit-address-family
!
```

PE:

```
vrf definition INTERNET
rd 192.168.25.3:1
route-target export 65001:1
route-target import 65001:1
!
address-family ipv4
exit-address-family
!
address-family ipv6
exit-address-family
!
ipv6 unicast-routing
ipv6 cef
!
router bgp 65001
address-family vpnv6
neighbor 192.168.25.2 activate
neighbor 192.168.25.2 send-community both
exit-address-family
!
address-family ipv6 vrf INTERNET
redistribute connected
redistribute static
exit-address-family
!
```

PE2:

```
vrf definition INTERNET
rd 192.168.25.4:1
route-target export 65001:1
route-target import 65001:1
!
address-family ipv4
exit-address-family
!
address-family ipv6
exit-address-family
!
```

```
ipv6 unicast-routing
ipv6 cef
!
router bgp 65001
  address-family vpv6
    neighbor 192.168.25.2 activate
    neighbor 192.168.25.2 send-community both
  exit-address-family
!
  address-family ipv6 vrf INTERNET
    redistribute connected
    redistribute static
  exit-address-family
!
```

Notas:

- El Route Distinguisher (rd) está definido como <loopback>:<servicio>
- El route-target está definido como <asn>:<servicio>

Comandos útiles:

- sh bgp vpv6 unicast all summary
- sh bgp vpv6 unicast all

IPv6 entre ISP y Upstream provider:

INT:

```
interface Ethernet0/0
 vrf forwarding INTERNET
 ipv6 address 2001:DB8:4000::2/126
 ipv6 nd ra suppress
!
```

Upstream Provider:

```
interface Ethernet0/0
 ipv6 address 2001:DB8:4000::1/126
 ipv6 nd ra suppress
!
```

Verificación:

```
ping vrf INTERNET ipv6 2001:DB8:4000::1
```

```
INT#ping vrf INTERNET ipv6 2001:DB8:4000::1
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 2001:DB8:4000::1, timeout is 2 seconds:
!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 1/2/6 ms
INT#
```

Referencia comando ipv6 enable:

The ipv6 enable command automatically configures an IPv6 link-local unicast address on the interface while also enabling the interface for IPv6 processing.

To enable IPv6 processing on an interface that has not been configured with an explicit IPv6 address, use the ipv6 enable command in interface configuration mode.

You do not need to use the ipv6 enable command if you enter any other ipv6 address commands on an interface; IPv6 support is automatically enabled as soon as you assign an IPv6 address to the interface

Seguridad IPv6 Borde de Internet:

INT:

```

ipv6 access-list ACL-IPV6-ITX-LABO
  remark PERMIT ULA
  permit ipv6 FE80::/10 any
!
  remark PERMIT LINK IPV6 ADDRESS
  permit ipv6 2001:DB8:4000::/126 any
!
  remark DENY ISP IPV6 NETWORKS
  deny ipv6 2001:DB8:4000::/34 any
  deny ipv6 2001:DB8:8000::/34 any
!
  remark DENY RESERVED IPV6
  deny ipv6 ::/8 any
  deny ipv6 100::/8 any
  deny ipv6 200::/7 any
  deny ipv6 400::/6 any
  deny ipv6 800::/5 any
  deny ipv6 1000::/4 any
  deny ipv6 4000::/3 any
  deny ipv6 6000::/3 any
  deny ipv6 8000::/3 any
  deny ipv6 A000::/3 any
  deny ipv6 C000::/3 any
  deny ipv6 E000::/4 any
  deny ipv6 F000::/5 any
  deny ipv6 F800::/6 any
  deny ipv6 FC00::/7 any
  deny ipv6 fe00::/9 any
  deny ipv6 fec0::/10 any
  deny ipv6 ff00::/8 any
  deny ipv6 2001::/32 any
! deny ipv6 2001:db8::/32 any
  deny ipv6 2001::/23 any
  deny ipv6 2002::/16 any
  permit ipv6 any any
!
interface Ethernet0/0
  ipv6 traffic-filter ACL-IPV6-ITX-LABO in
!
  
```

BGP entre ISP y Upstream Provider:

Upstream Provider:

```

router bgp 65000
  neighbor 2001:DB8:4000::2 remote-as 65001
  neighbor 2001:DB8:4000::2 description IPV6-ISP
  neighbor 2001:DB8:4000::2 password UpstreamISP
  address-family ipv6
    redistribute static
    network 2001:DB8::/34
    network 2001:DB8:C000::/34
    neighbor 2001:DB8:4000::2 activate
  exit-address-family
!
ipv6 route 2001:DB8::/34 Null0 200
ipv6 route 2001:DB8:C000::/34 Null0 200
!
  
```

Notas:

- Se ponen rutas estáticas a Null0 200 para instalar los prefijos en la tabla de ruteo.

INT:

! Declaramos un prefix-list con bloques reservados, excepto los utilizados en el Laboratorio

```

ipv6 prefix-list RESERVED-IPV6-LAB seq 20 permit ::/8
ipv6 prefix-list RESERVED-IPV6-LAB seq 30 permit 100::/8
ipv6 prefix-list RESERVED-IPV6-LAB seq 40 permit 200::/7
ipv6 prefix-list RESERVED-IPV6-LAB seq 50 permit 400::/6
ipv6 prefix-list RESERVED-IPV6-LAB seq 60 permit 800::/5
ipv6 prefix-list RESERVED-IPV6-LAB seq 70 permit 1000::/4
ipv6 prefix-list RESERVED-IPV6-LAB seq 80 permit 4000::/3
ipv6 prefix-list RESERVED-IPV6-LAB seq 90 permit 6000::/3
ipv6 prefix-list RESERVED-IPV6-LAB seq 100 permit 8000::/3
ipv6 prefix-list RESERVED-IPV6-LAB seq 110 permit A000::/3
ipv6 prefix-list RESERVED-IPV6-LAB seq 120 permit C000::/3
ipv6 prefix-list RESERVED-IPV6-LAB seq 130 permit E000::/4
ipv6 prefix-list RESERVED-IPV6-LAB seq 140 permit F000::/5
ipv6 prefix-list RESERVED-IPV6-LAB seq 150 permit F800::/6
ipv6 prefix-list RESERVED-IPV6-LAB seq 160 permit FC00::/7
ipv6 prefix-list RESERVED-IPV6-LAB seq 170 permit FE00::/9
ipv6 prefix-list RESERVED-IPV6-LAB seq 180 permit FEC0::/10
ipv6 prefix-list RESERVED-IPV6-LAB seq 190 permit FF00::/8
ipv6 prefix-list RESERVED-IPV6-LAB seq 200 permit 2001::/32
  
```



```

ipv6 prefix-list RESERVED-IPV6-LAB seq 210 permit 2001::/23
ipv6 prefix-list RESERVED-IPV6-LAB seq 220 permit 2002::/16
!
! Creamos un route-map para filtro entrante en BGP
route-map UPSTREAM-PROVIDER-IPV6-IN deny 10
  description DENY-DEFAULT-IPV6
  match ipv6 address prefix-list DEFAULT-IPV6
!
route-map UPSTREAM-PROVIDER-IPV6-IN deny 20
  description DENY-ISP-NETWORKS-IPV6
  match ipv6 address prefix-list ISP-NETWORKS-IPV6
!
route-map UPSTREAM-PROVIDER-IPV6-IN deny 30
  description DENY-RESERVED-IPV6
  match ipv6 address prefix-list RESERVED-IPV6-LAB
!
route-map UPSTREAM-PROVIDER-IPV6-IN permit 50
  description PERMIT ALL
!
! Declaramos un prefix-list con Los bloques del ISP
ipv6 prefix-list ISP-NETWORKS-IPV6 seq 5 permit 2001:DB8:4000::/34
ipv6 prefix-list ISP-NETWORKS-IPV6 seq 10 permit 2001:DB8:8000::/34
!
! Declaramos el route-map saliente hacia el Upstream-Provider
route-map UPSTREAM-PROVIDER-IPV6-OUT permit 10
  match ipv6 address prefix-list ISP-NETWORKS-IPV6
!
route-map UPSTREAM-PROVIDER-IPV6-OUT deny 20
  description DENY-ALL
!
! Configuramos La sesión de eBGP contra el Upstream Provider
router bgp 65001
  address-family ipv6 vrf INTERNET
    network ::/0
    network 2001:DB8:4000::/34
    network 2001:DB8:8000::/34
    neighbor 2001:DB8:4000::1 remote-as 65000
    neighbor 2001:DB8:4000::1 description IPV6-UPSTREAM-PROVIDER
    neighbor 2001:DB8:4000::1 password UpstreamISP
    neighbor 2001:DB8:4000::1 activate
    neighbor 2001:DB8:4000::1 route-map UPSTREAM-PROVIDER-IPV6-IN in
    neighbor 2001:DB8:4000::1 route-map UPSTREAM-PROVIDER-IPV6-OUT out
  exit-address-family
!
ipv6 route vrf INTERNET 2001:DB8:4000::/34 Null0 200
  
```

```

ipv6 route vrf INTERNET 2001:DB8:8000::/34 Null0 200
ipv6 route vrf INTERNET ::/0 2001:DB8:4000::1
ipv6 route vrf INTERNET ::/0 Null0 200
!

```

Verificar en INT:

```
sh bgp vrf INTERNET vpv6 unicast summary
```

```

INT#sh bgp vrf INTERNET vpv6 unicast summary
BGP router identifier 192.168.25.1, local AS number 65001
BGP table version is 8, main routing table version 8
5 network entries using 880 bytes of memory
5 path entries using 540 bytes of memory
3/2 BGP path/bestpath attribute entries using 456 bytes of memory
1 BGP AS-PATH entries using 24 bytes of memory
1 BGP extended community entries using 24 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 1924 total bytes of memory
BGP activity 9/0 prefixes, 11/2 paths, scan interval 60 secs

Neighbor      V      AS MsgRcvd MsgSent  TblVer  InQ OutQ Up/Down  State/PfxRcd
2001:DB8:4000::1  4      65000    15    13      8     0   0 00:07:09      2
INT#

```

```
sh bgp vrf INTERNET vpv6 unicast neighbors 2001:DB8:4000::1 routes
```

```

INT#sh bgp vrf INTERNET vpv6 unicast neighbors 2001:DB8:4000::1 routes
BGP table version is 8, local router ID is 192.168.25.1
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
Route Distinguisher: 192.168.25.1:1 (default for vrf INTERNET)
*> 2001:DB8::/34  2001:DB8:4000::1
                                0              0 65000 i
*> 2001:DB8:C000::/34
                                2001:DB8:4000::1
                                0              0 65000 i

Total number of prefixes 2
INT#

```

Verificar en Upstream-Provider:

```
sh bgp ipv6 unicast summary
```

```

Service-Provider#sh bgp ipv6 unicast summary
BGP router identifier 192.0.2.1, local AS number 65000
BGP table version is 9, main routing table version 9
4 network entries using 656 bytes of memory
4 path entries using 416 bytes of memory
2/2 BGP path/bestpath attribute entries using 288 bytes of memory
1 BGP AS-PATH entries using 24 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 1384 total bytes of memory
BGP activity 8/1 prefixes, 10/3 paths, scan interval 60 secs

Neighbor      V      AS MsgRcvd MsgSent  TblVer  InQ OutQ Up/Down  State/PfxRcd
2001:DB8:4000::2  4      65001    16    19      9     0   0 00:10:02      2
Service-Provider#

```

sh bgp ipv6 unicast neighbors 2001:DB8:4000::2 routes

```
Service-Provider#sh bgp ipv6 unicast neighbors 2001:DB8:4000::2 routes
BGP table version is 9, local router ID is 192.0.2.1
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
*> 2001:DB8:4000::/34 2001:DB8:4000::2
                                     0
                                     0 65001 i
*> 2001:DB8:8000::/34 2001:DB8:4000::2
                                     0
                                     0 65001 i

Total number of prefixes 2
Service-Provider#
```

Verificar en P-RR:

sh bgp vpnv6 unicast all

```
P-RR#sh bgp vpnv6 unicast all
BGP table version is 6, local router ID is 192.168.25.2
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
Route Distinguisher: 192.168.25.1:1
*>i ::/0             ::FFFF:192.168.25.1
                                     0 100
                                     0 i
*>i 2001:DB8::/34    ::FFFF:192.168.25.1
                                     0 100
                                     0 65000 i
*>i 2001:DB8:4000::/34 ::FFFF:192.168.25.1
                                     0 100
                                     0 i
*>i 2001:DB8:8000::/34 ::FFFF:192.168.25.1
                                     0 100
                                     0 i
*>i 2001:DB8:C000::/34 ::FFFF:192.168.25.1
                                     0 100
                                     0 65000 i

P-RR#
```

Se observa que el RR está recibiendo todos los prefijos desde el INT. Debemos aplicar un filtro para recibir sólo el Default IPv6.

INT:

```
ipv6 prefix-list DEFAULT-IPV6 seq 5 permit ::/0
!
route-map P-RR-IPV6-OUT permit 10
  description PERMIT-DEFAULT-IPV6
  match ipv6 address prefix-list DEFAULT-IPV6
!
route-map P-RR-IPV6-OUT deny 20
  description DENY-ALL
!
router bgp 65001
  address-family vpnv6
```

```
neighbor 192.168.25.2 route-map P-RR-IPV6-OUT out
exit-address-family
!
end
```

```
clear bgp vpnv6 unicast * soft out
```

Verificar en P-RR:

```
sh bgp vpnv6 unicast all
```

```
P-RR#sh bgp vpnv6 unicast all
BGP table version is 10, local router ID is 192.168.25.2
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
Route Distinguisher: 192.168.25.1:1
*>i ::/0            ::FFFF:192.168.25.1
                                0      100      0 i
P-RR#
```

Ahora recibimos sólo Default IPv6.

IPv6 en Acceso:

PE:

```
! Configuramos IPv6 contra Access-Router
! Utilizamos OSPFv3 entre PE y Access-Router.
interface Ethernet0/1
  ipv6 address FC00::1/64
  ospfv3 network point-to-point
  ospfv3 11 ipv6 area 11
!
interface Loopback1
  vrf forwarding INTERNET
  ipv6 address FC00::1/128
  ospfv3 11 ipv6 area 11
!
router ospfv3 11
  router-id 192.168.27.1
  !
  address-family ipv6 unicast vrf INTERNET
    default-information originate always
    redistribute bgp 65001
  exit-address-family
!
router bgp 65001
```

```

address-family ipv6 vrf INTERNET
  redistribute connected
  redistribute ospf 11 match internal external 1 external 2
  redistribute static
exit-address-family
!

```

Access-Router:

```

! Configuramos IPv6 contra PE y OSPFv3
interface Ethernet0/0
  ipv6 address FC00::2/64
  ospfv3 network point-to-point
  ospfv3 11 ipv6 area 11
!
router ospfv3 11
!
  address-family ipv6 unicast
  redistribute connected
  redistribute static
exit-address-family
!
! Configuramos IPv6 en interfaces de acceso
interface Ethernet0/1
  description CONNECTED TO OPENWRT
  ipv6 address 2001:DB8:4400::1/64
  ipv6 nd dad attempts 0
  ipv6 nd prefix default no-advertise
  ipv6 nd managed-config-flag
  ipv6 nd other-config-flag
  ipv6 nd ra interval 5
  no ipv6 redirects
  no ipv6 unreachable
  ipv6 dhcp relay destination FC00:0:100::2
  no shutdown
!
interface Ethernet0/2
  description CONNECTED TO ROUTER CPE
  ipv6 address 2001:DB8:4400:1::1/64
  ipv6 nd dad attempts 0
  ipv6 nd prefix default no-advertise
  ipv6 nd managed-config-flag
  ipv6 nd other-config-flag
  ipv6 nd ra interval 5
  no ipv6 redirects
  no ipv6 unreachable

```

```
ipv6 dhcp relay destination FC00:0:100::2
no shutdown
!
```

Verificar OSPV3:

```
sh ipv6 ospf neighbor
```

```
ACCESS-ROUTER#sh ipv6 ospf neighbor
OSPFv3 Router with ID (192.168.27.2) (Process ID 11)
Neighbor ID      Pri   State           Dead Time   Interface ID  Interface
192.168.27.1    0     FULL/ -         00:00:37   4             Ethernet0/0
ACCESS-ROUTER#
```

Verificar tabla de ruteo IPv6:

```
sh ipv6 route
```

```
ACCESS-ROUTER#sh ipv6 route
IPv6 Routing Table - default - 9 entries
Codes: C - Connected, L - Local, S - Static, U - Per-user Static route
B - BGP, HA - Home Agent, MR - Mobile Router, R - RIP
H - NHRP, I1 - ISIS L1, I2 - ISIS L2, IA - ISIS interarea
IS - ISIS summary, D - EIGRP, EX - EIGRP external, NM - NEMO
ND - ND Default, NDp - ND Prefix, DCE - Destination, NDR - Redirect
O - OSPF Intra, OI - OSPF Inter, OE1 - OSPF ext 1, OE2 - OSPF ext 2
ON1 - OSPF NSSA ext 1, ON2 - OSPF NSSA ext 2, ls - LISP site
ld - LISP dyn-EID, a - Application
OE2 ::/0 [110/1], tag 11
  via FE80::A8BB:CCFF:FE00:510, Ethernet0/0
C  2001:DB8:4400::/64 [0/0]
  via Ethernet0/1, directly connected
L  2001:DB8:4400::1/128 [0/0]
  via Ethernet0/1, receive
C  2001:DB8:4400:1::/64 [0/0]
  via Ethernet0/2, directly connected
L  2001:DB8:4400:1::1/128 [0/0]
  via Ethernet0/2, receive
O  FC00::1/128 [110/10]
  via FE80::A8BB:CCFF:FE00:510, Ethernet0/0
C  FC00:0:1::/126 [0/0]
  via Ethernet0/0, directly connected
L  FC00:0:1::2/128 [0/0]
  via Ethernet0/0, receive
L  FF00::/8 [0/0]
  via Null0, receive
ACCESS-ROUTER#
```

Probar conectividad IPv6 contra Upstream-Provider:

```
ping ipv6 2001:DB8:4000::1 source 2001:DB8:4400::1
```

```
ACCESS-ROUTER#ping ipv6 2001:DB8:4000::1 source 2001:DB8:4400::1
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 2001:DB8:4000::1, timeout is 2 seconds:
Packet sent with a source address of 2001:DB8:4400::1
!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 1/1/1 ms
ACCESS-ROUTER#
```

Dejamos configurado PE2 con OSPv3 (opcional):

PE2:

```
router ospfv3 11
router-id 192.168.27.4
!
```

```
address-family ipv6 unicast vrf INTERNET
  default-information originate always
  redistribute bgp 65001
exit-address-family
!
router bgp 65001
  address-family ipv6 vrf INTERNET
    redistribute connected
    redistribute ospf 11 match internal external 1 external 2
    redistribute static
  exit-address-family
!
```

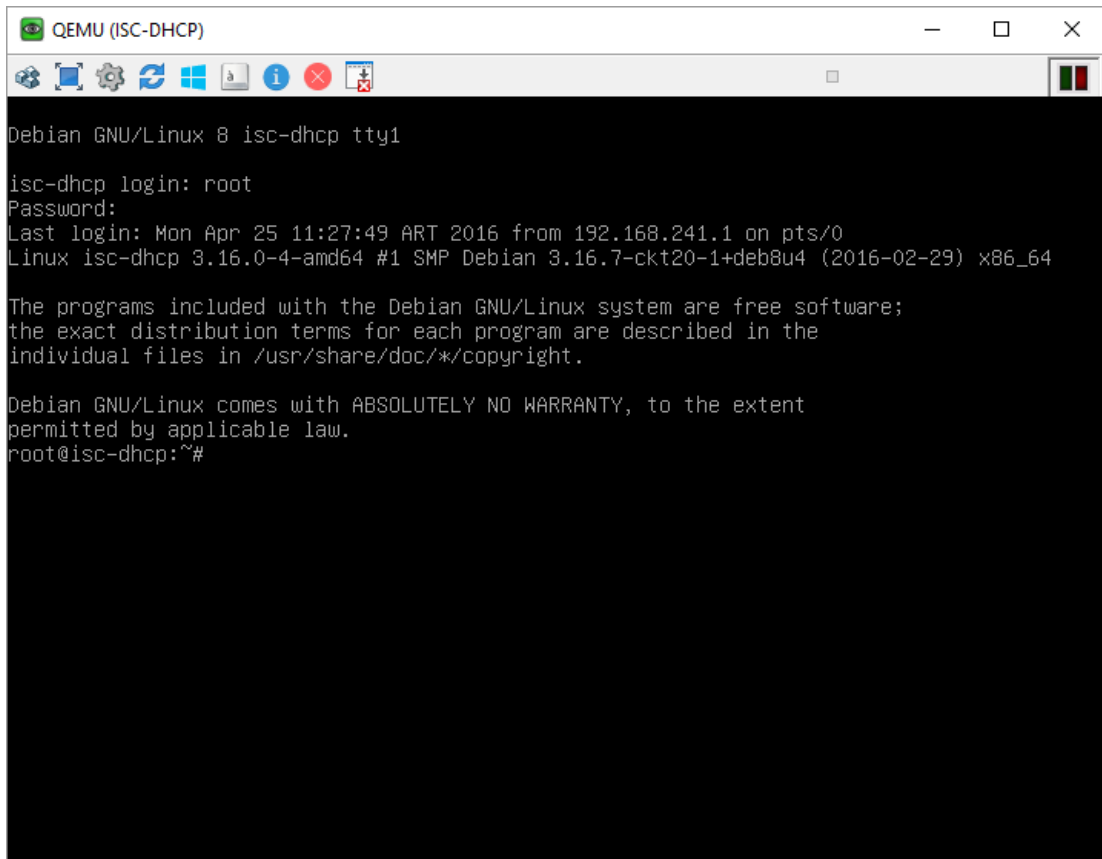
ISC-DHCP-SERVER:

Ya se encuentra configurada la eth0 con IPv6 contra PE2.

Conectarse por UltraVNC (hacer clic en el ícono):

Usuario: root

Contraseña: lacnic



```
QEMU (ISC-DHCP)
Debian GNU/Linux 8 isc-dhcp tty1
isc-dhcp login: root
Password:
Last login: Mon Apr 25 11:27:49 ART 2016 from 192.168.241.1 on pts/0
Linux isc-dhcp 3.16.0-4-amd64 #1 SMP Debian 3.16.7-ckt20-1+deb8u4 (2016-02-29) x86_64

The programs included with the Debian GNU/Linux system are free software;
the exact distribution terms for each program are described in the
individual files in /usr/share/doc/*/copyright.

Debian GNU/Linux comes with ABSOLUTELY NO WARRANTY, to the extent
permitted by applicable law.
root@isc-dhcp:~#
```

Verificar IP de eth1 para su gestión:

ifconfig eth1

```

root@isc-dhcp:~# ifconfig eth1
eth1      Link encap:Ethernet  HWaddr 50:00:00:03:00:01
          inet addr:192.168.241.129  Bcast:192.168.241.255  Mask:255.255.255.0
          inet6 addr: fe80::5200:ff:fe03:1/64  Scope:Link
          UP BROADCAST RUNNING MULTICAST  MTU:1500  Metric:1
          RX packets:274 errors:0 dropped:0 overruns:0 frame:0
          TX packets:115 errors:0 dropped:0 overruns:0 carrier:0
          collisions:0 txqueuelen:1000
          RX bytes:24363 (23.7 KiB)  TX bytes:15633 (15.2 KiB)

root@isc-dhcp:~#

```

Conectarse por SSH con root o seguir utilizando la consola de UltraVNC.

Servicio: /etc/init.d/isc-dhcp-server

Archivo de configuración: /etc/dhcp/dhcpd6.conf

Default: /etc/default/isc-dhcp-server

Leases: /var/lib/dhcp/dhcpd6.leases

Ver log: tail -f /var/log/dhcpd.log

Ver servicio:

ps -fea | grep dhcpd

```

root@isc-dhcp:~# ps -fea | grep dhcpd
root    542    1  0 14:33 ?        00:00:00 /usr/sbin/dhcpd -q -6 -cf /etc/dhcp/dhcpd6.conf -pf /var/run/dhcpd.pid eth0
root    969    799  0 17:04 pts/0    00:00:00 grep dhcpd
root@isc-dhcp:~#

```

Verificar archivo de configuración:

cat /etc/dhcp/dhcpd6.conf

```

subnet6 fc00:0:100::/64 {
}

```

Esto es necesario para que acepte mensajes de DHCPv6 sobre la interface que está en esta subnet.

Configurar la subnet del servicio residencial:

nano /etc/dhcp/dhcpd6.conf

```

subnet6 2001:db8:4400::/64 {
  # Range for clients
  # range6 2001:db8:4000::2 2001:db8:4000::ffff;
  range6 2001:db8:4400::/64;

  # Additional options
  option dhcp6.name-servers 2001:4860:4860::8888;
  option dhcp6.domain-search "lacnic.net";

  # Prefix range for delegation to sub-routers
  prefix6 2001:db8:4800:: 2001:db8:4bff:ffff:: /64;
}

```



```
}
```

```
service isc-dhcp-server restart
```

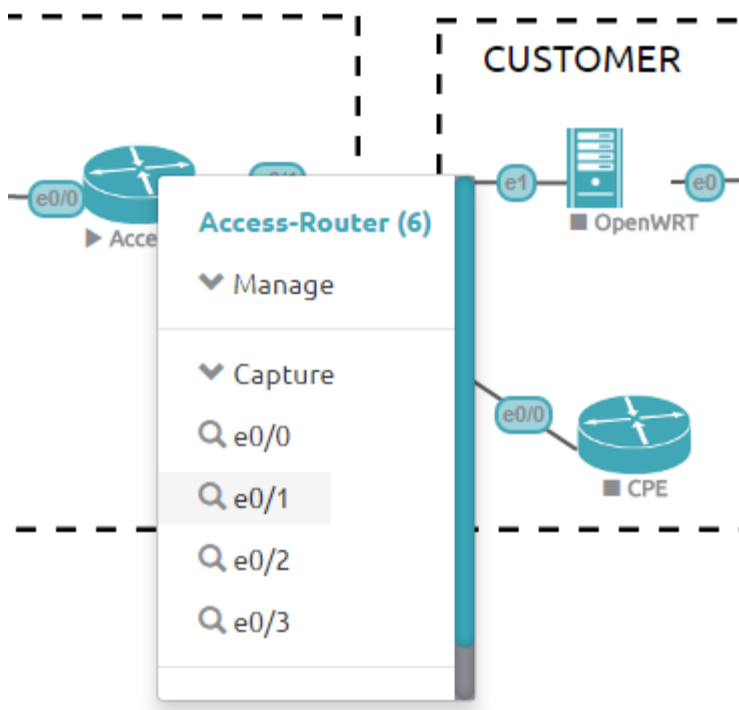
Verificar el servicio:

```
ps -fea | grep dhcpd
```

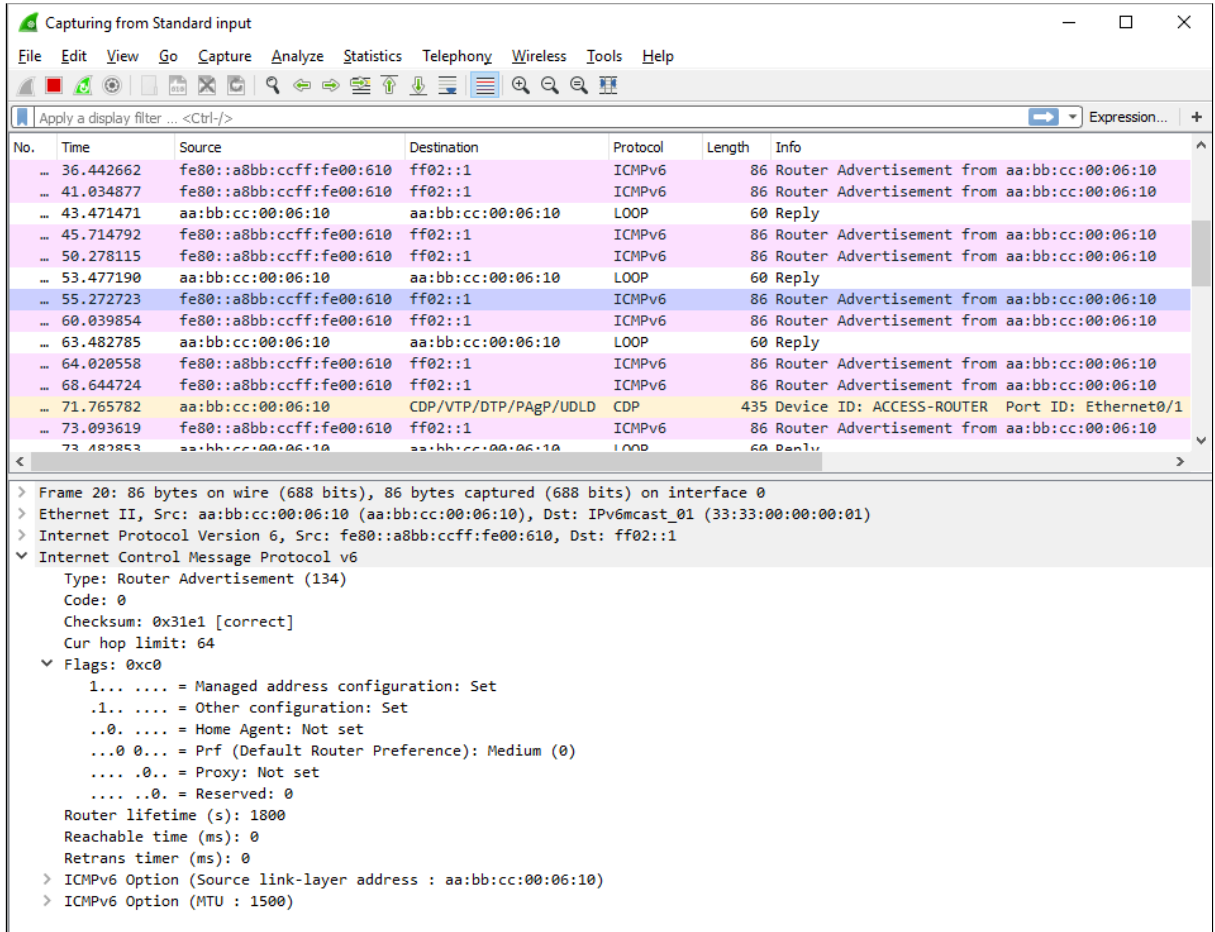
```
root@isc-dhcp:/# ps -fea | grep dhcpd
root      542      1  0 14:33 ?        00:00:00 /usr/sbin/dhcpd -q -6 -cf /etc/dhcp/dhcpd6.conf -pf /var/run/dhcpd.pid eth0
root      969     799  0 17:04 pts/0    00:00:00 grep dhcpd
root@isc-dhcp:/#
```

En este punto **ya estamos en condiciones de realizar una asignación de IPv6 por DHCP al CPE.**

Poner a capturar la interface ethernet0/1 de Access-Router:



Observar los paquetes de Router-Advertisement:



No.	Time	Source	Destination	Protocol	Length	Info
...	36.442662	fe80::a8bb:ccff:fe00:610	ff02::1	ICMPv6	86	Router Advertisement from aa:bb:cc:00:06:10
...	41.034877	fe80::a8bb:ccff:fe00:610	ff02::1	ICMPv6	86	Router Advertisement from aa:bb:cc:00:06:10
...	43.471471	aa:bb:cc:00:06:10	aa:bb:cc:00:06:10	LOOP	60	Reply
...	45.714792	fe80::a8bb:ccff:fe00:610	ff02::1	ICMPv6	86	Router Advertisement from aa:bb:cc:00:06:10
...	50.278115	fe80::a8bb:ccff:fe00:610	ff02::1	ICMPv6	86	Router Advertisement from aa:bb:cc:00:06:10
...	53.477190	aa:bb:cc:00:06:10	aa:bb:cc:00:06:10	LOOP	60	Reply
...	55.272723	fe80::a8bb:ccff:fe00:610	ff02::1	ICMPv6	86	Router Advertisement from aa:bb:cc:00:06:10
...	60.039854	fe80::a8bb:ccff:fe00:610	ff02::1	ICMPv6	86	Router Advertisement from aa:bb:cc:00:06:10
...	63.482785	aa:bb:cc:00:06:10	aa:bb:cc:00:06:10	LOOP	60	Reply
...	64.020558	fe80::a8bb:ccff:fe00:610	ff02::1	ICMPv6	86	Router Advertisement from aa:bb:cc:00:06:10
...	68.644724	fe80::a8bb:ccff:fe00:610	ff02::1	ICMPv6	86	Router Advertisement from aa:bb:cc:00:06:10
...	71.765782	aa:bb:cc:00:06:10	CDP/VTP/DTP/PAGP/UDLD	CDP	435	Device ID: ACCESS-ROUTER Port ID: Ethernet0/1
...	73.093619	fe80::a8bb:ccff:fe00:610	ff02::1	ICMPv6	86	Router Advertisement from aa:bb:cc:00:06:10
...	73.483853	aa:bb:cc:00:06:10	aa:bb:cc:00:06:10	LOOP	60	Reply

```

> Frame 20: 86 bytes on wire (688 bits), 86 bytes captured (688 bits) on interface 0
> Ethernet II, Src: aa:bb:cc:00:06:10 (aa:bb:cc:00:06:10), Dst: IPv6mcast_01 (33:33:00:00:00:01)
> Internet Protocol Version 6, Src: fe80::a8bb:ccff:fe00:610, Dst: ff02::1
  > Internet Control Message Protocol v6
    Type: Router Advertisement (134)
    Code: 0
    Checksum: 0x31e1 [correct]
    Cur hop limit: 64
    > Flags: 0xc0
      1... .... = Managed address configuration: Set
      .1.. .... = Other configuration: Set
      ..0. .... = Home Agent: Not set
      ...0 0... = Prf (Default Router Preference): Medium (0)
      .... .0.. = Proxy: Not set
      .... ..0. = Reserved: 0
      Router lifetime (s): 1800
      Reachable time (ms): 0
      Retrans timer (ms): 0
    > ICMPv6 Option (Source link-layer address : aa:bb:cc:00:06:10)
    > ICMPv6 Option (MTU : 1500)
  
```

```

  > Flags: 0xc0
    1... .... = Managed address configuration: Set
    .1.. .... = Other configuration: Set
    ..0. .... = Home Agent: Not set
    ...0 0... = Prf (Default Router Preference): Medium (0)
    .... .0.. = Proxy: Not set
    .... ..0. = Reserved: 0
  
```

ISC-Dhcp-Server:

Ingresar al isc-dhcp-server y dejar corriendo un "tail -f" del archivo de leases para ver la asignación en el momento:

tail -f /var/lib/dhcp/dhcpd6.leases

Prender el OpenWRT y observar la mensajería DHCPv6:

Source	Destination	Protocol	Length	Info
fe80::5200:ff:fe0a:1	ff02::1:2	DHCPv6	166	Solicit XID: 0xeb871f CID: 000300015000000a0001
fe80::a8bb:ccff:fe00:610	fe80::5200:ff:fe0a:1	DHCPv6	227	Advertise XID: 0xeb871f IAA: 2001:db8:4400:0:fc2d:412a:bc55:219b CID: 000300015000000a0001
fe80::5200:ff:fe0a:1	ff02::1:2	DHCPv6	241	Request XID: 0xf0f398 CID: 000300015000000a0001 IAA: 2001:db8:4400:0:fc2d:412a:bc55:219b
fe80::a8bb:ccff:fe00:610	fe80::5200:ff:fe0a:1	DHCPv6	227	Reply XID: 0xf0f398 IAA: 2001:db8:4400:0:fc2d:412a:bc55:219b CID: 000300015000000a0001

Una vez asignado el prefijo, el Access-Router crea una ruta estática del prefijo asignado con next-hop la Ethernet0/1:

sh ipv6 route

```
ACCESS-ROUTER#sh ipv6 route
IPV6 Routing Table - default - 13 entries
Codes: C - Connected, L - Local, S - Static, U - Per-user Static route
        B - BGP, HA - Home Agent, MR - Mobile Router, R - RIP
        H - NHRP, I1 - ISIS L1, I2 - ISIS L2, IA - ISIS interarea
        IS - ISIS summary, D - EIGRP, EX - EIGRP external, NM - NEMO
        ND - ND Default, NDP - ND Prefix, DCE - Destination, NDR - Redirect
        O - OSPF Intra, OI - OSPF Inter, OE1 - OSPF ext 1, OE2 - OSPF ext 2
        ON1 - OSPF NSSA ext 1, ON2 - OSPF NSSA ext 2, ls - LISP site
        ld - LISP dyn-EID, a - Application
OE2 ::/0 [110/1], tag 11
    via FE80::A8BB:CCFF:FE00:510, Ethernet0/0
C 2001:DB8:4400::/64 [0/0]
    via Ethernet0/1, directly connected
L 2001:DB8:4400::1/128 [0/0]
    via Ethernet0/1, receive
C 2001:DB8:4400:1::/64 [0/0]
    via Ethernet0/2, directly connected
L 2001:DB8:4400:1::1/128 [0/0]
    via Ethernet0/2, receive
C 2001:DB8:4400:2::/64 [0/0]
    via Ethernet0/3, directly connected
L 2001:DB8:4400:2::1/128 [0/0]
    via Ethernet0/3, receive
S 2001:DB8:4BFF:FFFF::/64 [1/0]
    via FE80::5200:FF:FE0A:1, Ethernet0/1
C FC00::/64 [0/0]
    via Ethernet0/0, directly connected
L FC00::2/128 [0/0]
    via Ethernet0/0, receive
OE2 FC00:0:100::/64 [110/1]
    via FE80::A8BB:CCFF:FE00:510, Ethernet0/0
OE2 FC00:D::/64 [110/1]
    via FE80::A8BB:CCFF:FE00:510, Ethernet0/0
L FF00::/8 [0/0]
    via Null0, receive
ACCESS-ROUTER#
```

sh ipv6 dhcp relay binding

```
ACCESS-ROUTER#sh ipv6 dhcp relay binding

Relay Bindings associated with default vrf:
Prefix: 2001:DB8:4BFF:FFFF::/64 (Ethernet0/1)
DUID: 000300015000000A0001
IAID: 1
lifetime: 600
expiration: 05:22:14 UTC Apr 29 2016
```

Verificar que se esté propagando el prefijo asignado hasta el INT:

sh ipv6 route vrf INTERNET 2001:DB8:4BFF:FFFF::/64

```
INT#sh ipv6 route vrf INTERNET 2001:DB8:4BFF:FFFF::/64
Routing entry for 2001:DB8:4BFF:FFFF::/64
Known via "bgp 65001", distance 200, metric 20, type internal
Route count is 1/1, share count 0
Routing paths:
  192.168.25.3%default indirectly connected
  MPLS label: 27
  Last updated 00:26:42 ago
INT#
```

Verificar acceso a INTERNET desde el OpenWRT, realizando un ping a IP del Upstream Provider:

ping6 2001:DB8:4000::1

```
root@OpenWrt:/# ping6 2001:db8:4000::1
PING 2001:db8:4000::1 (2001:db8:4000::1): 56 data bytes
64 bytes from 2001:db8:4000::1: seq=0 ttl=60 time=1.107 ms
64 bytes from 2001:db8:4000::1: seq=1 ttl=60 time=1.052 ms
64 bytes from 2001:db8:4000::1: seq=2 ttl=60 time=1.052 ms
^C
--- 2001:db8:4000::1 ping statistics ---
3 packets transmitted, 3 packets received, 0% packet loss
round-trip min/avg/max = 1.052/1.070/1.107 ms
```

IPv6 en PC-Lubuntu:

Poner a capturar e0 de PC-Lubuntu e Iniciar la VM.

Observar que está tomando IP del rango del Prefijo por autoconfiguración:

```
lubuntu@lubuntu-virtual-machine:~$ ifconfig
eth0    Link encap:Ethernet  direcciónHW 50:00:00:0b:00:00
        Direc. inet:192.168.1.244  Difus.:192.168.1.255  Másc:255.255.255.0
        Dirección inet6: fd73:c474:8c3b::bc7/128 Alcance:Global
        Dirección inet6: 2001:db8:4bff:ffff:5200:ff:fe0b:0/64 Alcance:Global
        Dirección inet6: fd73:c474:8c3b:0:5200:ff:fe0b:0/64 Alcance:Global
        Dirección inet6: fe80::5200:ff:fe0b:0/64 Alcance:Enlace
        ACTIVO DIFUSIÓN FUNCIONANDO MULTICAST MTU:1500 Métrica:1
        Paquetes RX:263 errores:0 perdidos:0 overruns:0 frame:0
        Paquetes TX:462 errores:0 perdidos:0 overruns:0 carrier:0
        colisiones:0 long.colaTX:1000
        Bytes RX:28861 (28.8 KB)  TX bytes:41767 (41.7 KB)
```

No.	Time	Source	Destination	Protocol	Length	Info
...	88...	::	ff02::16	ICMPv6	90	Multicast Listener Report Message v2
...	88...	::	ff02::16	ICMPv6	90	Multicast Listener Report Message v2
...	88...	::	ff02::1:ff0b:0	ICMPv6	78	Neighbor Solicitation for fe80::5200:ff:fe0b:0
...	89...	fe80::5200:ff:fe0b:0	ff02::16	ICMPv6	90	Multicast Listener Report Message v2
...	89...	fe80::5200:ff:fe0b:0	ff02::16	ICMPv6	90	Multicast Listener Report Message v2
...	90...	fe80::5200:ff:fe0b:0	ff02::2	ICMPv6	62	Router Solicitation
...	90...	fe80::5200:ff:fe0a:0	fe80::5200:ff:fe0b:0	ICMPv6	230	Router Advertisement from 50:00:00:0a:00:00

```
> Frame 325: 230 bytes on wire (1840 bits), 230 bytes captured (1840 bits) on interface 0
> Ethernet II, Src: 50:00:00:0a:00:00 (50:00:00:0a:00:00), Dst: 50:00:00:0b:00:00 (50:00:00:0b:00:00)
> Internet Protocol Version 6, Src: fe80::5200:ff:fe0a:0, Dst: fe80::5200:ff:fe0b:0
  Internet Control Message Protocol v6
    Type: Router Advertisement (134)
    Code: 0
    Checksum: 0x1308 [correct]
    Cur hop limit: 64
    > Flags: 0xc0
    Router lifetime (s): 1800
    Reachable time (ms): 0
    Retrans timer (ms): 0
    > ICMPv6 Option (Source link-layer address : 50:00:00:0a:00:00)
    > ICMPv6 Option (MTU : 1500)
    > ICMPv6 Option (Prefix information : 2001:db8:4bff:ffff::/64)
    > ICMPv6 Option (Prefix information : fd73:c474:8c3b::/64)
    > ICMPv6 Option (Route Information : Medium fd73:c474:8c3b::/48)
    > ICMPv6 Option (Recursive DNS Server fd73:c474:8c3b::1)
    > ICMPv6 Option (DNS Search List Option lan)
    > ICMPv6 Option (Advertisement Interval : 130500)
```

Para observar Tabla de Ruteo IPv6:

```
route -A inet6
```

Verificar salida a INTERNET:

```
ping6 2001:DB8:4000::1
```

```

lubuntu@lubuntu-virtual-machine:~$ ping6 2001:db8:4000::1
PING 2001:db8:4000::1(2001:db8:4000::1) 56 data bytes
64 bytes from 2001:db8:4000::1: icmp_seq=1 ttl=59 time=1.55 ms
64 bytes from 2001:db8:4000::1: icmp_seq=2 ttl=59 time=1.73 ms
64 bytes from 2001:db8:4000::1: icmp_seq=3 ttl=59 time=1.45 ms
64 bytes from 2001:db8:4000::1: icmp_seq=4 ttl=59 time=1.74 ms
64 bytes from 2001:db8:4000::1: icmp_seq=5 ttl=59 time=1.84 ms
^C
--- 2001:db8:4000::1 ping statistics ---
5 packets transmitted, 5 received, 0% packet loss, time 4009ms
rtt min/avg/max/mdev = 1.454/1.663/1.842/0.150 ms
lubuntu@lubuntu-virtual-machine:~$

```

Configuración de Router CPE Corporativo:

Este CPE simula ser utilizado para un servicio corporativo.

Recibe un Prefijo /48 el cual se subnetea para asignar a sus Interfaces LAN

```
ipv6 unicast-routing
```

```
ipv6 cef
```

```
!
```

```
interface Ethernet0/0
```

```
description CONNECTED TO ACCESS-ROUTER
```

```
ipv6 address dhcp
```

```
ipv6 enable
```

```
ipv6 nd ra suppress
```

```
ipv6 nd autoconfig default-route
```

```
ipv6 dhcp client pd prefix-from-provider
```

```
!
```

```
interface Ethernet0/1
```

```
description CONNECTED TO LOCAL-LAN-1
```

```
ipv6 address prefix-from-provider ::1:0:0:0:1/64
```

```
ipv6 enable
```

```
!
```

```
interface Ethernet0/2
```

```
description CONNECTED TO LOCAL-LAN-2
```

```
ipv6 address prefix-from-provider ::2:0:0:0:1/64
```

```
ipv6 enable
```

```
!
```

```
interface Ethernet0/3
```

```
description CONNECTED TO LOCAL-LAN-3
```

```
ipv6 address prefix-from-provider ::3:0:0:0:1/64
```

```
ipv6 address prefix-from-provider ::100:0:0:0:1/56
```

```
ipv6 enable  
!
```

Configurar la subnet del servicio corporativo en el isc-dhcp.server:
nano /etc/dhcp/dhcpd6.conf

```
subnet6 2001:db8:4400:1::/64 {  
  # Range for clients  
  range6 2001:db8:4400:1::/64;  
  
  # Additional options  
  option dhcp6.name-servers 2001:4860:4860::8888;  
  option dhcp6.domain-search "lacnic.net";  
  
  # Prefix range for delegation to sub-routers  
  prefix6 2001:db8:4c00:: 2001:db8:4fff:: /48;  
}  
  
service isc-dhcp-server restart
```

Verificar que reciba IPv6 e IPv6-PD, y el prefijo se subnetee y se asigne a las interfaces LAN:

```
CPE#sh ipv6 interface brief  
Ethernet0/0 [up/up]  
FE80::A8BB:CCFF:FE00:700  
2001:DB8:4400:1:70AB:B678:90FC:C9C4  
Ethernet0/1 [up/up]  
FE80::A8BB:CCFF:FE00:710  
2001:DB8:4FFF:1::1  
Ethernet0/2 [up/up]  
FE80::A8BB:CCFF:FE00:720  
2001:DB8:4FFF:2::1  
Ethernet0/3 [up/up]  
FE80::A8BB:CCFF:FE00:730  
2001:DB8:4FFF:3::1  
2001:DB8:4FFF:100::1  
CPE#
```

Verificar acceso a INTERNET:

```
ping ipv6 2001:db8:4000::1 source 2001:DB8:4FFF:3::1
```

```
CPE#ping ipv6 2001:db8:4000::1 source 2001:DB8:4FFF:3::1  
Type escape sequence to abort.  
sending 5, 100-byte ICMP Echos to 2001:DB8:4000::1, timeout is 2 seconds:  
Packet sent with a source address of 2001:DB8:4FFF:3::1  
!!!!  
Success rate is 100 percent (5/5), round-trip min/avg/max = 4/4/5 ms  
CPE#
```


Referencias:

Direccionamiento:

<https://www.iana.org/assignments/ipv6-address-space/ipv6-address-space.xml>
<http://www.iana.org/assignments/iana-ipv6-special-registry/iana-ipv6-special-registry.xhtml>
Bloques IPv4 reservados - (RFC 6890 - <https://tools.ietf.org/html/rfc6890>)
http://www.gestioip.net/cgi-bin/subnet_calculator.cgi

DHCPv6 en Cisco:

<http://www.cisco.com/c/en/us/support/docs/ip/ip-version-6-ipv6/113141-DHCPv6-00.html>
<http://www.cisco.com/c/en/us/td/docs/ios-xml/ios/ipv6/configuration/xs-3s/ipv6-xe-36-s-book/ip6-dhcp.html>
<http://www.cisco.com/c/en/us/td/docs/ios-xml/ios/ipv6/configuration/15-2mt/ipv6-15-2mt-book/ip6-dhcp.html>
<https://supportforums.cisco.com/discussion/11836346/how-configure-ospfv3-vrf-ios-guide>
<https://supportforums.cisco.com/document/116221/part-1-implementing-dhcpv6-stateful-dhcpv6>
<https://supportforums.cisco.com/document/118551/stateful-dhcpv6-relay-configuration-example>

ISC-DHCP:

<http://www.goletdoit.com/how-to-setup-dhcp-server-on-debian/>
<http://linux.die.net/man/5/dhcp-options>
<https://help.ubuntu.com/community/isc-dhcp-server>
<https://www.netbsd.org/docs/network/netboot/dhcpd.html>
<https://syconet.wordpress.com/2013/03/19/instalacion-y-configuracion-de-un-servidor-dhcp-en-debian-6-squeeze/>

Script Perl DUID:

<https://isc.sans.edu/diary/DHCPv6+and+DUID+Confusion/18015>
<https://isc.sans.edu/diaryimages/duidconvert.pl>