Improving IPv6-only experience on Linux

How to get rid of the last dependencies on IPv4

Ondřej Caletka | 3 February 2024 | FOSDEM 2024
IPv6? You mean Dual Stack!

- IPv4-only and IPv6-only resources **directly accessible**
- IPv6 preferred for dual-stack resources
- Problems with IPv6 masked by Happy Eyeballs algorithm
- But it does not address IPv4 scarcity
NAT64 allows IPv6-only networks

- IPv6 accessible **natively**
- IPv4 is **translated** into part of IPv6 address space
- Together with **DNS64**, everything seems to be **accessible over IPv6**
- But sometimes you run into…
  - IPv4 literals
  - Legacy software opening IPv4-only sockets
  - Dual-stack servers with broken IPv6

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464XLAT closes the gap

- **CLAT** translator inside the host
- Translates residual IPv4 traffic to IPv6
- Translated IPv6 traffic get translated to IPv4 by NAT64 = **PLAT**
- Applications see *good old* dual-stack
## Can my device work on IPv6-only?

<table>
<thead>
<tr>
<th>Fully</th>
<th>Mostly</th>
<th>No way!</th>
</tr>
</thead>
<tbody>
<tr>
<td>Android</td>
<td>iOS</td>
<td>IoT</td>
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<tr>
<td>macOS</td>
<td>Windows</td>
<td>Linux</td>
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<tr>
<td>macOS</td>
<td>Linux</td>
<td>Smart home</td>
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</tbody>
</table>

- CLAT is present*
- Some mobile networks run billions of IPv6-only phones for years already
- No CLAT*
- Applications relying on IPv4 are broken
- No IPv6 support*
- Native IPv4 required

*) some statements are simplified
Can we do IPv6-only?

At least for those devices that support it?
IPv6-only Preferred option of DHCP

Parameters requested: GW, DNS, ..., 108

DHCP client is willing to run IPv6-only

IPv4, netmask, GW, DNS, ...

Option 108 is ignored by the DHCP server

DHCP client

DHCP server
Using DHCP to turn IPv4 off

DHCP CLIENT

Parameters requested: GW, DNS, ..., 108

IPv4, netmask, GW, DNS, ..., 108: 30 minutes

OFFER

DHCP client aborts the transaction and waits 30 minutes

DHCP server is configured to prefer IPv6-only operation

(RFC 8925)
What is an IPv6-mostly network?

• A network designed to run **IPv6-only**, but still providing **some IPv4** for legacy devices

• Must provide *perfectly* working IPv6 with **NAT64 support**
  - NAT64 prefix should be signalled using **PREF64** option of RAs

• Must provide **native IPv4**
  - DHCP server must offer option 108

![PREF64 option of Router Advertisement](image-url)
Linux on IPv6-only

How to avoid the need to have native IPv4 on Linux
What needs to be done

• **Option 1:** fix everything that has a hard dependency on IPv4  
  - Mostly done, reaching 100% is **virtually impossible**

• **Option 2:** make sure **CLAT is there** for residual issues  
  - The **most complex problem**  
  - Requires **third-party software** and a **proper orchestration**

• **Then finally:** implement handling of DHCP option 108  
  - So even IPv6-mostly network works as IPv6-only for Linux  
  - This should not be enabled **before implementing Option 2**  
  - We **already have this implemented** in dhcpcd and systemd-networkd
Running CLAT on Linux

- No native kernel support for address family translation
- Third party software like TAYGA, tundra-nat64, nat46, Jool
- Perl script clatd
  - detects if CLAT is needed
  - uses TAYGA or nat46 for actual translation
  - sets up addressing, forwarding, firewall rules
  - does not react to renumbering
  - does not support multiple instances
Ideal CLAT

• Supports **multiple instances**
  - One per interface
  - Should deal with **conflicting NAT64 prefixes**

• Sets itself up as soon as **NAT64 is detected**
  - Either using **PREF64 RA option** or doing `ipv4only.arpa` DNS64 detection
  - Installs IPv4 default route with a **higher metric than potential native IPv4 route**

• **Reacts dynamically** to changing conditions

• **Does not touch** firewall of forwarding

Individual draft in IETF: CLAT Node Recommendations
Using ipvlan and namespaces

- IPv4
  - eth0
  - eth0-v4
  - eth0-clat-v4
  - IPv4 veth pair
- IPv6
  - eth0-clat-v6
  - ipvlan interface
- CLAT namespace
  - running Jool
- Main namespace
- IPv6-only network

Proof of Concept code

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Using ipvlan and namespaces

• No change to routing or firewall of the main namespace
  - ipvlan will branch a single IPv6 address to the CLAT namespace
  - IPv4 is provided via a new network interface (veth link to the CLAT namespace)

• Supports multiple instances, even with conflicting prefixes
  - the only issue is to assign a unique IPv4 address from 192.0.0.0/29

• Any translator can run in the CLAT namespace
  - for instance: kernel-space Jool if available, userspace tundra-nat64 as a fallback

• Simple teardown without any side effects
  - just delete the network namespace
What is missing

• A software responsible for **setting up, (re-)configuring** and **tearing down** the CLAT
  - detect NAT64 presence
  - set up a *(checksum-neutral)* IPv6 address for the CLAT
  - assigns a **free IPv4 address** from 192.0.0.0/29
  - react to subsequent RAs and adjust **configuration on the fly**

• Ideally integrated in common Linux distributions
Questions

Ondrej@Caletka.cz
https://Ondřej.Caletka.nl
@Oskar456@mastodon.social