Survey of inconsistencies in Linux kernel IPv4/IPv6 UAPI

Roopa Prabhu

Agenda

- Goals
- Introduction to Kernel Netlink UAPI for IPv4/IPv6
- Introduction to userspace apps relying on the UAPI
- Survey areas of inconsistencies and discuss solutions

Goals

- Guide to deploy IPv4 and IPv6

- And hope to provide enough motivation to keep the IPv4 and IPv6 UAPI consistent in the future

Introduction

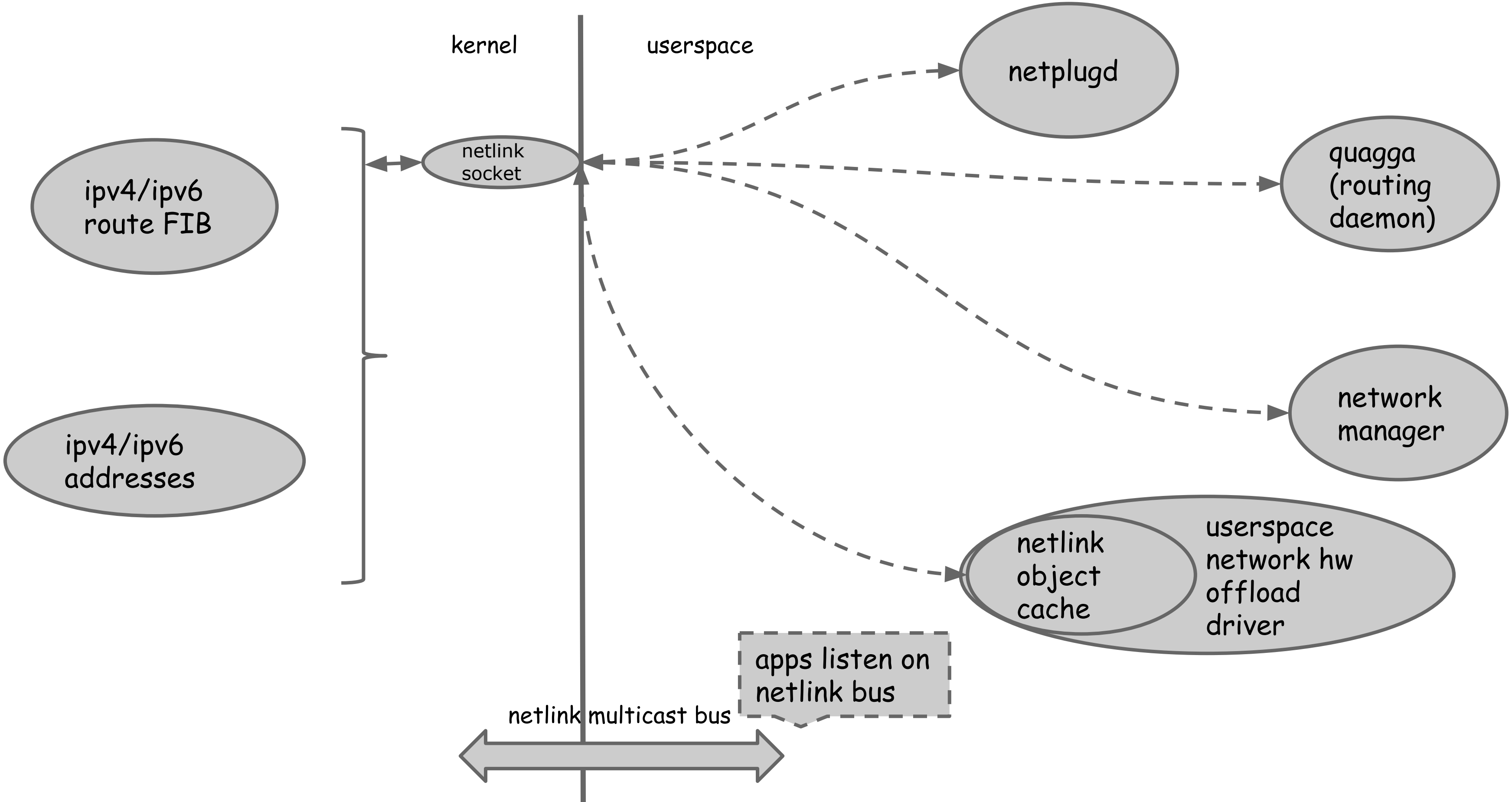
- Kernel provides netlink based UAPI and tools to manage IPv4 and IPv6 (Netlink message types: RTM_NEWROUTE, RTM_DELROUTE and RTM_GETROUTE)

- Kernel notifies user space via Netlink notifications

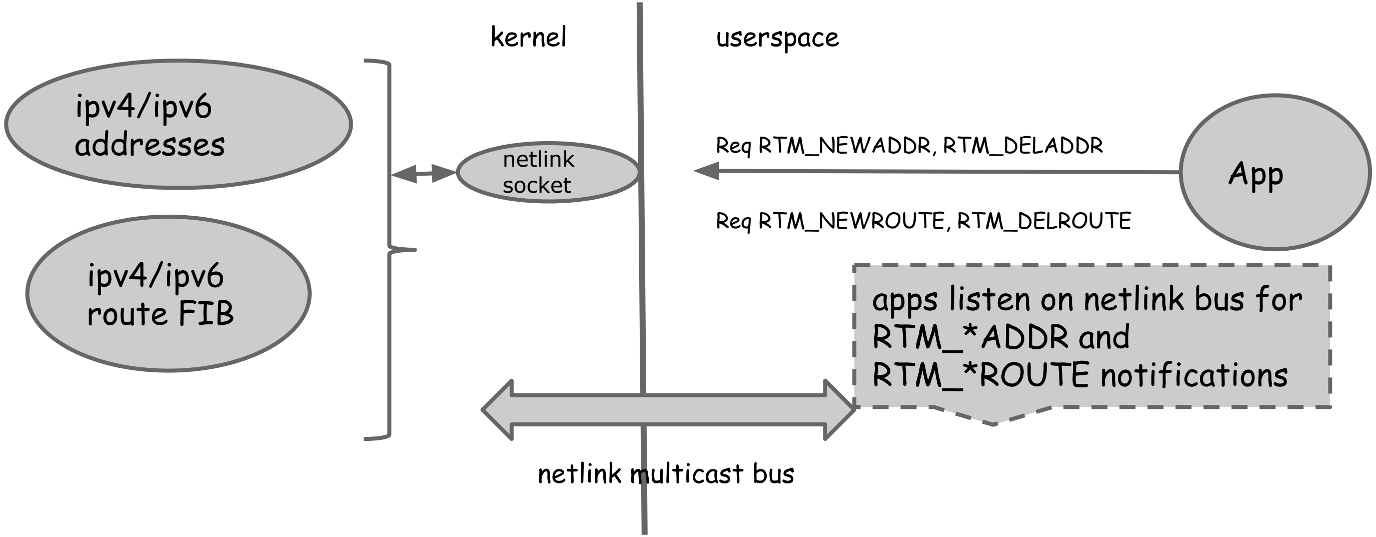
Example Applications using the API

- Network Managers
- Routing daemons
- Userspace netlink caches
- Userspace hardware offload drivers

Netlink apps ...



RTnetlink addr and route messages



apps listen on netlink bus for RTM_*ADDR and RTM_*ROUTE notifications

We will discuss the following UAPI's:

- Address handling on interface down
- Route delete notifications on interface down
- Multipath route add/del UAPI
- Multipath route netlink notification
- Multipath route replaces
- Multipath route appends
- Handling un-equal cost multipath routes

Address handling on interface down

IPv6 global addresses are flushed on ifdown, but IPv4 stay

Example: address handling on ifdown

```
# interface dummy0 below has an ipv4 address, ipv6 global
# and ipv6 link local address
ip addr show
        4: dummy0: <BROADCAST,NOARP,UP,LOWER_UP> mtu 1500 qdisc
        noqueue state UNKNOWN group default
        link/ether 12:3f:92:73:f7:1f brd ff:ff:ff:ff:ff:ff
        inet 10.0.13.2/24 scope global dummy0
        valid_lft forever preferred_lft forever
        inet6 2001:20:1::2/64 scope global
        valid_lft forever preferred_lft forever
        inet6 fe80::103f:92ff:fe73:f71f/64 scope link
        valid_lft forever preferred_lft forever
# down dummy0
ip link set dev dummy0 down
ip monitor addr
        Deleted 4: dummy0 inet6 2001:20:1::2/64 scope global
        valid_lft forever preferred_lft forever
        Deleted 4: dummy0 inet6 fe80::103f:92ff:fe73:f71f/64 scope link valid_lft
        forever preferred_lft forever
```

```
# bring interface dummy0 up
ip link set dev dummy0 up

# ip monitor output showing ipv6 link local address coming
# back up
ip monitor addr
        4: dummy0 inet6 fe80::103f:92ff:fe73:f71f/64 scope link
        valid_lft forever preferred_lft forever

# ipv6 global scope address 2001:20:1::2/64, never came back # and is lost
ip addr show
        4: dummy0: <BROADCAST,NOARP,UP,LOWER_UP> mtu 1500 qdisc
        noqueue state UNKNOWN group default
        link/ether 12:3f:92:73:f7:1f brd ff:ff:ff:ff:ff:ff
        inet 10.0.13.2/24 scope global dummy0
        valid_lft forever preferred_lft forever
        inet6 fe80::103f:92ff:fe73:f71f/64 scope link
        valid_lft forever preferred_lft forever
```

Solutions

In user-space: monitor link down messages and re-configure addresses on ifup (netplugd is an option)

Problems: This special handling becomes part of multiple applications (problem aggravated with multiple network namespaces: multiple netplugd instances)

In kernel: Don't flush IPv6 addresses on Link down (Thanks to a recent fix from David Ahern)

Route delete notifications on interface down

- Kernel notifies user-space of IPv6 dead routes on interface down

- But, user-space is not notified of IPv4 dead routes on interface down

Example: route delete notifications

```
# interface dummy0 below has an ipv4 address, ipv6 global
# and ipv6 link local address
ip addr show
4: dummy0: <BROADCAST,NOARP,UP,LOWER_UP> mtu 1500 qdisc
noqueue state UNKNOWN group default
link/ether 12:3f:92:73:f7:1f brd ff:ff:ff:ff:ff:ff
inet 10.0.13.2/24 scope global dummy0
valid_lft forever preferred_lft forever
inet6 2001:20:1::2/64 scope global
valid_lft forever preferred_lft forever
inet6 fe80::103f:92ff:fe73:f71f/64 scope link
valid_lft forever preferred_lft forever
# showing IPv4 connected routes installed by the kernel
# for the IPv4 address
ip -4 route show
10.0.13.0/24 dev dummy0 proto kernel scope link src 10.0.13.2
```

```
# showing IPv6 connected routes installed by the kernel
# for the IPv6 address
ip -6 route show
2001:20:1::/64 dev dummy0 proto kernel metric 256
fe80::/64 dev dummy0 proto kernel metric 256

# As you can see below, only notifications for IPv6 were
# generated by the kernel. There were no notifications for
# IPv4 route delete.
ip monitor route
Deleted 2001:20:1::/64 dev dummy0 proto kernel metric 256
Deleted fe80::/64 dev dummy0 proto kernel metric 256
Deleted ff00::/8 dev dummy0 table local metric 256
Deleted local 2001:20:1::2 dev lo table local proto none metric 0
Deleted local fe80::103f:92ff:fe73:f71f dev lo table local proto none metric 0

# Both IPv4 and IPv6 connected routes were deleted by
# the kernel
ip -4 route show
ip -6 route show
```

Solutions

In user-space: An application can listen to link notifications and purge all IPv4 dead routes

Problems: Handling of route purging gets duplicated in multiple applications

In kernel: IPv4 UAPI can be fixed to generate notifications on all dead routes similar to IPv6

(**Note:** Kernel does not generate notifications for dead routes today because user-space can figure this out. Which we believe might be the right thing to do given that this can generate a notification storm on interface down)

Multipath route add/del api

IPv4:

```
ip route add 10.0.15.2 \
        nexthop via 10.0.12.2 dev dummy0 \
        nexthop via 10.0.13.2 dev dummy1
```

IPv6: Two ways to add multipath routes

(legacy, currently there for backward compatibility)

```
ip -6 route add 3ffe:304:124:2306::/64 \
        nexthop via fe80::b077:f0ff:fe23:5cc7 dev dummy0
ip -6 route add 3ffe:304:124:2306::/64  \
        nexthop via fe80::d850:e7ff:fe87:cf6a dev dummy1
```

and

```
ip -6 route add 3ffe:304:124:2306::/64 \
                nexthop via fe80::b077:f0ff:fe23:5cc7 dev dummy0 \
                nexthop via fe80::d850:e7ff:fe87:cf6a dev dummy1
```

Multipath route notifications

Ipv4: Notification contains all nexthop information

```
ip monitor route
10.0.15.2
        nexthop via 10.0.12.2  dev dummy0 weight 1
        nexthop via 10.0.13.2  dev dummy1 weight 1
```

Ipv6: One separate notification for each nexthop

```
ip monitor route
3ffe:304:124:2306::/64 via fe80::b077:f0ff:fe23:5cc7 dev dummy0  metric 1024
3ffe:304:124:2306::/64 via fe80::d850:e7ff:fe87:cf6a dev dummy1  metric 1024
```

Solutions

- **In user-space:** Application re-builds a multipath route in userspace from individual notifications

- **Problems:** guessing multipath route in userspace from individual notifications can be error prone

- **In kernel:** IPv6 multipath notification format should be made similar to IPv4

Multipath route replaces

- Route replace: RTM_NEWROUTE with NLM_F_REPLACE flag

- Unlike IPv4, IPv6 allows replacing a single nexthop in a multipath route

Route replace example

#ipv4

```
$ip route show
10.0.12.2
        nexthop via 10.0.13.2 dev dummy0 weight 1
        nexthop via 10.0.14.2 dev dummy1 weight 1

$ip route replace 10.0.12.2 nexthop via 10.0.15.2 dev dummy2

$ip monitor route
10.0.12.2 via 10.0.15.2 dev dummy2

$ip route show
10.0.12.2 via 10.0.15.2 dev dummy2
```

#ipv6

```
$ ip -6 route show
3ffe:304:124:2306::/64 via fe80::b077:f0ff:fe23:5cc7 dev dummy0
metric 1024
3ffe:304:124:2306::/64 via fe80::d850:e7ff:fe87:cf6a dev dummy1
metric 1024

$ip -6 route replace 3ffe:304:124:2306::/64 nexthop via fe80::c26:
cdff:feca:18f2 dev dummy2

$ip monitor route
3ffe:304:124:2306::/64 via fe80::c26:cdff:feca:18f2 dev dummy2
metric 1024

$ip -6 route show /* replaced a single nexthop of a multipath route */
3ffe:304:124:2306::/64 via fe80::c26:cdff:feca:18f2 dev dummy2
metric 1024
3ffe:304:124:2306::/64 via fe80::d850:e7ff:fe87:cf6a dev dummy1
metric 1024
```

Solutions

- In user-space: Always replace the first next hop in the list if the notification contained NLM_F_REPLACE flag

- Problems: *guessing replace sequence in userspace* is error prone

- In kernel: IPv6 multipath notification format should be made similar to IPv4 (Additionally, replace notification can contain more info on which route was replaced)

Multipath route appends

- Route append: RTM_NEWROUTE with NLM_F_APPEND flag

- Unlike IPv4, IPv6 allows appending a single nexthop to a multipath route

Example: IPv6 route append

#ipv4

```
ip route show
10.0.12.2
        nexthop via 10.0.13.2 dev dummy0 weight 1
        nexthop via 10.0.14.2 dev dummy1 weight 1

ip route append 10.0.12.2 nexthop via 10.0.15.2 dev dummy2

ip monitor route
10.0.12.2 via 10.0.15.2 dev dummy2

ip route show
10.0.12.2
        nexthop via 10.0.13.2 dev dummy0 weight 1
        nexthop via 10.0.14.2 dev dummy1 weight 1
10.0.12.2 via 10.0.15.2 dev dummy2
```

#ipv6

```
ip -6 route show
3ffe:304:124:2306::/64 via fe80::b077:f0ff:fe23:5cc7 dev dummy0 metric 1024
3ffe:304:124:2306::/64 via fe80::d850:e7ff:fe87:cf6a dev dummy1 metric 1024

ip monitor route
3ffe:304:124:2306::/64 via fe80::c26:cdff:feca:18f2 dev dummy2 metric 1024

ip -6 route append 3ffe:304:124:2306::/64 nexthop via fe80::c26:cdff:feca:18f2 dev dummy2

ip -6 route show
3ffe:304:124:2306::/64 via fe80::b077:f0ff:fe23:5cc7 dev dummy0 metric 1024
3ffe:304:124:2306::/64 via fe80::d850:e7ff:fe87:cf6a dev dummy1 metric 1024
3ffe:304:124:2306::/64 nexthop via fe80::c26:cdff:feca:18f2 dev dummy2
```

Solutions

- **In user-space**: Append nexthops learnt from new notification to end of the nexthop list
- **Problems:** *guessing* append sequence in userspace is error prone
- **In kernel:** IPv6 multipath notification format to be made similar to IPv4

Unequal cost multipath routes

Two ways to assign weights to nexthops:

1. Repeat nexthop times equal to the weight of the nexthop
2. Use ‘weight’ attribute to assign weights

IPv4 supports both 1) and 2) today. IPv6 supports only 2)

Solutions

In user-space: weights can be used in the case of both IPv4 and IPv6

In kernel: IPv6 can be made consistent with IPv4

(Note: The difference is because of the way IPv6 stores its nexthops in the kernel)

Conclusions

Keeping the IPv4 and IPv6 kernel API consistent will simplify user space networking apps

Futures

- Patches to unify IPv4 and IPv6 API (under a sysctl if it changes default behaviour)

- Future IPv4 and IPv6 API can keep consistency in mind