
Praktikum Rechnernetze

Protokoll zu Versuch 4 (IPv6) von Gruppe 1

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1 Einführung

1.1 Mitwirken

Diese Materialien basieren auf [Professor Kiefers “Praktikum Rechnernetze”-Vorlesung der HdM Stuttgart](#).

Sie haben einen Fehler gefunden oder haben einen Verbesserungsvorschlag? Bitte eröffnen Sie ein Issue auf GitHub (github.com/pojntfx/uni-netpractice-notes):



Abbildung 1: QR-Code zum Quelltext auf GitHub

Wenn Ihnen die Materialien gefallen, würden wir uns über einen GitHub-Stern sehr freuen.

1.2 Lizenz

Dieses Dokument und der enthaltene Quelltext ist freie Kultur bzw. freie Software.



Abbildung 2: Badge der AGPL-3.0-Lizenz

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SPDX-License-Identifier: AGPL-3.0

2 IPv6-Adressen

Erkunden sie unter Windows und Ubuntu, wie viele IP-Adressen dem physikalischen Interface zugeordnet sind.

```
1 $ ip addr
2 1: lo: <LOOPBACK,UP,LOWER_UP> mtu 65536 qdisc noqueue state UNKNOWN
   group default qlen 1000
3     link/loopback 00:00:00:00:00:00 brd 00:00:00:00:00:00
4     inet 127.0.0.1/8 scope host lo
5         valid_lft forever preferred_lft forever
6 2: enp0s31f6: <BROADCAST,MULTICAST,UP,LOWER_UP> mtu 1500 qdisc
   pfifo_fast state UP group default qlen 1000
7     link/ether 4c:52:62:0e:54:8b brd ff:ff:ff:ff:ff:ff
8     inet 141.62.66.5/24 brd 141.62.66.255 scope global dynamic
   enp0s31f6
9     valid_lft 13993sec preferred_lft 13993sec
```

```
1 # /etc/sysctl.conf
2 net.ipv6.conf.all.disable_ipv6 = 0
3 net.ipv6.conf.default.disable_ipv6 = 0
4 net.ipv6.conf.lo.disable_ipv6 = 0
```

```
1 $ sudo sysctl -p
```

```
1 $ ip a
2 1: lo: <LOOPBACK,UP,LOWER_UP> mtu 65536 qdisc noqueue state UNKNOWN
   group default qlen 1000
3     link/loopback 00:00:00:00:00:00 brd 00:00:00:00:00:00
4     inet 127.0.0.1/8 scope host lo
5         valid_lft forever preferred_lft forever
6     inet6 ::1/128 scope host
7         valid_lft forever preferred_lft forever
8 2: enp0s31f6: <BROADCAST,MULTICAST,UP,LOWER_UP> mtu 1500 qdisc
   pfifo_fast state UP group default qlen 1000
9     link/ether 4c:52:62:0e:54:8b brd ff:ff:ff:ff:ff:ff
10    inet 141.62.66.5/24 brd 141.62.66.255 scope global dynamic
   enp0s31f6
11    valid_lft 13621sec preferred_lft 13621sec
12    inet6 2001:470:6d:4d0:4e52:62ff:fe0e:548b/64 scope global dynamic
   mngtmpaddr
13    valid_lft 86367sec preferred_lft 14367sec
14    inet6 fe80::4e52:62ff:fe0e:548b/64 scope link
15    valid_lft forever preferred_lft forever
```

Es sind 3 Adressen zu finden; eine Host-Local-Adresse, eine Global-Unique-Adresse und eine Link-Local-Adresse.

Nun wird noch IPv4 deaktiviert:

```
1 $ sudo ip addr delete 141.62.66.5/24 dev enp0s31f6
2 $ ip a
3 1: lo: <LOOPBACK,UP,LOWER_UP> mtu 65536 qdisc noqueue state UNKNOWN
   group default qlen 1000
4     link/loopback 00:00:00:00:00:00 brd 00:00:00:00:00:00
5     inet 127.0.0.1/8 scope host lo
6         valid_lft forever preferred_lft forever
7     inet6 ::1/128 scope host
8         valid_lft forever preferred_lft forever
9 2: enp0s31f6: <BROADCAST,MULTICAST,UP,LOWER_UP> mtu 1500 qdisc
   pfifo_fast state UP group default qlen 1000
10    link/ether 4c:52:62:0e:54:8b brd ff:ff:ff:ff:ff:ff
11    inet6 2001:470:6d:4d0:4e52:62ff:fe0e:548b/64 scope global dynamic
        mngtmpaddr
12        valid_lft 86328sec preferred_lft 14328sec
13    inet6 fe80::4e52:62ff:fe0e:548b/64 scope link
14        valid_lft forever preferred_lft forever
```

Woraus setzt sich die Link-Lokale-Adresse zusammen und erkennen Sie das EUI-64 Format?

Die Link-Lokale-Adresse setzt sich aus Prefix `fe80` und 48 Füll-Nullen sowie und der mit EUI-64 erweiterten MAC-Adresse zusammen.

Das EUI-64-Format lässt sich mittels `fe0e` bei `2001:470:6d:4d0:4e52:62ff:fe0e:548b/64` und `fe80::4e52:62ff:fe0e:548b/64` erkennen.

Wie lautet der Prefix und die Host-ID der Global-Unicast-Adresse?

Prefix: `2001:470:6d:4d0`

Host-ID: `4e52:62ff:fe0e:548b`

Testen Sie die Netzwerkverbindung zwischen dem Linux und dem Windows-Rechner mit einem Ping (IPv6)?

Vom Linux-Host zum Windows-Host:

```
1 $ ping6 2001:470:6d:4d0:4e52:62ff:fe0e:542b
2 PING 2001:470:6d:4d0:4e52:62ff:fe0e:542b(2001:470:6d:4d0:4e52:62ff:fe0e
   :542b) 56 data bytes
3 64 bytes from 2001:470:6d:4d0:4e52:62ff:fe0e:542b: icmp_seq=1 ttl=64
   time=1.33 ms
4 64 bytes from 2001:470:6d:4d0:4e52:62ff:fe0e:542b: icmp_seq=2 ttl=64
   time=0.790 ms
5 64 bytes from 2001:470:6d:4d0:4e52:62ff:fe0e:542b: icmp_seq=3 ttl=64
   time=0.787 ms
6 64 bytes from 2001:470:6d:4d0:4e52:62ff:fe0e:542b: icmp_seq=4 ttl=64
   time=0.787 ms
7 64 bytes from 2001:470:6d:4d0:4e52:62ff:fe0e:542b: icmp_seq=5 ttl=64
   time=0.775 ms
```

```
8 64 bytes from 2001:470:6d:4d0::4e52:62ff:fe0e:542b: icmp_seq=6 ttl=64
   time=0.808 ms
9 ^C
10 --- 2001:470:6d:4d0::4e52:62ff:fe0e:542b ping statistics ---
11 6 packets transmitted, 6 received, 0% packet loss, time 5078ms
12 rtt min/avg/max/mdev = 0.775/0.879/1.327/0.200 ms
```

Lassen Sie sich die Routen anzeigen und ermitteln Sie die „Default Route“

```
$ ip -6 route show 2001:470:6d:4d0::/64 dev enp0s31f6 proto kernel metric 256 expires 86097sec pref medium
fe80::/64 dev enp0s31f6 proto kernel metric 256 pref medium default via fe80::fad1:11ff:febd:6612 dev enp0s31f6 proto ra metric 1024 expires 1497sec hoplimit 64 pref medium
```

Wer antwortet auf Multicast-Adressen?

```
1 $ ping6 ff02::1%enp0s31f6 # Stations
2 PING ff02::1%enp0s31f6(ff02::1%enp0s31f6) 56 data bytes
3 64 bytes from fe80::4e52:62ff:fe0e:548b%enp0s31f6: icmp_seq=1 ttl=64
   time=0.057 ms
4 64 bytes from fe80::268:ebff:feb3:3487%enp0s31f6: icmp_seq=1 ttl=64
   time=0.292 ms
5 64 bytes from fe80::fad1:11ff:febd:6612%enp0s31f6: icmp_seq=1 ttl=64
   time=0.292 ms
6 64 bytes from fe80::dcab:6dff:fe0e:ad58%enp0s31f6: icmp_seq=1 ttl=64
   time=0.359 ms
7 64 bytes from fe80::b858:f6ff:fe60:f766%enp0s31f6: icmp_seq=1 ttl=64
   time=0.359 ms
8 64 bytes from fe80::a4e2:e2ff:fe0e:e47d%enp0s31f6: icmp_seq=1 ttl=64
   time=0.359 ms
9 64 bytes from fe80::4e52:62ff:fe0e:5401%enp0s31f6: icmp_seq=1 ttl=64
   time=0.426 ms
10 64 bytes from fe80::4e52:62ff:fe0e:e0e6%enp0s31f6: icmp_seq=1 ttl=64
   time=0.426 ms
11 64 bytes from fe80::4e52:62ff:fe0e:545d%enp0s31f6: icmp_seq=1 ttl=64
   time=0.426 ms
12 64 bytes from fe80::4e52:62ff:fe0e:e0e9%enp0s31f6: icmp_seq=1 ttl=64
   time=0.478 ms
13 64 bytes from fe80::b04f:d6ff:fe65:93c7%enp0s31f6: icmp_seq=1 ttl=64
   time=0.478 ms
14 64 bytes from fe80::268:ebff:feb3:3358%enp0s31f6: icmp_seq=1 ttl=64
   time=0.704 ms
15 64 bytes from fe80::6039:f6ff:fe7b:b087%enp0s31f6: icmp_seq=1 ttl=64
   time=0.777 ms
16 64 bytes from fe80::24c5:4ff:fe8a:faeb%enp0s31f6: icmp_seq=1 ttl=64
   time=0.777 ms
17 64 bytes from fe80::e0a2:5fff:fe18:2fe8%enp0s31f6: icmp_seq=1 ttl=64
   time=0.777 ms
18 64 bytes from fe80::74a8:deff:fe8b:4aa%enp0s31f6: icmp_seq=1 ttl=64
   time=0.778 ms
19 64 bytes from fe80::6cfd:9fff:fe6d:3174%enp0s31f6: icmp_seq=1 ttl=64
   time=0.841 ms
```

```
20 64 bytes from fe80::8461:e8ff:fec4:28e5%enp0s31f6: icmp_seq=1 ttl=64
    time=0.841 ms
21 64 bytes from fe80::40bc:f2ff:fec8:62dd%enp0s31f6: icmp_seq=1 ttl=64
    time=0.841 ms
22 64 bytes from fe80::f02a:80ff:fe19:5233%enp0s31f6: icmp_seq=1 ttl=64
    time=0.841 ms
23 64 bytes from fe80::609:73ff:feaa:8ac0%enp0s31f6: icmp_seq=1 ttl=64
    time=0.888 ms
24 64 bytes from fe80::609:73ff:feaa:8b80%enp0s31f6: icmp_seq=1 ttl=64
    time=0.971 ms
25 64 bytes from fe80::215:99ff:fe7f:339d%enp0s31f6: icmp_seq=1 ttl=64
    time=1.21 ms
26 ^C
27 --- ff02::1%enp0s31f6 ping statistics ---
28 1 packets transmitted, 1 received, +22 duplicates, 0% packet loss, time
    0ms
29 rtt min/avg/max/mdev = 0.057/0.617/1.210/0.274 ms
30 $ ping6 ff02::2%enp0s31f6 # Router
31 PING ff02::2%enp0s31f6(ff02::2%enp0s31f6) 56 data bytes
32 64 bytes from fe80::fad1:11ff:febd:6612%enp0s31f6: icmp_seq=1 ttl=64
    time=0.299 ms
33 64 bytes from fe80::268:ebff:feb3:3487%enp0s31f6: icmp_seq=1 ttl=64
    time=0.525 ms
34 64 bytes from fe80::268:ebff:feb3:3358%enp0s31f6: icmp_seq=1 ttl=64
    time=0.675 ms
35 64 bytes from fe80::fad1:11ff:febd:6612%enp0s31f6: icmp_seq=2 ttl=64
    time=0.302 ms
36 64 bytes from fe80::268:ebff:feb3:3487%enp0s31f6: icmp_seq=2 ttl=64
    time=0.465 ms
37 64 bytes from fe80::268:ebff:feb3:3358%enp0s31f6: icmp_seq=2 ttl=64
    time=0.697 ms
38 64 bytes from fe80::fad1:11ff:febd:6612%enp0s31f6: icmp_seq=3 ttl=64
    time=0.294 ms
39 64 bytes from fe80::268:ebff:feb3:3487%enp0s31f6: icmp_seq=3 ttl=64
    time=0.294 ms
40 64 bytes from fe80::268:ebff:feb3:3358%enp0s31f6: icmp_seq=3 ttl=64
    time=0.648 ms
41 ^C
42 --- ff02::2%enp0s31f6 ping statistics ---
43 3 packets transmitted, 3 received, +6 duplicates, 0% packet loss, time
    2057ms
44 rtt min/avg/max/mdev = 0.294/0.466/0.697/0.165 ms
```

TODO: Add interpretation

Können Sie einzelne Notes anhand der MAC-Adresse (siehe Anhang) identifizieren?

Die Station `fe80::fad1:11ff:febd:6612` konnte erkannt werden; diese ist wie zuvor schon beschrieben (`ip -6 route show`) das Standardgateway

Wieviele unterschiedliche Stationen antworten darauf, oder wieviele aktive Komponenten im

RN-LAN arbeiten bereits mit IPv6?

Es sind 23 IPv6-Stationen im Netzwerk; die Adressen der Router `fe80::fad1:11ff:febd:6612`, `fe80::268:ebff:feb3:3487` und `fe80::268:ebff:feb3:3358` finden sich wie oben zu erkennen ist auch im 1. ping-Command.

3 IPv6 und DNS

Identifizieren Sie mit Wireshark die Pakete mit denen der Router im Netz das Prefix mitteilt. Welches Protokoll wird dafür benutzt und um welchen Type handelt es sich und wie lautet die Zieladresse des Pakets?

Protokoll: ICMPv6 Type: Router Solicitation bzw. Router Advertisement

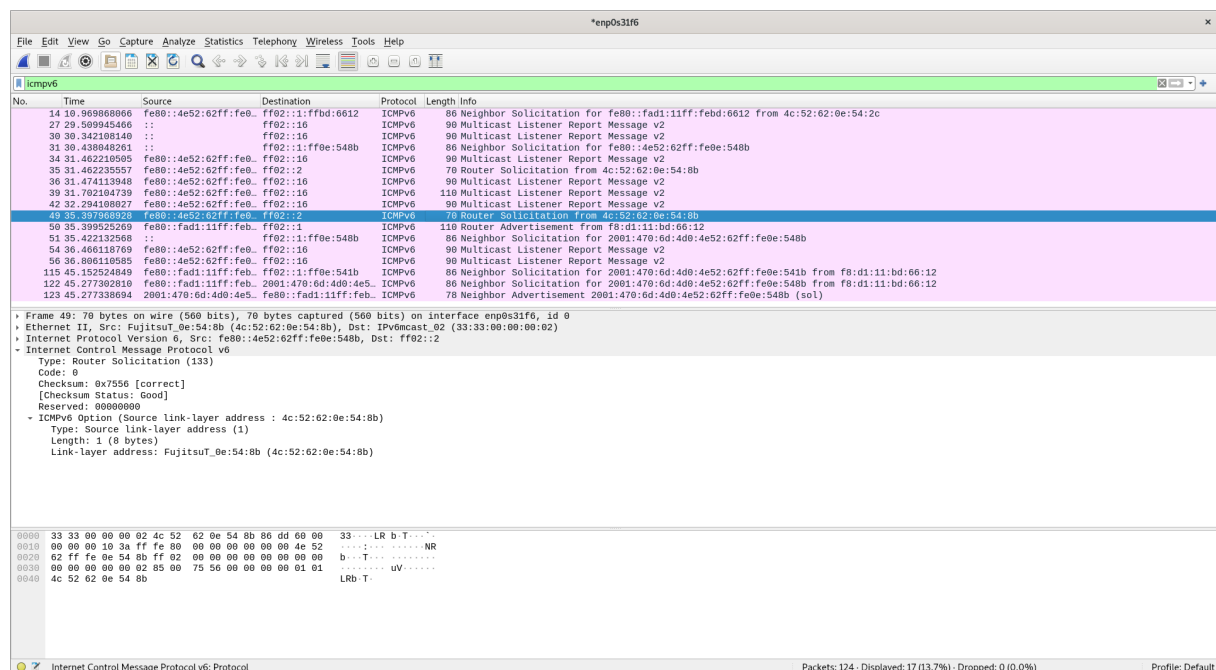


Abbildung 3: Router Solicitation

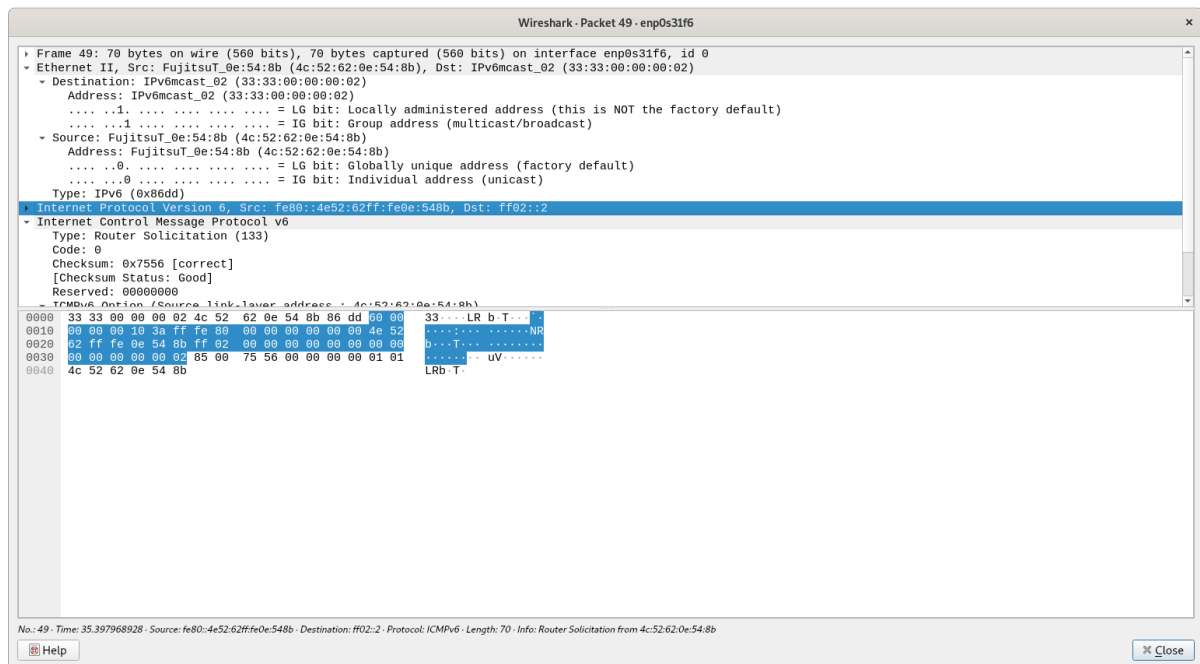


Abbildung 4: Router Solicitation Details: Die Zieladresse ist ff02::2.

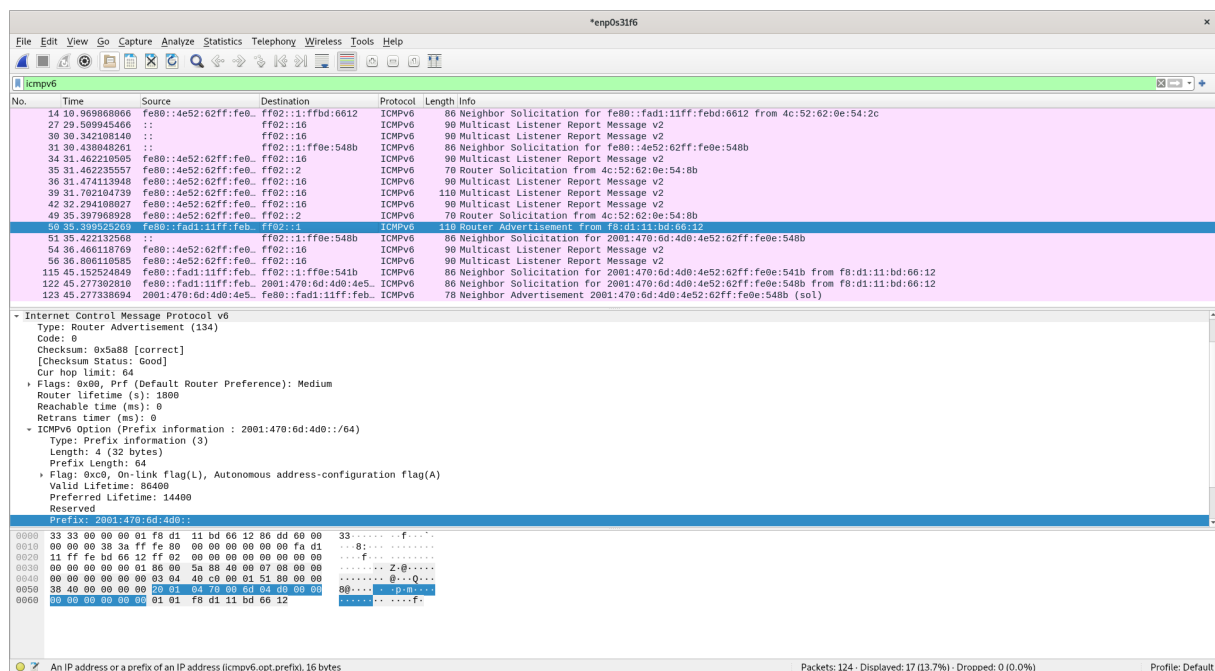


Abbildung 5: Router Advertisement

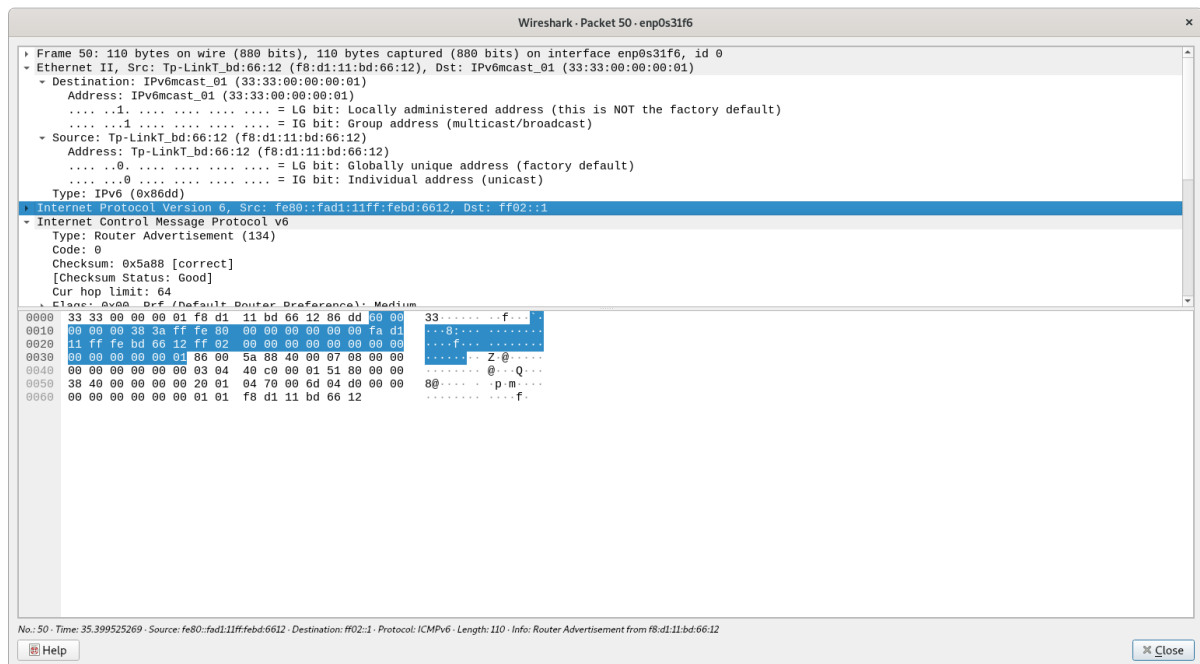


Abbildung 6: Router Advertisement Details: Die Zieladresse ist ff02::1.

Kommen Sie raus in das Internet? Was ist dazu noch erforderlich?

```

1 praktikum@rn05:~$ ping google.com
2 PING google.com(fra24s06-in-x0e.1e100.net (2a00:1450:4001:829::200e))
   56 data bytes
3 64 bytes from fra24s06-in-x0e.1e100.net (2a00:1450:4001:829::200e):
   icmp_seq=1 ttl=117 time=55.7 ms
4 ^C
5 --- google.com ping statistics ---
6 1 packets transmitted, 1 received, 0% packet loss, time 0ms
7 rtt min/avg/max/mdev = 55.651/55.651/55.651/0.000 ms
8 praktikum@rn05:~$ sudo ip addr del 141.62.66.5/24 dev enp0s31f6
9 praktikum@rn05:~$ ip a
10 1: lo: <LOOPBACK,UP,LOWER_UP> mtu 65536 qdisc noqueue state UNKNOWN
   group default qlen 1000
   link/loopback 00:00:00:00:00:00 brd 00:00:00:00:00:00
   inet 127.0.0.1/8 scope host lo
       valid_lft forever preferred_lft forever
   inet6 ::1/128 scope host
       valid_lft forever preferred_lft forever
16 2: enp0s31f6: <BROADCAST,MULTICAST,UP,LOWER_UP> mtu 1500 qdisc
   pfifo_fast state UP group default qlen 1000
   link/ether 4c:52:62:0e:54:8b brd ff:ff:ff:ff:ff:ff
   inet6 2001:470:6d:4d0:4e52:62ff:fe0e:548b/64 scope global dynamic
       mngtmpaddr
       valid_lft 86055sec preferred_lft 14055sec
19

```

```
20     inet6 fe80::4e52:62ff:fe0e:548b/64 scope link
21     valid_lft forever preferred_lft forever
22 praktikum@rn05:~$ ping 8.8.8.8
23 ping: connect: Network is unreachable
24 praktikum@rn05:~$ ping google.com
25 ping: google.com: Name or service not known
26 praktikum@rn05:~$ ping6 2a00:1450:4001:829::200e
27 PING 2a00:1450:4001:829::200e(2a00:1450:4001:829::200e) 56 data bytes
28 64 bytes from 2a00:1450:4001:829::200e: icmp_seq=1 ttl=117 time=55.9 ms
29 64 bytes from 2a00:1450:4001:829::200e: icmp_seq=2 ttl=117 time=56.0 ms
30 ^C
31 --- 2a00:1450:4001:829::200e ping statistics ---
32 2 packets transmitted, 2 received, 0% packet loss, time 1001ms
33 rtt min/avg/max/mdev = 55.925/55.962/56.000/0.037 ms
```

Wie zu erkennen ist, können DNS-Requests noch nicht beantwortet werden (`sudo ip addr del 141.62.66.5/24 dev enp0s31f6` deaktiviert hier IPv6), wird jedoch die IPv6-Adresse `2a00:1450:4001:829::200e` direkt verwendet, so kann eine direkte Verbindung (hier z.B. zu Google) aufgebaut werden. Um das Internet jedoch im vollem Umfang nutzen zu können, muss noch ein IPv6-fähiger Nameserver eingerichtet werden.

Rufen Sie die Webseite www.kame.net mittels IPv6-Adresse auf (kame.net ist manchmal instabil, alternativ versuchen Sie ipv6.google.com)

Zuerst wurde ein IPv6-fähiger Nameserver eingerichtet und getestet:

```
1 $ cat /etc/resolv.conf
2 nameserver 2001:4860:4860::8888
3 $ ping6 2001:4860:4860::8888
4 PING 2001:4860:4860::8888(2001:4860:4860::8888) 56 data bytes
5 64 bytes from 2001:4860:4860::8888: icmp_seq=1 ttl=119 time=34.1 ms
6 ^C
7 --- 2001:4860:4860::8888 ping statistics ---
8 1 packets transmitted, 1 received, 0% packet loss, time 0ms
9 rtt min/avg/max/mdev = 34.118/34.118/34.118/0.000 ms
10 $ dig @2001:4860:4860::8888 +noall +answer google.com AAAA
11 google.com.      300 IN  AAAA      2a00:1450:4005:802::200e
12 $ dig +noall +answer google.com AAAA
13 google.com.      300 IN  AAAA      2a00:1450:4005:802::200e
14 $ ping google.com
15 PING google.com(ham02s21-in-x0e.1e100.net (2a00:1450:4005:802::200e))
16 56 data bytes
17 64 bytes from ham02s21-in-x0e.1e100.net (2a00:1450:4005:802::200e):
18 icmp_seq=1 ttl=119 time=26.5 ms
19 ^C
20 --- google.com ping statistics ---
21 1 packets transmitted, 1 received, 0% packet loss, time 0ms
22 rtt min/avg/max/mdev = 26.463/26.463/26.463/0.000 ms
```

www.kame.net zeigt eine drehende Schildkröte:

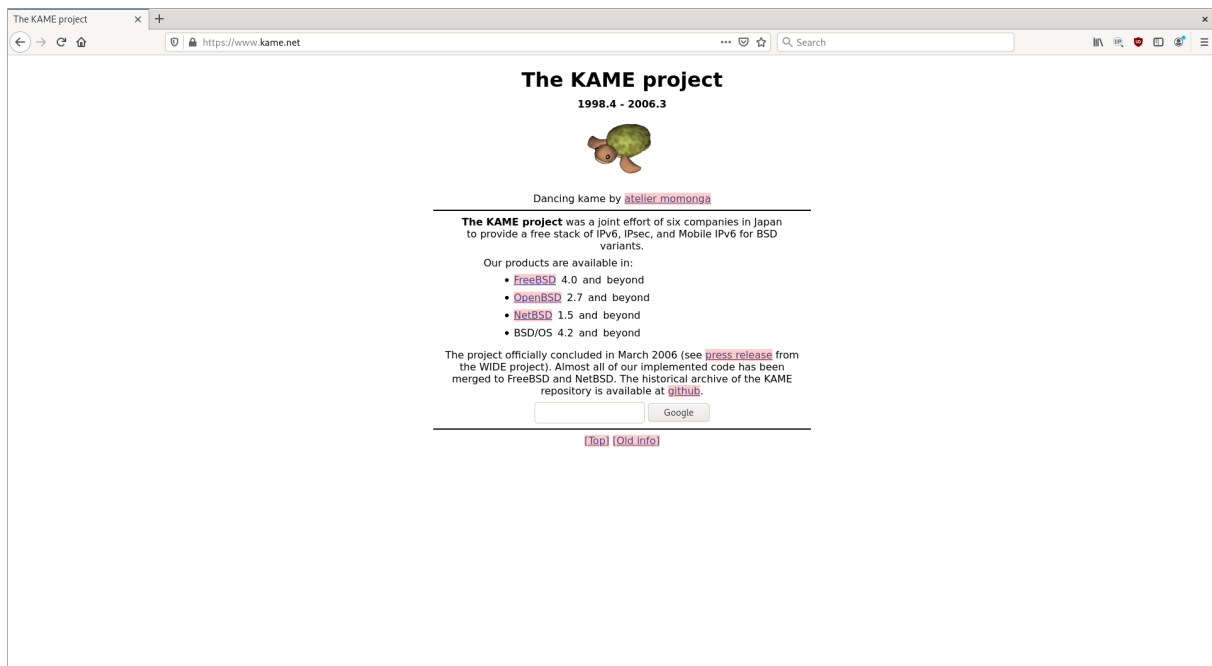


Abbildung 7: Firefox stellt www.kame.net dar

Mit welcher IPv6-Adresse sie im Netz unterwegs sind, zeigt die Seite <http://www.heise.de/netze/tools/meine-ip-adresse> an

Wir haben hierzu den Dienst ifconfig.io verwendet.

```
1 $ curl https://ifconfig.io
2 2001:470:6d:4d0:4e52:62ff:fe0e:548b
```

Welche IPv6-Adresse hat <http://www.google.com>?

```
1 $ dig +noall +answer google.com AAAA
2 google.com.      300 IN  AAAA    2a00:1450:4005:802::200e
```

Was ist das besondere an der IPv6-Adresse von Facebook?

```
1 $ dig +noall +answer facebook.com AAAA
2 facebook.com.    300 IN  AAAA    2a03:2880:f131:83:face:b00c:0:25de
```

Facebook hat das 5. und 6. Hextet **face** und **b00c**, als Anspielung zum Firmennamen, in deren IPv6-Adresse.

Lösen Sie mittels nslookup oder dig die URL openldap.org in die IPv6-Adresse auf!

```
1 $ dig +noall +answer openldap.org AAAA
2 openldap.org.    300 IN  AAAA    2600:3c00:e000:2d3::1
```

4 Neighbor Solicitation

Starten Sie den „Kabelhai“ und pingen Sie ihren Nachbarrechner. Welches Protokoll/Type wird anstatt ARP zur Ermittlung der MAC-Adressen verwendet?

```

1 $ sudo ip neigh flush dev enp0s31f6
2 $ ping6 fe80::fad1:11ff:febd:6612
3 PING fe80::fad1:11ff:febd:6612(fe80::fad1:11ff:febd:6612) 56 data bytes
4 64 bytes from fe80::fad1:11ff:febd:6612%enp0s31f6: icmp_seq=1 ttl=255
   time=0.568 ms
5 ^C
6 --- fe80::fad1:11ff:febd:6612 ping statistics ---
7 1 packets transmitted, 1 received, 0% packet loss, time 0ms
8 rtt min/avg/max/mdev = 0.568/0.568/0.568/0.000 ms

```

The screenshot shows a Wireshark packet capture on interface enp0s31f6. The packet list displays several ICMPv6 packets. The first packet (No. 25) is a Neighbor Solicitation from fe80::4e52:02ff:fe0e:542b to ff02::1:ffbd:6612. The second packet (No. 26) is a Neighbor Solicitation from fe80::4e52:02ff:fe0e:542b to ff02::1:ffbd:6612. The third packet (No. 30) is a Neighbor Solicitation from fe80::fad1:11ff:febd:6612 to ff02::1:ffbf:c99f. The fourth packet (No. 33) is a Neighbor Solicitation from fe80::4e52:02ff:fe0e:540b to ff02::1:ffbd:6612. The fifth packet (No. 34) is a Neighbor Advertisement from fe80::fad1:11ff:febd:6612 to fe80::4e52:02ff:fe0e:540b. The sixth packet (No. 35) is a Neighbor Advertisement from fe80::4e52:02ff:fe0e:540b to fe80::fad1:11ff:febd:6612. The seventh packet (No. 36) is an Echo (ping) request from fe80::4e52:02ff:fe0e:540b to fe80::fad1:11ff:febd:6612. The eighth packet (No. 37) is an Echo (ping) reply from fe80::fad1:11ff:febd:6612 to fe80::4e52:02ff:fe0e:540b. The ninth packet (No. 38) is a Neighbor Solicitation from fe80::4e52:02ff:fe0e:540b to ff02::1:ffbd:6612. The tenth packet (No. 41) is a Neighbor Advertisement from fe80::4e52:02ff:fe0e:540b to fe80::fad1:11ff:febd:6612. The eleventh packet (No. 42) is a Neighbor Advertisement from fe80::4e52:02ff:fe0e:540b to fe80::fad1:11ff:febd:6612. The twelfth packet (No. 44) is a Neighbor Solicitation from fe80::4e52:02ff:fe0e:542b to ff02::1:ffbd:6612. The thirteenth packet (No. 56) is a Neighbor Solicitation from fe80::fad1:11ff:febd:6612 to ff02::1:ffbd:6612. The fourteenth packet (No. 57) is a Neighbor Advertisement from fe80::4e52:02ff:fe0e:540b to fe80::fad1:11ff:febd:6612. The fifteenth packet (No. 59) is a Neighbor Solicitation from fe80::4e52:02ff:fe0e:542b to ff02::1:ffbd:6612.

No.	Time	Source	Destination	Protocol	Length	Info
25	8.062806299	fe80::4e52:02ff:fe0e:542b	ff02::1:ffbd:6612	ICMPv6	86	Neighbor Solicitation for fe80::fad1:11ff:febd:6612 from 4c:52:02:0e:54:2b
26	8.050300016	fe80::4e52:02ff:fe0e:542b	ff02::1:ffbd:6612	ICMPv6	86	Neighbor Solicitation for fe80::fad1:11ff:febd:6612 from 4c:52:02:0e:54:2b
30	9.919313755	fe80::fad1:11ff:febd:6612	ff02::1:ffbf:c99f	ICMPv6	86	Neighbor Solicitation for 2001:470:6d:400:b931:b02b:e5bf:c99f from f8:d1:11:bd:66:12
33	12.975880193	fe80::4e52:02ff:fe0e:540b	ff02::1:ffbd:6612	ICMPv6	86	Neighbor Solicitation for fe80::fad1:11ff:febd:6612 from 4c:52:02:0e:54:0b
34	12.976149355	fe80::fad1:11ff:febd:6612	fe80::4e52:02ff:fe0e:540b	ICMPv6	86	Neighbor Advertisement fe80::fad1:11ff:febd:6612 (rtr, sol, ovr) is at f8:d1:11:bd:66:12
35	12.976174889	fe80::4e52:02ff:fe0e:540b	fe80::fad1:11ff:febd:6612	ICMPv6	118	Echo (ping) request id=8x87dc, seq=1, hop limit=64 (reply in 36)
36	12.976300763	fe80::fad1:11ff:febd:6612	fe80::4e52:02ff:fe0e:540b	ICMPv6	118	Echo (ping) reply id=8x87dc, seq=1, hop limit=255 (request in 35)
37	12.977278184	fe80::fad1:11ff:febd:6612	2001:470:6d:400:4e5:2ff:fe0e:540b	ICMPv6	86	Neighbor Solicitation for 2001:470:6d:400:4e5:2ff:fe0e:540b from f8:d1:11:bd:66:12
38	12.977305236	2001:470:6d:400:4e5:2ff:fe0e:540b	fe80::fad1:11ff:febd:6612	ICMPv6	78	Neighbor Advertisement 2001:470:6d:400:4e5:2ff:fe0e:540b (sol)
41	17.977394043	fe80::4e52:02ff:fe0e:540b	fe80::fad1:11ff:febd:6612	ICMPv6	86	Neighbor Solicitation for fe80::4e52:02ff:fe0e:540b from f8:d1:11:bd:66:12
42	17.977432122	fe80::4e52:02ff:fe0e:540b	fe80::fad1:11ff:febd:6612	ICMPv6	78	Neighbor Advertisement fe80::4e52:02ff:fe0e:540b (sol)
44	20.059815013	fe80::4e52:02ff:fe0e:542b	ff02::1:ffbd:6612	ICMPv6	86	Neighbor Solicitation for fe80::fad1:11ff:febd:6612 from 4c:52:02:0e:54:2b
56	34.797401538	fe80::fad1:11ff:febd:6612	2001:470:6d:400:4e5:2ff:fe0e:540b	ICMPv6	86	Neighbor Solicitation for 2001:470:6d:400:4e5:2ff:fe0e:540b from f8:d1:11:bd:66:12
57	34.797438306	2001:470:6d:400:4e5:2ff:fe0e:540b	fe80::fad1:11ff:febd:6612	ICMPv6	78	Neighbor Advertisement 2001:470:6d:400:4e5:2ff:fe0e:540b (sol)
59	38.051559696	fe80::4e52:02ff:fe0e:542b	ff02::1:ffbd:6612	ICMPv6	86	Neighbor Solicitation for fe80::fad1:11ff:febd:6612 from 4c:52:02:0e:54:2b

Abbildung 8: Solicitation und Advertisement-Pakete in Wireshark

Hier wird ICMPv6 mit den Types Neighbor Solicitation und Neighbor Advertisement verwendet.

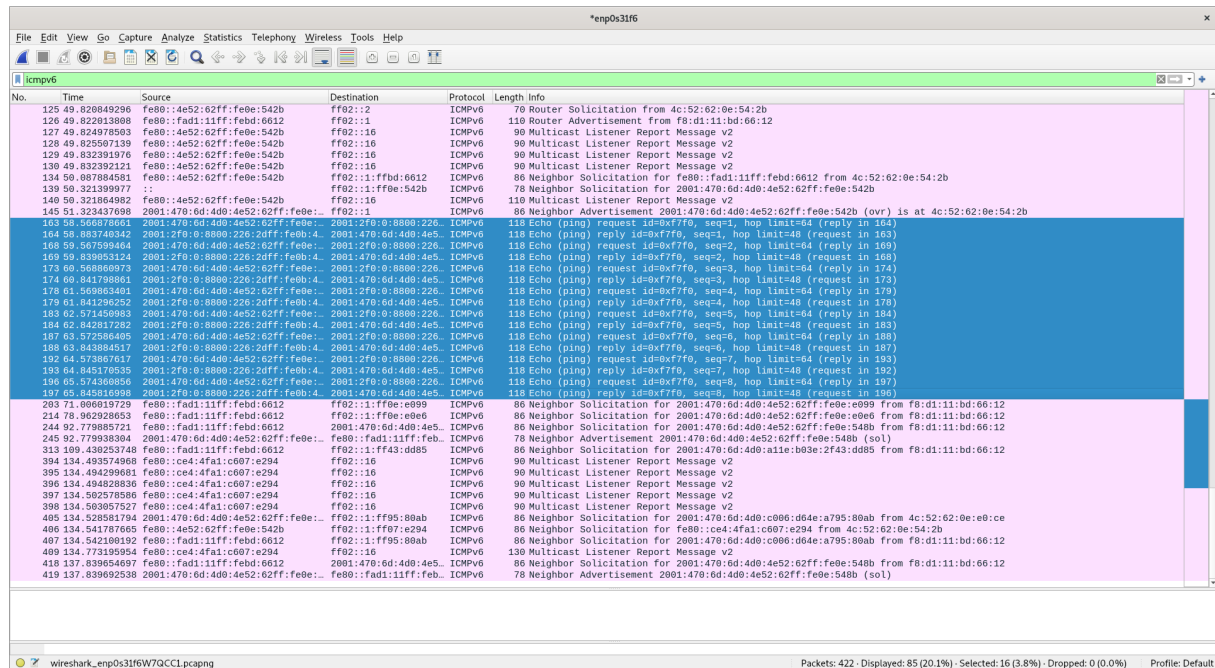
Welche Zieladresse wird im ersten Neighbor-Paket verwendet und um welchen Adresstyp handelt es sich?

Es wird eine Multicast-Adresse (ff02::1:ffbd:6612) verwendet.

5 IPv6-Header

Starten Sie Wireshark und senden sie ein ping an einen IPv6-fähigen Webserver (www.ix.de, http://www.heise.de, http://www.kame.net), stoppen Sie Wireshark und schauen sich den Trace an.

```
1 $ ping www.kame.net
2 PING www.kame.net(2001:2f0:0:8800:226:2dff:fe0b:4311 (2001:2f0
  :0:8800:226:2dff:fe0b:4311)) 56 data bytes
3 64 bytes from 2001:2f0:0:8800:226:2dff:fe0b:4311 (2001:2f0:0:8800:226:2
  dff:fe0b:4311): icmp_seq=1 ttl=48 time=317 ms
4 64 bytes from 2001:2f0:0:8800:226:2dff:fe0b:4311 (2001:2f0:0:8800:226:2
  dff:fe0b:4311): icmp_seq=2 ttl=48 time=271 ms
5 64 bytes from 2001:2f0:0:8800:226:2dff:fe0b:4311 (2001:2f0:0:8800:226:2
  dff:fe0b:4311): icmp_seq=3 ttl=48 time=273 ms
6 64 bytes from 2001:2f0:0:8800:226:2dff:fe0b:4311 (2001:2f0:0:8800:226:2
  dff:fe0b:4311): icmp_seq=4 ttl=48 time=271 ms
7 64 bytes from 2001:2f0:0:8800:226:2dff:fe0b:4311 (2001:2f0:0:8800:226:2
  dff:fe0b:4311): icmp_seq=5 ttl=48 time=271 ms
8 64 bytes from 2001:2f0:0:8800:226:2dff:fe0b:4311 (2001:2f0:0:8800:226:2
  dff:fe0b:4311): icmp_seq=6 ttl=48 time=271 ms
9 64 bytes from 2001:2f0:0:8800:226:2dff:fe0b:4311 (2001:2f0:0:8800:226:2
  dff:fe0b:4311): icmp_seq=7 ttl=48 time=271 ms
10 64 bytes from 2001:2f0:0:8800:226:2dff:fe0b:4311 (2001:2f0:0:8800:226:2
  dff:fe0b:4311): icmp_seq=8 ttl=48 time=272 ms
11 ^C
12 --- www.kame.net ping statistics ---
13 8 packets transmitted, 8 received, 0% packet loss, time 7008ms
14 rtt min/avg/max/mdev = 271.343/277.307/316.896/14.971 ms
```

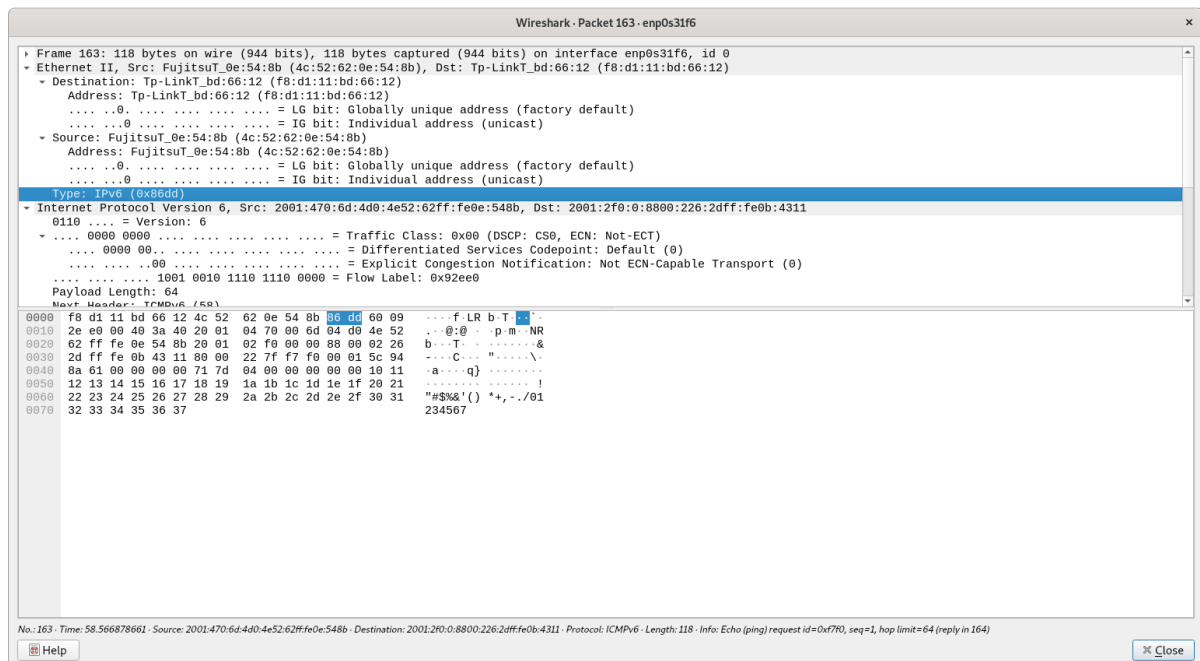


The screenshot shows a Wireshark packet capture on interface enp0s31f6. The packet list displays 422 packets, with 85 displayed (20.1%). The selected packet is packet 163, an ICMPv6 Echo (ping) request from 2001:470:6d:4d0:4e52:62ff:fe0e:548b to 2001:2f0:0:8800:226:2dff:fe0b:4311. The packet details pane shows the Ethernet II header and the ICMPv6 Echo (ping) request. The packet bytes pane shows the raw data of the packet, including the Ethernet II header and the ICMPv6 Echo (ping) request.

No.	Time	Source	Destination	Protocol	Length	Info
125	49.829849296	fe80::4e52:62ff:fe0e:542b	ff02::2	ICMPv6	70	Router Solicitation from 4c:52:62:0e:54:2b
126	49.829813868	fe80::fad1:11ff:febd:6612	ff02::1	ICMPv6	118	Router Advertisement from f8:d1:11:bd:66:12
127	49.829878503	fe80::4e52:62ff:fe0e:542b	ff02::16	ICMPv6	90	Multicast Listener Report Message v2
128	49.825507139	fe80::4e52:62ff:fe0e:542b	ff02::16	ICMPv6	90	Multicast Listener Report Message v2
129	49.832391976	fe80::4e52:62ff:fe0e:542b	ff02::16	ICMPv6	90	Multicast Listener Report Message v2
130	49.832392111	fe80::4e52:62ff:fe0e:542b	ff02::16	ICMPv6	90	Multicast Listener Report Message v2
134	50.087884581	fe80::4e52:62ff:fe0e:542b	ff02::1:ffbd:6612	ICMPv6	86	Neighbor Solicitation for fe80::fad1:11ff:febd:6612 from 4c:52:62:0e:54:2b
139	50.321399977	:	ff02::1:ffbd:6612	ICMPv6	78	Neighbor Solicitation for 2001:470:6d:4d0:4e52:62ff:fe0e:542b
140	50.321064982	fe80::4e52:62ff:fe0e:542b	ff02::16	ICMPv6	118	Multicast Listener Report Message v2
145	51.3234337698	2001:470:6d:4d0:4e52:62ff:fe0e:542b	ff02::1	ICMPv6	86	Neighbor Advertisement 2001:470:6d:4d0:4e52:62ff:fe0e:542b (ovr) is at 4c:52:62:0e:54:2b
163	58.566878661	2001:470:6d:4d0:4e52:62ff:fe0e:548b	2001:2f0:0:8800:226:2dff:fe0b:4311	ICMPv6	118	Echo (ping) request id=0xf7f0, seq=1, hop limit=64 (reply in 164)
164	58.883748342	2001:2f0:0:8800:226:2dff:fe0b:4311	2001:470:6d:4d0:4e52:62ff:fe0e:548b	ICMPv6	118	Echo (ping) reply id=0xf7f0, seq=1, hop limit=64 (request in 163)
168	59.507599404	2001:470:6d:4d0:4e52:62ff:fe0e:548b	2001:2f0:0:8800:226:2dff:fe0b:4311	ICMPv6	118	Echo (ping) request id=0xf7f0, seq=2, hop limit=64 (reply in 168)
169	59.839053124	2001:2f0:0:8800:226:2dff:fe0b:4311	2001:470:6d:4d0:4e52:62ff:fe0e:548b	ICMPv6	118	Echo (ping) reply id=0xf7f0, seq=2, hop limit=64 (request in 168)
173	60.568080973	2001:470:6d:4d0:4e52:62ff:fe0e:548b	2001:2f0:0:8800:226:2dff:fe0b:4311	ICMPv6	118	Echo (ping) request id=0xf7f0, seq=3, hop limit=64 (reply in 174)
174	60.841786051	2001:2f0:0:8800:226:2dff:fe0b:4311	2001:470:6d:4d0:4e52:62ff:fe0e:548b	ICMPv6	118	Echo (ping) reply id=0xf7f0, seq=3, hop limit=64 (request in 173)
178	61.569803491	2001:470:6d:4d0:4e52:62ff:fe0e:548b	2001:2f0:0:8800:226:2dff:fe0b:4311	ICMPv6	118	Echo (ping) request id=0xf7f0, seq=4, hop limit=64 (reply in 179)
179	61.84126252	2001:2f0:0:8800:226:2dff:fe0b:4311	2001:470:6d:4d0:4e52:62ff:fe0e:548b	ICMPv6	118	Echo (ping) reply id=0xf7f0, seq=4, hop limit=64 (request in 178)
183	62.571459883	2001:470:6d:4d0:4e52:62ff:fe0e:548b	2001:2f0:0:8800:226:2dff:fe0b:4311	ICMPv6	118	Echo (ping) request id=0xf7f0, seq=5, hop limit=64 (reply in 184)
184	62.843917252	2001:2f0:0:8800:226:2dff:fe0b:4311	2001:470:6d:4d0:4e52:62ff:fe0e:548b	ICMPv6	118	Echo (ping) reply id=0xf7f0, seq=5, hop limit=64 (request in 183)
187	63.572586495	2001:470:6d:4d0:4e52:62ff:fe0e:548b	2001:2f0:0:8800:226:2dff:fe0b:4311	ICMPv6	118	Echo (ping) request id=0xf7f0, seq=6, hop limit=64 (reply in 188)
188	63.843884517	2001:2f0:0:8800:226:2dff:fe0b:4311	2001:470:6d:4d0:4e52:62ff:fe0e:548b	ICMPv6	118	Echo (ping) reply id=0xf7f0, seq=6, hop limit=64 (request in 187)
192	64.573807617	2001:470:6d:4d0:4e52:62ff:fe0e:548b	2001:2f0:0:8800:226:2dff:fe0b:4311	ICMPv6	118	Echo (ping) request id=0xf7f0, seq=7, hop limit=64 (reply in 193)
193	64.845176535	2001:2f0:0:8800:226:2dff:fe0b:4311	2001:470:6d:4d0:4e52:62ff:fe0e:548b	ICMPv6	118	Echo (ping) reply id=0xf7f0, seq=7, hop limit=64 (request in 192)
196	65.574368856	2001:470:6d:4d0:4e52:62ff:fe0e:548b	2001:2f0:0:8800:226:2dff:fe0b:4311	ICMPv6	118	Echo (ping) request id=0xf7f0, seq=8, hop limit=64 (reply in 197)
197	65.845102920	2001:2f0:0:8800:226:2dff:fe0b:4311	2001:470:6d:4d0:4e52:62ff:fe0e:548b	ICMPv6	118	Echo (ping) reply id=0xf7f0, seq=8, hop limit=64 (request in 196)
283	71.090619729	fe80::fad1:11ff:febd:6612	ff02::1:ffbd:e099	ICMPv6	86	Neighbor Solicitation for 2001:470:6d:4d0:4e52:62ff:fe0e:e099 from f8:d1:11:bd:66:12
214	78.962928653	fe80::fad1:11ff:febd:6612	ff02::1:ffbd:e0e6	ICMPv6	86	Neighbor Solicitation for 2001:470:6d:4d0:4e52:62ff:fe0e:e0e6 from f8:d1:11:bd:66:12
244	77.99885721	fe80::fad1:11ff:febd:6612	2001:470:6d:4d0:4e52:62ff:fe0e:548b	ICMPv6	86	Neighbor Solicitation for 2001:470:6d:4d0:4e52:62ff:fe0e:548b from f8:d1:11:bd:66:12
245	92.779398304	2001:470:6d:4d0:4e52:62ff:fe0e:548b	fe80::fad1:11ff:febd:6612	ICMPv6	78	Neighbor Solicitation for 2001:470:6d:4d0:4e52:62ff:fe0e:548b (sol)
313	109.430253748	fe80::fad1:11ff:febd:6612	ff02::1:ff43:d885	ICMPv6	86	Neighbor Solicitation for 2001:470:6d:4d0:4e52:62ff:fe0e:548b from f8:d1:11:bd:66:12
394	134.493574968	fe80::ce4:4fa1:c007:e294	ff02::16	ICMPv6	90	Multicast Listener Report Message v2
395	134.494299681	fe80::ce4:4fa1:c007:e294	ff02::16	ICMPv6	90	Multicast Listener Report Message v2
396	134.494828836	fe80::ce4:4fa1:c007:e294	ff02::16	ICMPv6	90	Multicast Listener Report Message v2
397	134.502578586	fe80::ce4:4fa1:c007:e294	ff02::16	ICMPv6	90	Multicast Listener Report Message v2
398	134.503657527	fe80::ce4:4fa1:c007:e294	ff02::16	ICMPv6	90	Multicast Listener Report Message v2
405	134.520881794	2001:470:6d:4d0:4e52:62ff:fe0e:548b	ff02::1:ff95:80ab	ICMPv6	86	Neighbor Solicitation for 2001:470:6d:4d0:4e52:62ff:fe0e:548b from 4c:52:62:0e:54:2b
406	134.541787655	fe80::4e52:62ff:fe0e:542b	ff02::1:ff95:80ab	ICMPv6	86	Neighbor Solicitation for fe80::ce4:4fa1:c007:e294 from 4c:52:62:0e:54:2b
407	134.542108192	fe80::fad1:11ff:febd:6612	ff02::1:ff95:80ab	ICMPv6	86	Neighbor Solicitation for 2001:470:6d:4d0:4e52:62ff:fe0e:548b from f8:d1:11:bd:66:12
409	134.731993954	fe80::ce4:4fa1:c007:e294	ff02::16	ICMPv6	90	Multicast Listener Report Message v2
418	137.839654697	fe80::fad1:11ff:febd:6612	2001:470:6d:4d0:4e52:62ff:fe0e:548b	ICMPv6	86	Neighbor Solicitation for 2001:470:6d:4d0:4e52:62ff:fe0e:548b from f8:d1:11:bd:66:12
419	137.839629238	2001:470:6d:4d0:4e52:62ff:fe0e:548b	fe80::fad1:11ff:febd:6612	ICMPv6	78	Neighbor Advertisement 2001:470:6d:4d0:4e52:62ff:fe0e:548b (sol)

Abbildung 9: Packets, welche in Wireshark gecaptured wurden

Wodurch wird im Ethernet-Frame auf das eingepackte IPv6 hingewiesen?



The screenshot shows the packet details for packet 163. The Ethernet II header is expanded, showing the destination and source MAC addresses. The ICMPv6 Echo (ping) request is also expanded, showing the request ID, sequence number, and hop limit. The packet bytes pane shows the raw data of the packet, including the Ethernet II header and the ICMPv6 Echo (ping) request.

Frame 163: 118 bytes on wire (944 bits), 118 bytes captured (944 bits) on interface enp0s31f6, id 0
Ethernet II, Src: FujitsuT_0e:54:8b (4c:52:62:0e:54:8b), Dst: Tp-LinkT_bd:66:12 (f8:d1:11:bd:66:12)
Destination: Tp-LinkT_bd:66:12 (f8:d1:11:bd:66:12)
Address: Tp-LinkT_bd:66:12 (f8:d1:11:bd:66:12)
.....0..... = LG bit: Globally unique address (factory default)
.....0..... = IG bit: Individual address (unicast)
Source: FujitsuT_0e:54:8b (4c:52:62:0e:54:8b)
Address: FujitsuT_0e:54:8b (4c:52:62:0e:54:8b)
.....0..... = LG bit: Globally unique address (factory default)
.....0..... = IG bit: Individual address (unicast)
Internet Protocol Version 6, Src: 2001:470:6d:4d0:4e52:62ff:fe0e:548b, Dst: 2001:2f0:0:8800:226:2dff:fe0b:4311
0110..... = Version: 6
.....0000 0000..... = Traffic Class: 0x00 (DSCP: CS0, ECN: Not-ECT)
.....0000 00..... = Differentiated Services Codepoint: Default (0)
.....00..... = Explicit Congestion Notification: Not ECN-Capable Transport (0)
.....1001 0010 1110 1110 0000 = Flow Label: 0x92ee0
Payload Length: 64
0000 f8 d1 11 bd 66 12 4c 52 62 0e 54 8b 86 d6 60 09f LR b-T..
0010 2e 00 00 40 3a 40 20 01 04 70 00 6d 04 d0 4e 52 ...@...p.m.NR
0020 62 ff fe 0e 54 8b 20 01 02 f0 00 00 88 00 02 26 b-T...&
0030 2d ff fe 0b 43 11 80 00 22 7f f7 f0 00 01 5c 94 ...C...\"
0040 8a 61 00 00 00 00 71 7d 04 00 00 00 00 00 10 11 -a...q.....
0050 12 13 1d 1e 1f 19 1a 1b 1c 1d 1e 1f 20 21I
0060 22 23 24 25 26 27 28 29 2a 2b 2c 2d 2e 2f 30 31 \"#\$%&'()*+,-./01
0070 32 33 34 35 36 37 234567

Abbildung 10: IPv6-Protokoll-Typ in Wireshark

Der Type IPv6 im Ethernet-Frame lässt auf das “eingepackte” IPv6 schließen.

Welche Bedeutung haben folgende Felder des IPv6-Headers und gibt es Entsprechungen in IPv4?

TODO: Add information about different header fields.

	Version	Traffic	Class	Flow	Label	Payload	Length	Hop Limit
IPv6								
IPv4								

Senden Sie nun ein 5000 Byte großes Paket vom Windows-PC an den Ubuntu-PC und schauen sich die Abfolge der Pakete an

```
1 # TODO: Add command with `~l 5000` flag
```

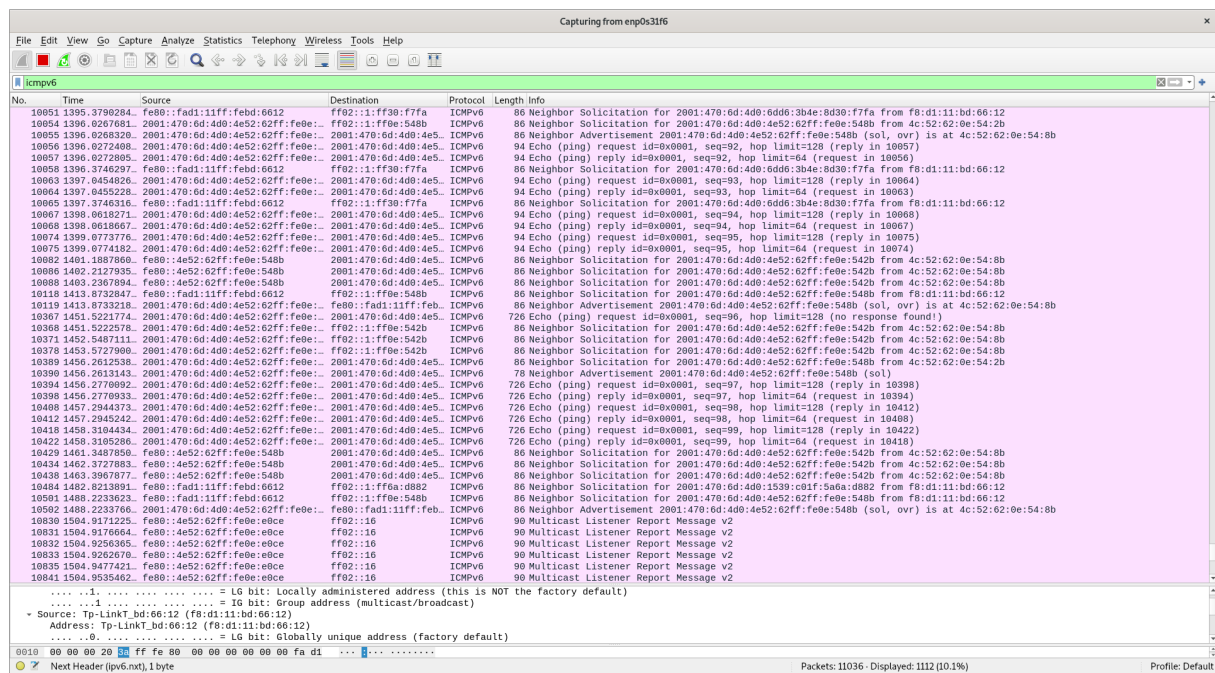


Abbildung 11: Capture der Packets

Welcher Wert taucht im Next-Header-Feld Ihres IPv6 Headers auf?

Hier tauch der Fragment-Header auf.

No.	Time	Source	Destination	Protocol	Length	Info
10888	1493.2367894	fe80::4e52:62ff:fe0e:548b	2001:470:6d:400:4e52:62ff:fe0e:542b	ICMPv6	86	Neighbor Solicitation for 2001:470:6d:400:4e52:62ff:fe0e:542b from 4c:52:62:0e:54:8b
10118	1413.8732847	fe80::fad1:11ff:febd:6612	ff02::1:fffe:548b	ICMPv6	86	Neighbor Solicitation for 2001:470:6d:400:4e52:62ff:fe0e:548b from f8:d1:11:bd:66:12
10119	1413.8733216	2001:470:6d:400:4e52:62ff:fe0e:548b	fe80::fad1:11ff:febd:6612	ICMPv6	86	Neighbor Advertisement 2001:470:6d:400:4e52:62ff:fe0e:548b (sol, ovf) is at 4c:52:62:0e:54:8b
10367	1451.5221774	2001:470:6d:400:4e52:62ff:fe0e:548b	2001:470:6d:400:4e52:62ff:fe0e:542b	ICMPv6	726	Echo (ping) request id=0x0001, seq=96, hop limit=128 (no response found!)
10368	1451.5222578	2001:470:6d:400:4e52:62ff:fe0e:542b	ff02::1:fffe:542b	ICMPv6	86	Neighbor Solicitation for 2001:470:6d:400:4e52:62ff:fe0e:542b from 4c:52:62:0e:54:8b
10371	1452.5487111	2001:470:6d:400:4e52:62ff:fe0e:542b	ff02::1:fffe:542b	ICMPv6	86	Neighbor Solicitation for 2001:470:6d:400:4e52:62ff:fe0e:542b from 4c:52:62:0e:54:8b
10378	1453.5727980	2001:470:6d:400:4e52:62ff:fe0e:542b	ff02::1:fffe:542b	ICMPv6	86	Neighbor Solicitation for 2001:470:6d:400:4e52:62ff:fe0e:542b from 4c:52:62:0e:54:8b
10389	1456.2612538	2001:470:6d:400:4e52:62ff:fe0e:548b	2001:470:6d:400:4e52:62ff:fe0e:542b	ICMPv6	86	Neighbor Solicitation for 2001:470:6d:400:4e52:62ff:fe0e:548b from 4c:52:62:0e:54:2b
10390	1456.2613143	2001:470:6d:400:4e52:62ff:fe0e:548b	2001:470:6d:400:4e52:62ff:fe0e:548b	ICMPv6	78	Neighbor Advertisement 2001:470:6d:400:4e52:62ff:fe0e:548b (sol)
10394	1456.2770092	2001:470:6d:400:4e52:62ff:fe0e:548b	2001:470:6d:400:4e52:62ff:fe0e:542b	ICMPv6	726	Echo (ping) request id=0x0001, seq=97, hop limit=128 (reply in 10398)
10398	1456.2770933	2001:470:6d:400:4e52:62ff:fe0e:542b	2001:470:6d:400:4e52:62ff:fe0e:548b	ICMPv6	726	Echo (ping) reply id=0x0001, seq=97, hop limit=64 (request in 10394)
10408	1457.2944373	2001:470:6d:400:4e52:62ff:fe0e:548b	2001:470:6d:400:4e52:62ff:fe0e:542b	ICMPv6	726	Echo (ping) request id=0x0001, seq=98, hop limit=128 (reply in 10412)
10412	1457.2945242	2001:470:6d:400:4e52:62ff:fe0e:548b	2001:470:6d:400:4e52:62ff:fe0e:542b	ICMPv6	726	Echo (ping) reply id=0x0001, seq=98, hop limit=64 (request in 10408)
10418	1458.3104434	2001:470:6d:400:4e52:62ff:fe0e:548b	2001:470:6d:400:4e52:62ff:fe0e:542b	ICMPv6	726	Echo (ping) request id=0x0001, seq=99, hop limit=128 (reply in 10422)
10422	1458.3105286	2001:470:6d:400:4e52:62ff:fe0e:548b	2001:470:6d:400:4e52:62ff:fe0e:542b	ICMPv6	726	Echo (ping) reply id=0x0001, seq=99, hop limit=64 (request in 10418)
10429	1461.3407850	fe80::4e52:62ff:fe0e:548b	2001:470:6d:400:4e52:62ff:fe0e:542b	ICMPv6	86	Neighbor Solicitation for 2001:470:6d:400:4e52:62ff:fe0e:542b from 4c:52:62:0e:54:8b
10434	1462.3727883	fe80::4e52:62ff:fe0e:548b	2001:470:6d:400:4e52:62ff:fe0e:542b	ICMPv6	86	Neighbor Solicitation for 2001:470:6d:400:4e52:62ff:fe0e:542b from 4c:52:62:0e:54:8b
10438	1463.3967877	fe80::4e52:62ff:fe0e:548b	2001:470:6d:400:4e52:62ff:fe0e:542b	ICMPv6	86	Neighbor Solicitation for 2001:470:6d:400:4e52:62ff:fe0e:542b from 4c:52:62:0e:54:8b
10484	1482.8213891	fe80::fad1:11ff:febd:6612	ff02::1:fffa:d882	ICMPv6	86	Neighbor Solicitation for 2001:470:6d:400:1539:c01f:5a6a:d882 from f8:d1:11:bd:66:12
10491	1488.2233603	fe80::fad1:11ff:febd:6612	ff02::1:fffe:548b	ICMPv6	86	Neighbor Solicitation for 2001:470:6d:400:4e52:62ff:fe0e:548b from f8:d1:11:bd:66:12

Frame 10398: 726 bytes on wire (5808 bits), 726 bytes captured on interface enp0s31f6, id 0

Ethernet II, Src: FujitsuT_0e:54:8b (4c:52:62:0e:54:8b), Dst: FujitsuT_0e:54:2b (4c:52:62:0e:54:2b)

- Destination: FujitsuT_0e:54:2b (4c:52:62:0e:54:2b)
 - Address: FujitsuT_0e:54:2b (4c:52:62:0e:54:2b)
 -0. = LG bit: Globally unique address (factory default)
 -0. = IG bit: Individual address (unicast)
- Source: FujitsuT_0e:54:8b (4c:52:62:0e:54:8b)
 - Address: FujitsuT_0e:54:8b (4c:52:62:0e:54:8b)
 -0. = LG bit: Globally unique address (factory default)
 -0. = IG bit: Individual address (unicast)

Type: IPv6 (0x86dd)

Internet Protocol Version 6, Src: 2001:470:6d:400:4e52:62ff:fe0e:548b, Dst: 2001:470:6d:400:4e52:62ff:fe0e:542b

8100 = Version: 6

....0000 0000 = Traffic Class: 0x00 (DSCP: CS0, ECN: Not-ECT)

....0000 00. = Differentiated Services Codepoint: Default (0)

....0. = Explicit Congestion Notification: Not ECN-Capable Transport (0)

.... 1110 1010 1010 0000 = Flow Label: 0xaaaa

Payload Length: 672

Next Header: Fragment Header for IPv6 (44)

Hop Limit: 64

Source Address: 2001:470:6d:400:4e52:62ff:fe0e:548b

Destination Address: 2001:470:6d:400:4e52:62ff:fe0e:542b

[Source SA MAC: FujitsuT_0e:54:8b (4c:52:62:0e:54:8b)]

[Destination SA MAC: FujitsuT_0e:54:2b (4c:52:62:0e:54:2b)]

Fragment Header for IPv6

[4 IPv6 Fragments (5808 bytes): #10395(1448), #10396(1448), #10397(1448), #10398(664)]

Internet Control Message Protocol v6

Frame (.z. bytes) [hexiemoed ipv6 (z. bytes)]

Next Header (ipv6.nxt), 1 byte

Packets: 11130 - Displayed: 1117 (10.0%)

Profile: Default

Abbildung 12: Details eines gecaptureten Packets

Welche Bedeutung haben die unterschiedlichen Felder des Fragmentation Headers, oder anders gefragt; wie setzt IPv6 die Pakete wieder zusammen?

TODO: Add interpretation

No.	Time	Source	Destination	Protocol	Length	Info
10088	1403.2367894	fe80::4e52:62ff:fe0e:548b	2001:470:6d:400:4e52:62ff:fe0e:542b	ICMPv6	86	Neighbor Solicitation for 2001:470:6d:400:4e52:62ff:fe0e:542b from 4c:52:62:0e:54:8b
10118	1413.8732847	fe80::fada:11ff:febd:6612	ff02::1:ff0e:548b	ICMPv6	86	Neighbor Solicitation for 2001:470:6d:400:4e52:62ff:fe0e:548b from fe:d1:11:bd:66:12
10119	1413.8733216	2001:470:6d:400:4e52:62ff:fe0e:548b	fe80::fada:11ff:febd:6612	ICMPv6	86	Neighbor Advertisement 2001:470:6d:400:4e52:62ff:fe0e:548b (sol, ovr) is at 4c:52:62:0e:54:8b
10367	1451.5221774	2001:470:6d:400:4e52:62ff:fe0e:548b	2001:470:6d:400:4e52:62ff:fe0e:542b	ICMPv6	726	Echo (ping) request id=0x0001, seq=96, hop limit=128 (no response found)
10368	1451.5222578	2001:470:6d:400:4e52:62ff:fe0e:548b	ff02::1:ff0e:542b	ICMPv6	86	Neighbor Solicitation for 2001:470:6d:400:4e52:62ff:fe0e:542b from 4c:52:62:0e:54:8b
10371	1452.5487111	2001:470:6d:400:4e52:62ff:fe0e:542b	ff02::1:ff0e:542b	ICMPv6	86	Neighbor Solicitation for 2001:470:6d:400:4e52:62ff:fe0e:542b from 4c:52:62:0e:54:8b
10378	1453.5727980	2001:470:6d:400:4e52:62ff:fe0e:548b	ff02::1:ff0e:542b	ICMPv6	86	Neighbor Solicitation for 2001:470:6d:400:4e52:62ff:fe0e:542b from 4c:52:62:0e:54:8b
10389	1456.2612538	2001:470:6d:400:4e52:62ff:fe0e:548b	2001:470:6d:400:4e52:62ff:fe0e:542b	ICMPv6	86	Neighbor Solicitation for 2001:470:6d:400:4e52:62ff:fe0e:548b from 4c:52:62:0e:54:2b
10390	1456.2613143	2001:470:6d:400:4e52:62ff:fe0e:548b	2001:470:6d:400:4e52:62ff:fe0e:542b	ICMPv6	78	Neighbor Advertisement 2001:470:6d:400:4e52:62ff:fe0e:548b (sol)
10394	1456.2770092	2001:470:6d:400:4e52:62ff:fe0e:548b	2001:470:6d:400:4e52:62ff:fe0e:542b	ICMPv6	726	Echo (ping) request id=0x0001, seq=97, hop limit=128 (reply in 10398)
10398	1456.2770933	2001:470:6d:400:4e52:62ff:fe0e:548b	2001:470:6d:400:4e52:62ff:fe0e:542b	ICMPv6	726	Echo (ping) reply id=0x0001, seq=97, hop limit=64 (request in 10394)
10408	1457.2944372	2001:470:6d:400:4e52:62ff:fe0e:548b	2001:470:6d:400:4e52:62ff:fe0e:542b	ICMPv6	726	Echo (ping) request id=0x0001, seq=99, hop limit=128 (reply in 10412)
10412	1457.2945242	2001:470:6d:400:4e52:62ff:fe0e:548b	2001:470:6d:400:4e52:62ff:fe0e:542b	ICMPv6	726	Echo (ping) reply id=0x0001, seq=99, hop limit=64 (request in 10408)
10418	1458.3104434	2001:470:6d:400:4e52:62ff:fe0e:548b	2001:470:6d:400:4e52:62ff:fe0e:542b	ICMPv6	726	Echo (ping) request id=0x0001, seq=99, hop limit=128 (reply in 10422)
10422	1458.3105286	2001:470:6d:400:4e52:62ff:fe0e:548b	2001:470:6d:400:4e52:62ff:fe0e:542b	ICMPv6	726	Echo (ping) reply id=0x0001, seq=99, hop limit=64 (request in 10418)
10429	1461.3407050	fe80::4e52:62ff:fe0e:548b	2001:470:6d:400:4e52:62ff:fe0e:542b	ICMPv6	86	Neighbor Solicitation for 2001:470:6d:400:4e52:62ff:fe0e:542b from 4c:52:62:0e:54:8b
10434	1462.3727883	fe80::4e52:62ff:fe0e:548b	2001:470:6d:400:4e52:62ff:fe0e:542b	ICMPv6	86	Neighbor Solicitation for 2001:470:6d:400:4e52:62ff:fe0e:542b from 4c:52:62:0e:54:8b
10438	1463.3907877	fe80::4e52:62ff:fe0e:548b	2001:470:6d:400:4e52:62ff:fe0e:542b	ICMPv6	86	Neighbor Solicitation for 2001:470:6d:400:4e52:62ff:fe0e:542b from 4c:52:62:0e:54:8b
10484	1482.8213891	fe80::fada:11ff:febd:6612	ff02::1:ff0a:d882	ICMPv6	86	Neighbor Solicitation for 2001:470:6d:400:1539:c01f:5a6a:d882 from fe:d1:11:bd:66:12
10491	1488.2233603	fe80::fada:11ff:febd:6612	ff02::1:ff0e:548b	ICMPv6	86	Neighbor Solicitation for 2001:470:6d:400:4e52:62ff:fe0e:548b from fe:d1:11:bd:66:12

Type: IPv6 (0x86dd)
Internet Protocol Version 6, Src: 2001:470:6d:400:4e52:62ff:fe0e:542b, Dst: 2001:470:6d:400:4e52:62ff:fe0e:548b
0110 = Version: 6
* 0000 0000 = Traffic Class: 0x00 (DSCP: CS0, ECN: Not-ECT)
* 0000 00 .. = Differentiated Services Codepoint: Default (0)
* 00 .. = Explicit Congestion Notification: Not ECN-Capable Transport (0)
* 0000 0000 0000 0000 = Flow Label: 0x000000
Payload Length: 672
Next Header: Fragment Header for IPv6 (44)
Hop Limit: 128
Source Address: 2001:470:6d:400:4e52:62ff:fe0e:542b
Destination Address: 2001:470:6d:400:4e52:62ff:fe0e:548b
[Source SA MAC: FujitsuT_0e:54:2b (4c:52:62:0e:54:2b)]
[Destination SA MAC: FujitsuT_0e:54:8b (4c:52:62:0e:54:8b)]
Fragment Header for IPv6
Next header: ICMPv6 (58)
Reserved octet: 0x00
0001 0000 1111 1... = Offset: 543 (4344 bytes)
* 00 .. = Reserved bits: 0
* 00 .. = More Fragments: No
Identification: 0xd15db77f
* [4 IPv6 Fragments (5000 bytes): #10405(1448), #10406(1448), #10407(1448), #10408(664)]
Internet Control Message Protocol v6
Type: Echo (ping) request (128)
Code: 0
Checksum: 0x5a4e [correct]
Frame (720 bytes) | hexassembled IPv6 (2000 bytes)
Fragment Header for IPv6 (IPv6 fraghdr), 8 bytes

Packets: 14961. Displayed: 1480 (9.9%) Profile: Default

Abbildung 13: Details des Fragment-Headers

6 Privacy Extension

Tragen Sie weitere Informationen zur „Privacy Extension“ (vor allem auch zur Konfiguration unter Windows und Ubuntu) zusammen und versuchen hier im Versuch die Einstellungen für die „Privacy Extension“ auf beiden Rechnern (Windows und Ubuntu) zu realisieren.

TODO: Add research results

Mit welchen IPv6-Adressen sind sie nach dem Aktivieren der Privacy Extension im Internet unterwegs?

TODO: Add research results

7 Feste IPv6-Adressen

Weisen Sie in dieser Aufgabe ihrem Netzwerkinterface eine feste sinnvolle (heißt: Der Prefix ist weiterhin gültig) IPv6-Adresse zu.

```
1 $ ip a
2 1: lo: <LOOPBACK,UP,LOWER_UP> mtu 65536 qdisc noqueue state UNKNOWN
   group default qlen 1000
```

```
3   link/loopback 00:00:00:00:00:00 brd 00:00:00:00:00:00
4   inet 127.0.0.1/8 scope host lo
5       valid_lft forever preferred_lft forever
6   inet6 ::1/128 scope host
7       valid_lft forever preferred_lft forever
8 2: enp0s31f6: <BROADCAST,MULTICAST,UP,LOWER_UP> mtu 1500 qdisc
   pfifo_fast state UP group default qlen 1000
9   link/ether 4c:52:62:0e:54:8b brd ff:ff:ff:ff:ff:ff
10  inet6 2001:470:6d:4d0:4e52:62ff:fe0e:548b/64 scope global dynamic
    mngtmpaddr
11     valid_lft 86255sec preferred_lft 14255sec
12  inet6 fe80::4e52:62ff:fe0e:548b/64 scope link
13     valid_lft forever preferred_lft forever
14 praktikum@rn05:~$ sudo ip addr add 2001:470:6d:4d0:4e52:62ff:fe0e:548c
   /64 dev enp0s31f6
15 praktikum@rn05:~$ ip a
16 1: lo: <LOOPBACK,UP,LOWER_UP> mtu 65536 qdisc noqueue state UNKNOWN
    group default qlen 1000
17   link/loopback 00:00:00:00:00:00 brd 00:00:00:00:00:00
18   inet 127.0.0.1/8 scope host lo
19       valid_lft forever preferred_lft forever
20   inet6 ::1/128 scope host
21       valid_lft forever preferred_lft forever
22 2: enp0s31f6: <BROADCAST,MULTICAST,UP,LOWER_UP> mtu 1500 qdisc
   pfifo_fast state UP group default qlen 1000
23   link/ether 4c:52:62:0e:54:8b brd ff:ff:ff:ff:ff:ff
24   inet6 2001:470:6d:4d0:4e52:62ff:fe0e:548c/64 scope global
25       valid_lft forever preferred_lft forever
26   inet6 2001:470:6d:4d0:4e52:62ff:fe0e:548b/64 scope global dynamic
    mngtmpaddr
27       valid_lft 86207sec preferred_lft 14207sec
28   inet6 fe80::4e52:62ff:fe0e:548b/64 scope link
29       valid_lft forever preferred_lft forever
```

Warum sollten Sie jetzt alle übrigen IPv6-Adressen löschen?

TODO: Add interpretation

```
1 $ sudo ip addr del 2001:470:6d:4d0:4e52:62ff:fe0e:548b/64 dev enp0s31f6
2 $ ip a
3 1: lo: <LOOPBACK,UP,LOWER_UP> mtu 65536 qdisc noqueue state UNKNOWN
   group default qlen 1000
4   link/loopback 00:00:00:00:00:00 brd 00:00:00:00:00:00
5   inet 127.0.0.1/8 scope host lo
6       valid_lft forever preferred_lft forever
7   inet6 ::1/128 scope host
8       valid_lft forever preferred_lft forever
9 2: enp0s31f6: <BROADCAST,MULTICAST,UP,LOWER_UP> mtu 1500 qdisc
   pfifo_fast state UP group default qlen 1000
10  link/ether 4c:52:62:0e:54:8b brd ff:ff:ff:ff:ff:ff
11  inet6 2001:470:6d:4d0:4e52:62ff:fe0e:548c/64 scope global
```

```
12     valid_lft forever preferred_lft forever
13     inet6 fe80::4e52:62ff:fe0e:548b/64 scope link
14     valid_lft forever preferred_lft forever
```

Reicht das aus?

TODO: Add interpretation

Konfigurieren Sie die statische IPv6-Adresse über /etc/network/interfaces. Was wird dadurch verhindert? (U. U. müssen sie mit ifdown und ifup die Schnittstelle neu starten

```
1 # /etc/network/interfaces
2 auto enp0s31f6
3     allow-hotplug enp0s31f6
4     iface enp0s31f6 inet6 static
5         address 2001:470:6d:4d0:4e52:62ff:fe0e:548c
6         netmask 64
```

```
1 $ sudo ifdown enp0s31f6
2 $ sudo ifup enp0s31f6
3 Waiting for DAD... Done
4 $ ip a
5 1: lo: <LOOPBACK,UP,LOWER_UP> mtu 65536 qdisc noqueue state UNKNOWN
6     group default qlen 1000
7     link/loopback 00:00:00:00:00:00 brd 00:00:00:00:00:00
8     inet 127.0.0.1/8 scope host lo
9         valid_lft forever preferred_lft forever
10    inet6 ::1/128 scope host
11        valid_lft forever preferred_lft forever
12 2: enp0s31f6: <BROADCAST,MULTICAST,UP,LOWER_UP> mtu 1500 qdisc
13    pfifo_fast state UP group default qlen 1000
14    link/ether 4c:52:62:0e:54:8b brd ff:ff:ff:ff:ff:ff
15    inet6 2001:470:6d:4d0:4e52:62ff:fe0e:548c/64 scope global
16        valid_lft forever preferred_lft forever
17    inet6 fe80::4e52:62ff:fe0e:548b/64 scope link
18        valid_lft forever preferred_lft forever
19 $ ping www.kame.net
20 PING www.kame.net(2001:2f0:0:8800:226:2dff:fe0b:4311 (2001:2f0
21    :0:8800:226:2dff:fe0b:4311)) 56 data bytes
22 64 bytes from 2001:2f0:0:8800:226:2dff:fe0b:4311 (2001:2f0:0:8800:226:2
23    dff:fe0b:4311): icmp_seq=1 ttl=48 time=280 ms
24 64 bytes from 2001:2f0:0:8800:226:2dff:fe0b:4311 (2001:2f0:0:8800:226:2
25    dff:fe0b:4311): icmp_seq=2 ttl=48 time=274 ms
26 ^C64 bytes from 2001:2f0:0:8800:226:2dff:fe0b:4311: icmp_seq=3 ttl=48
27    time=275 ms
28
29 --- www.kame.net ping statistics ---
30 3 packets transmitted, 3 received, 0% packet loss, time 2003ms
31 rtt min/avg/max/mdev = 274.357/276.472/280.370/2.759 ms
```

TODO: Add interpretation

Mit welcher IPv6-Adresse sind sie jetzt im Netz unterwegs? Die Seite <http://www.heise.de/netze/tools/meine-ip-adresse> gibt Aufschluss.

TODO: Add interpretation

```
1 $ curl https://ipconfig.io
2 2001:470:6d:4d0:4e52:62ff:fe0e:548c
```

8 Lease-Zeiten

Die Werte für “Maximale bevorzugte Gültigkeitsdauer” und “Maximale Gültigkeitsdauer” setzt man in Windows über die Schlüssel `maxpreferredlifetime` und `maxvalidlifetime`, die Zeitangaben in Tagen (d), Stunden (h), Minuten (m) und Sekunden (s) entgegennehmen. Wie sind diese Parameter bei Ihnen gesetzt?

TODO: Add interpretation

Halbieren Sie die “Maximale bevorzugte Gültigkeitsdauer” auf den Rechnern.

TODO: Add interpretation

Verringern Sie ebenso die Zeitspanne, in der Windows über eine temporäre IPv6-Adresse eingehende Pakete empfängt.

TODO: Add interpretation

Stellen Sie den Zusammenhang zwischen Preferred Lifetime und Valid Lifetime anschaulich dar

TODO: Add interpretation

9 OS-Updates

```
1 $ sudo ip addr del 141.62.66.5/24 dev enp0s31f6
2 $ sudo apt update
3 Hit:1 http://deb.debian.org/debian bullseye InRelease
4 Hit:2 http://security.debian.org bullseye-security InRelease
5 Get:3 http://deb.debian.org/debian bullseye-updates InRelease [39.4 kB]
6 Hit:4 http://ppa.launchpad.net/ansible/ansible/ubuntu bionic InRelease
7 Fetched 39.4 kB in 5s (7,169 B/s)
8 Reading package lists... Done
9 Building dependency tree... Done
10 Reading state information... Done
11 1 package can be upgraded. Run 'apt list --upgradable' to see it.
12 $ sudo apt upgrade -y
13 Reading package lists... Done
```

```
14 Building dependency tree... Done
15 Reading state information... Done
16 Calculating upgrade... Done
17 The following packages will be upgraded:
18   tzdata
19 1 upgraded, 0 newly installed, 0 to remove and 0 not upgraded.
20 Need to get 0 B/284 kB of archives.
21 After this operation, 0 B of additional disk space will be used.
22 apt-listchanges: Reading changelogs...
23 Preconfiguring packages ...
24 (Reading database ... 199845 files and directories currently installed
   .)
25 Preparing to unpack .../tzdata_2021a-1+deb11u2_all.deb ...
26 Unpacking tzdata (2021a-1+deb11u2) over (2021a-1+deb11u1) ...
27 Setting up tzdata (2021a-1+deb11u2) ...
28
29 Current default time zone: 'Europe/Berlin'
30 Local time is now:      Tue Nov  9 16:52:29 CET 2021.
31 Universal Time is now:  Tue Nov  9 15:52:29 UTC 2021.
32 Run 'dpkg-reconfigure tzdata' if you wish to change it.
```