IPv6 prefix delegation using systemd-networkd

Sebastian Meisel

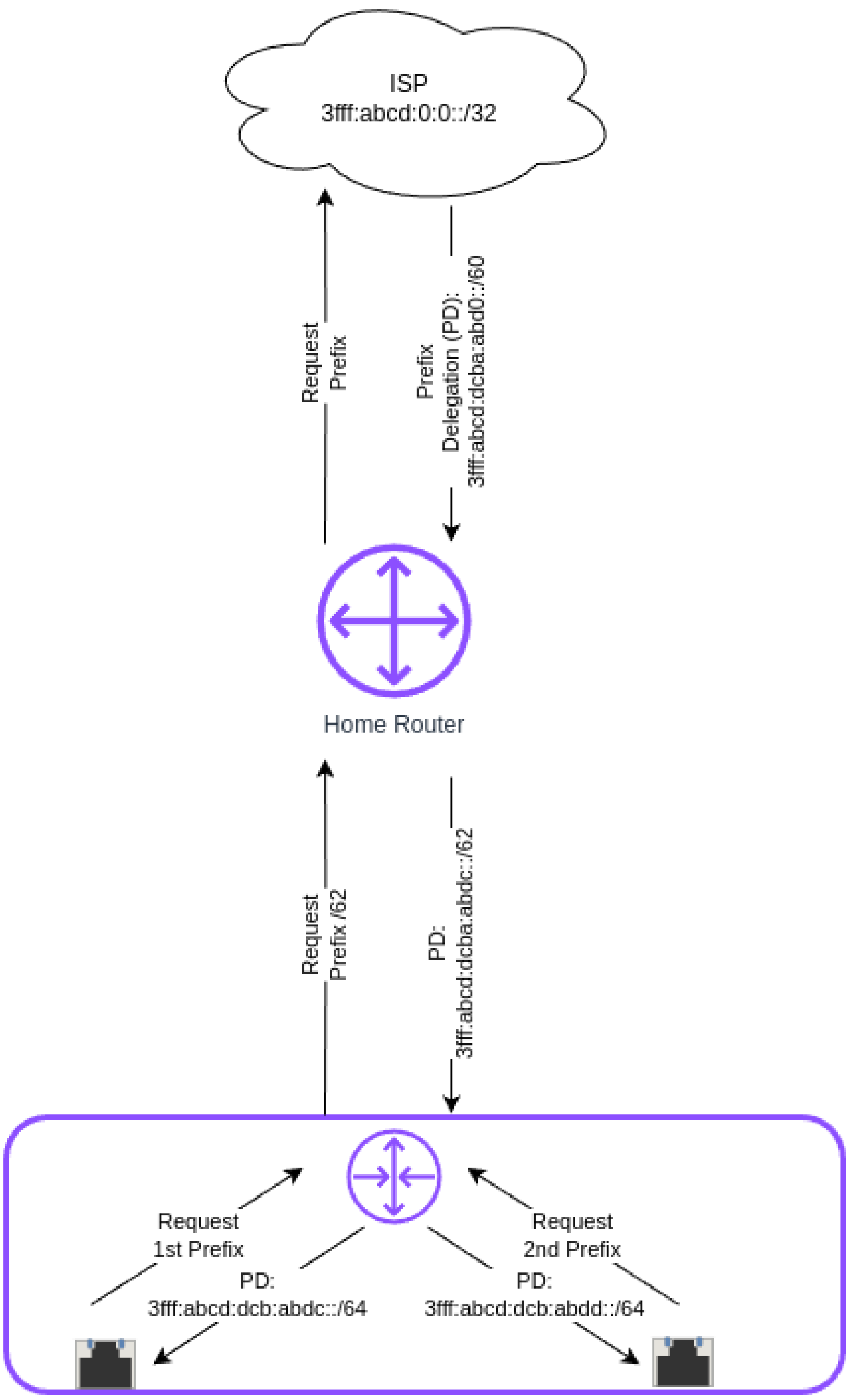
Mi, 4. Jun. 2025

1 Introduction

Recently my `ISP` (Internet Service Provider) finally provided me with modern `IPv6`. I at least got an `/60` prefix, which allows me to do subnetting, with up to 16 subnets, as the network identifier in `IPv6` has `64 bits`. So far so good. But I soon realized, that my prefix changes frequently, just as the `IPv4` prefix. That however is a problem. I do have two VLANs, beside my default network, that need their own GUA (Global Unicast Address) prefix. So whenever my prefix changes I would need to change my VLAN configurations and my routes. That's not feasible.
Gladly there is a solution to that problem: `IPv6` Prefix delegation (PD).

2 How it works

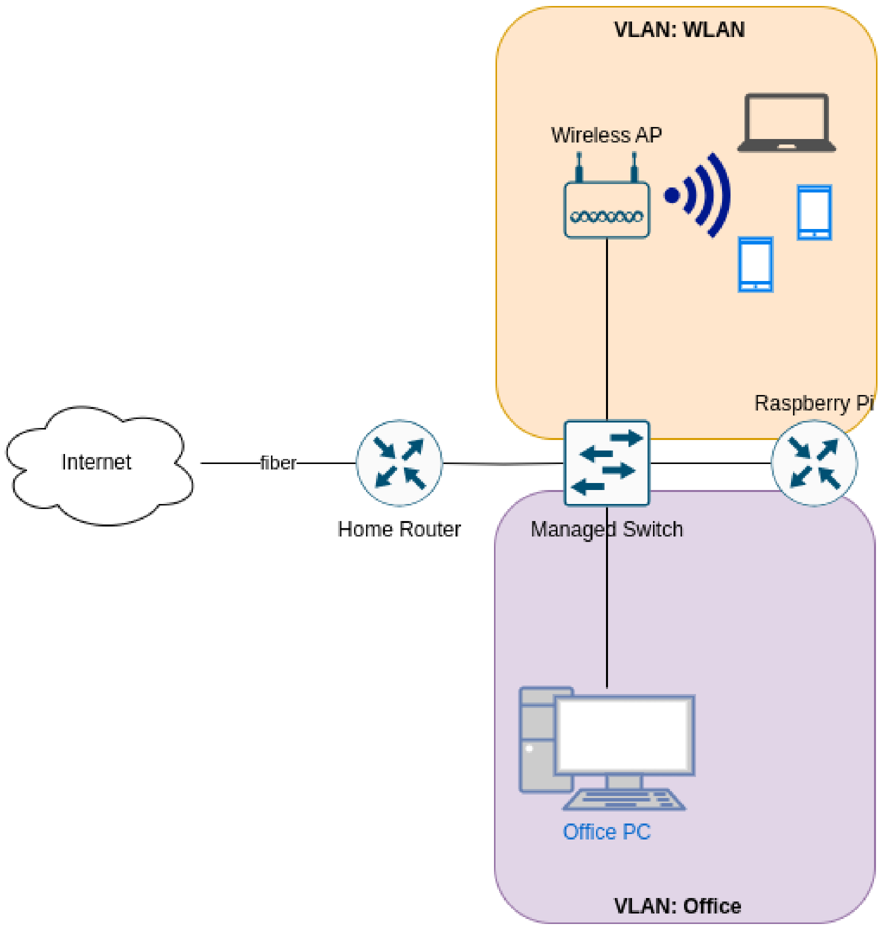
With legacy DHCP you can automatically provide `IPv4` addresses and other configuration information to clients. With modern `ICMPv6` you can of course do the same. But there is more: With PD you can provide whole network prefixes to a device.
That's actually how you get your `IPv6` prefix from your `ISP`. Your Home router request a Prefix from the `ISP's` DHCPv6 server. The `ISP's` DHCP server answers with a prefix of a certain length it delegates to your Home router. The good thing now is, that (given your Home router supports `IA_PD`) you can use an internal router (e. g. a Linux machine) to request itself a portion of this prefix to again provide whole networks e. g. for VLANs, as in my scenario.


ISP
3fff:abcd:0:0::/32
Request Prefix
Prefix Delegation (PD): 3fff:abcd:dcba:abd0::/60
Home Router
Request Prefix /62
PD: 3fff:abcd:dcba:abdc::/62
Request 1st Prefix
PD: 3fff:abcd:dcb:abdc::/64
Request 2nd Prefix
PD: 3fff:abcd:dcb:abdd::/64

The individual Interfaces of the downstream router can now themselves request a /64/ network and an IPv6 address in that network.

3 Set up

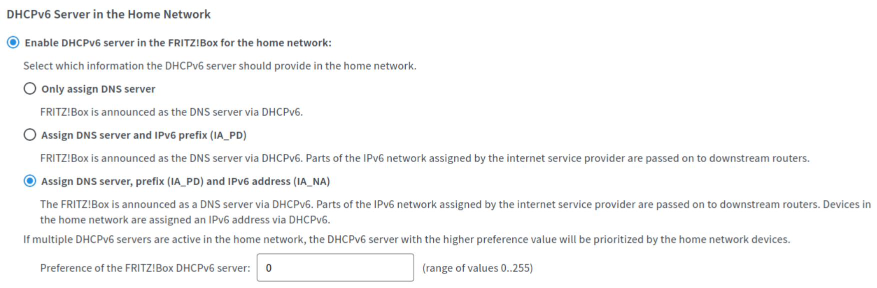
This is how my network currently looks:



My Home router gets a `/60` IPv6 prefix which changes every few days. To that Home Router I connected a managed switch, so I can have VLANs. The firewall, DHCP(v6) server und router for these VLANs live on a Raspberry Pi, that functions as a router on a stick: It is connected to the switch on a trunk port and has 2 virtual devices for the two VLANs — Office (VLAN Id 10) and WLAN (VLAN Id 20).
My Wifi access point is connect on an access port configured for VLAN 10 on my switch. The Office VLAN so far only contains my desktop Office PC.

3.1 Configuring the Home router

First you have to find out if and where you can enable the DHCPv6 option `IA_PD` on your Home router. On my Home router (called Fritz!Box) the menu looks like this an is found under `Home Network → Network → Network Settings → IPv6 Settings`.



DHCPv6 Server in the Home Network

[✓ Enable DHCPv6 server in the FRITZ!Box for the home network:]

Select which information the DHCPv6 server should provide in the home network.

Only assign DNS server

FRITZ!Box is announced as the DNS server via DHCPv6.

Assign DNS server and IPv6 prefix (IA_PD)

FRITZ!Box is announced as the DNS server via DHCPv6. Parts of the IPv6 network assigned by the internet service provider are passed on to downstream routers.

[✓ Assign DNS server, prefix (IA_PD) and IPv6 address (IA_NA)]

The FRITZ!Box is announced as a DNS server via DHCPv6. Parts of the IPv6 network assigned by the internet service provider are passed on to downstream routers. Devices in the home network are assigned an IPv6 address via DHCPv6.

If multiple DHCPv6 servers are active in the home network, the DHCPv6 server with the higher preference value will be prioritized by the home network devices.

Preference of the FRITZ!Box DHCPv6 server: 0 (range of values 0..255)

3.2 Configuring the Raspberry Pi router

Next we need to configure the internal router. As mentioned I use a Raspberry Pi, but the following steps should work on most modern Linux distributions and any PC hardware. You might prefer a device with more power and more importantly more bandwidth.

I first referred to the Debian wiki to get an idea on how to do this. I decided to settle on `systemd-networkd` to configure my interfaces. I run Raspberry Pi Os, which is based on Debian bookworm. It uses NetworkManager for network management.
`systemd-networkd` is however installed. So I decided to first configure everything, before disabling `NetworkManager.service` and enabling `systemd-networkd.service`.

3.2.1 Configuring the WAN interface

I started with my physical interface, which naturally acts as my WAN interface:
The first line are the general setup. In the section `[Match]` you have to provide the interface name, as setup by the system. Here it is `eth0`, on other systems it might be something like `enp0s16f0u1`. Next you have to specify the interface type which is `ether` for a wired ethernet link. For a wifi interface it would be `wlan`. There are other options to match your interface, e. g. the `MACAddress`.
`/etc/systemd/network/10-eth0.network`

```
[Match]
Name=eth0
Type=ether
```

Next comes the `[Network]` section, starting with a description. You can put anything here.

```
[Network]
Description=WAN Ethernet port
```

Now comes the first (slightly) interesting part. We tell `networkd` to use DHCPv6 to get an `IPv6` address and — more importantly — to accept `IPv6` Router Advertisements (RA). IP forwarding should also be activated on all interfaces on a router.

```
DHCP=ipv6
IPv6AcceptRA=yes
IPForward=yes
```

In this section we also have to configure which `VLAN`s we want to associate with this physical interface.

```
VLAN=Office
VLAN=WLAN
```

You most likely want to run dual stack. You should use static addressing for the legacy IP address that matches the network you'r in, e. g.:

```
[Address]
Address=192.168.178.254/24
```

Don't forget the `IPv4` default route. As we use Prefix Delegation for `IPv6` you do not need to set any routes there. It is done by DHCP`v6` for us.

```
[Route]
Gateway=192.168.178.1
```

We can make our live easier by assigning a Host-ID to our interface instead of using a random one. I just use `::1` as my Home router doesn't:

```
[IPv6AcceptRA]
Token=::1
```

So finally there comes the part, where we configure `IA_PD` for the WAN interface:

PrefixDelegationHint: You need to specify the size of the prefix, you want to get. It must be bigger the the prefix you got from your ISP, but at least `/64`, which would however mean, you can only provide 1 subnet downstream. Normally it is recommend to observe the nibble boundaries, which means you take steps of 4 bits, so on hex digit stands for one step in your network hierarchy. As I only got a `/60` I only have one nibble to work with. I decided that 4 subnets should be enough for now and settled on a `/62`.[1]

UseDelegatedPrefix: This option activates the use Prefix Delegation and should be set, although it seems to work without it.

```
[DHCPv6]
PrefixDelegationHint=::/62
UseDelegatedPrefix=yes
```

3.2.2 Configuring the Virtual LAN devices

The next step is to set up the virtual devices for the `VLAN`s. For that we need to create a `.netdev` for **each** `VLAN` under `/etc/systemd/network/`. These virtual devices must be created first before the physical device is configured, so the filename should start with `00-`.
The files need two section:

[NetDev]: Define a virtual device with a `Name` of `Kind` `vlan`.

[VLAN]: In this section the `VLAN` `Id` is defined. This must be a number between 1 and 4096. It must match the VLAN Id configured on the managed switch.

```
[NetDev]
Name=Office
Kind=vlan

[VLAN]
Id=10
```

Lastly a `.network` file must be created for **each** `VLAN` in the same directory. The number these files start we must be greater than the one the `.network` file for the physical starts with. I settled on `20-`.
It starts with a `[Match]` section, just as the `.network` file for physical interface. The `Name` to match is that configured for the virtual LAN device in the `.netdev` file. The `Type` must be set to `vlan`.
If you use physical Interfaces instead, use `Type` of `ether` or `wlan~`.

```
[Match]
Name=Office
Type=vlan
```

In the `[Network]` section is the place where some `DHCPv6` option must be configured:

DHCP=ipv6: We want to use DHCPv6.

IPForward: IP forwarding should be activated for both IPv4 and IPv6.

IPv6SendRA: We want to send Router Advertisements, so the devices in the

IPv6AcceptRA: We also need to accept Router Advertisments from upstream.

DHCPPrefixDelegation: `IA_PD` must also be activated.

```
[Network]
Description=Office VLAN interface
DHCP=ipv6
IPForward=yes
IPv6SendRA=yes
IPv6AcceptRA=no
DHCPPrefixDelegation=yes
```

[1]Each extra bit halves the number of possible subnets. So `/61` would give me 8, `/62` 4, `/63` 2, and `/64` 1 possible subnet.

Again a legacy address should be provided for dual stack.

```
[Address]
Address=172.16.10.1/24
```

Finally an `[DHCPPrefixDelegation]` section is need. You can decide whether your Unique Local (Unicast) Addresses (ULAs). It doesn't hurt, although they will not actually be used, as legacy `IPv4` is preferred over `IPv6` for private addressing.
The second option is more important. With `SubnetId` you can configure which of the available subnets you want to use. It's the number of the subnet in hexadecimal numbering. So `0x0` would be the first `0xf` would be the 16th subnets if you have so many to choose from.
I also like to use `::1` as the Host-ID, configure with `Token`, so I can easily ping the router.

```
[DHCPPrefixDelegation]
ULA=true
SubnetId=0x0
Token=::1
```

3.2.3 Disabling NetworkManager and enabling systemd-networkd

Now it's time to move from `NetworkManager` to `systemd-networkd`:

```
sudo systemctl disable --now NetworkManager.service
sudo systemctl enable --now systemd-networkd.service
```

I recommend also checking that everything works by running:

```
systemctl status systemd-networkd
```

Which should look something like this:

```
● systemd-networkd.service - Network Configuration
   Loaded: loaded (/lib/systemd/system/systemd-networkd.service; enabled; preset: enab
     Active: active (running) since Sat 2025-06-14 21:02:05 CEST; 14h ago
TriggeredBy: ● systemd-networkd.socket
       Docs: man:systemd-networkd.service(8)
             man:org.freedesktop.network1(5)
   Main PID: 97581 (systemd-network)
     Status: "Processing requests..."
      Tasks: 1 (limit: 9564)
        CPU: 583ms
     CGroup: /system.slice/systemd-networkd.service
             └─97581 /lib/systemd/systemd-networkd
```

You may also check if you got the expected prefixes with:

```
ip --brief a
```

3.3 Configure Firewall

It might however be, that you don't get an address on your inbound ports. This could be because ports 547 used by `ICMPv6` on the server side und 546 used on the client side are blocked. In this case you need to add the following rule to your input filter chain with nftables.

```
iifname "eth0" udp sport 547 udp dport 546 accept comment "Allow DHCPv6 from
   server to client"
```

If you don’t feel comfortable with nftables, you might use `ufw` on a Debian based system:

```
sudo ufw allow in on eth0 proto udp from any port 547 to any port 546 comment '
    Allow␣DHCPv6␣from␣server␣to␣client'
```

Or you could use `firewalld-cmd` on a Red Hat based system:

```
sudo firewall-cmd --permanent \
  --add-rich-rule='rule␣family="ipv6"␣\
␣␣source␣address="::/0"␣\
␣␣protocol␣value="udp"␣\
␣␣port␣port="547"␣protocol="udp"␣\
␣␣destination-port␣port="546"␣protocol="udp"␣\
␣␣interface␣name="eth0"␣\
␣␣accept'
```

4 Conclusion

With this setup all my downstream machine get their `IPv6` addresses in their `VLAN` with the correct prefix, no matter how often my ISP changes it. All routes are configured automatically and I don’t have to care about any of this any more.
This once again proves, that `IPv6` is more advanced and more simple then legacy `IP(v4)`.