

Lightweight IPv6 and IPv4 traffic offloading using IPv6 neighbor discovery

WiBrA Workshop

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Background

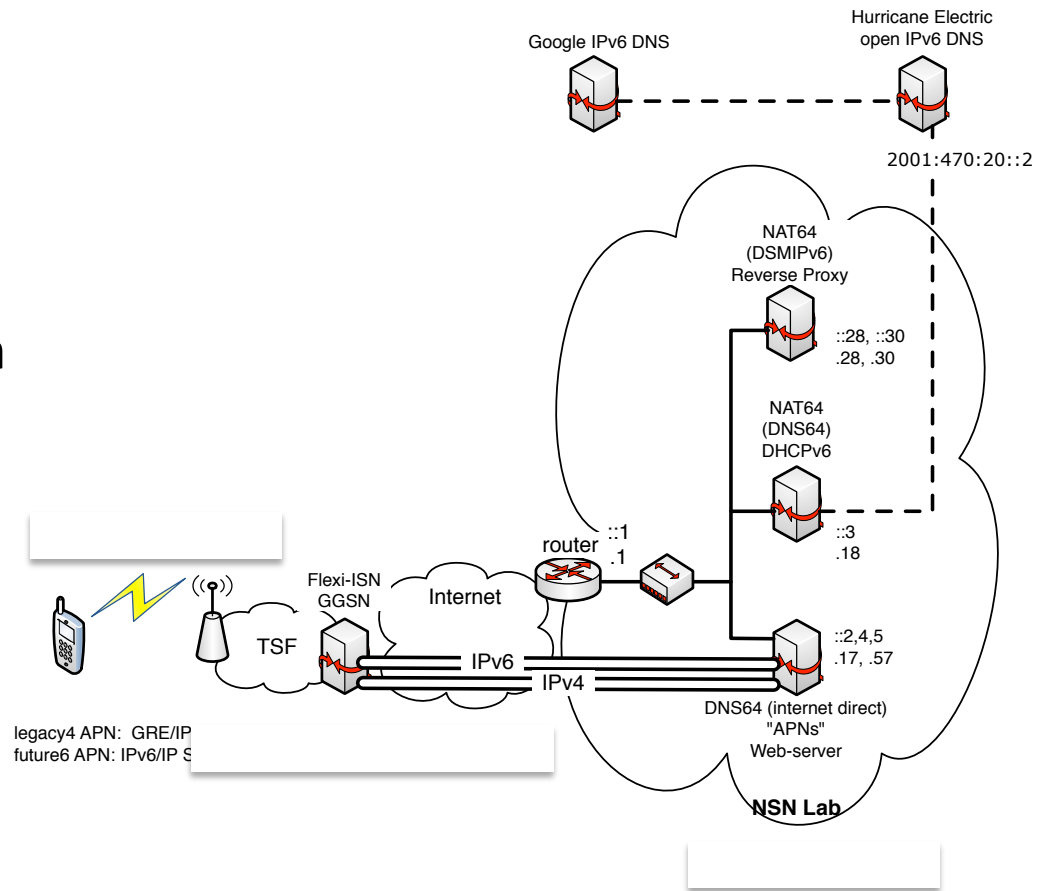
- Original idea: use native IPv6 Neighbor Discovery (ND) for network controlled offloading of traffic:
 - Network tells preferences using standardized means, which every compliant end host should then adhere.
 - ND is mandatory to implement in 3GPP.
 - Host does the hard work i.e. selects what packets go where – which also then works for encrypted traffic.
 - Does not guarantee 100% correct decision every time but majority of cases are ok. Everything works as long as there are no walled gardens.
- Basic work & PoC was done spring/summer 2010.

Basic principle

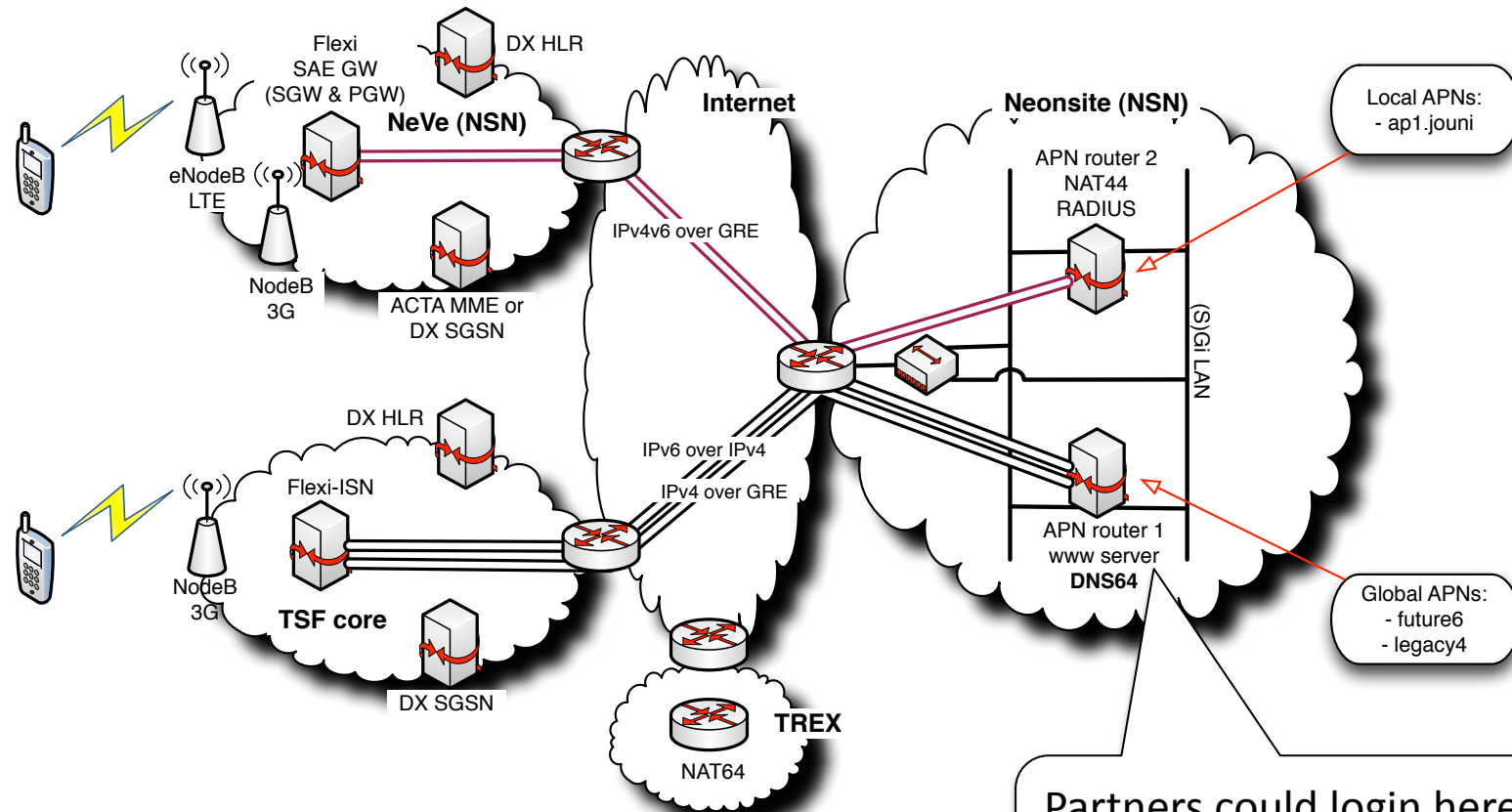
- RFC 4191 defines ‘default router preferences and more specific routes’ extension to neighbor discovery :
 - End host implementations for Windows since XP, Linux including Androids(!), *BSD, etc.. code is out there already.
- Allows a GGSN/PGW to say simple rules e.g.,:
 - “I am the lowest preferred router. Use anything else except me **if possible**” -> e.g., pickup WLAN.
 - “I still want to **get traffic** going to these prefixes”.
- Has a **push model** – the GGSN/PGW can initiate a Router Advertisement at any time.
- Not meant for offloading but works just fine!
- Natural to use 3GPP link as the **only source** for rules!

Test network since summer 2010 – Courtesy of a helping operator partner

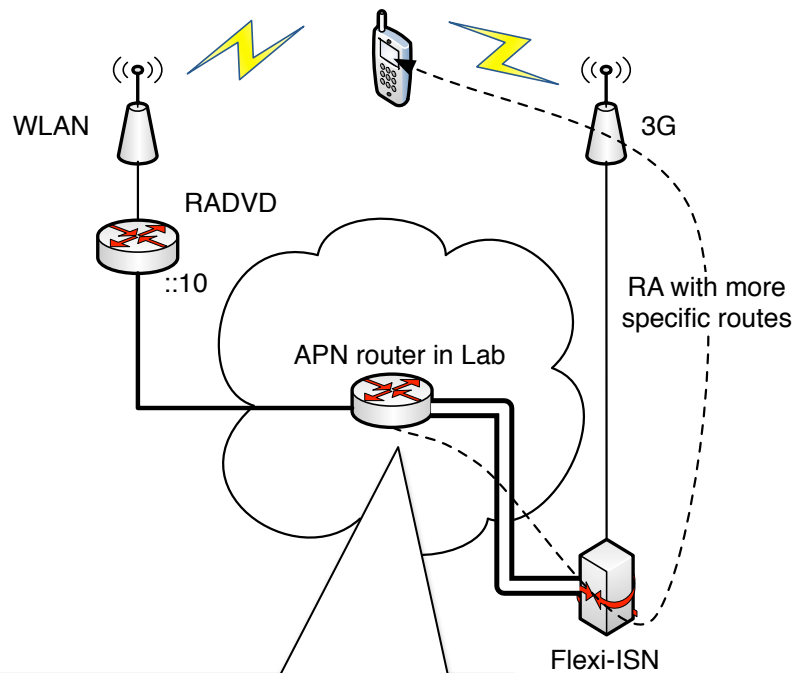
- A live network GPRS access and a bag of SIM cards (with roaming enabled).
- Normal transition gear:
 - NAT64 and DNS64 (open source obviously).
- Public IPv4 and IPv6.
- Best 3G dongles ever from Nokia.
- All partners (and some additional folks outside the project had access).



And test network evolved to this..



Basic IPv6-only offloading..



Project implemented *ndsend* tool that allows sending RAs and NAs to the mobile device.. spoofing to be the Flexi-ISN..

- Traffic steering affects only new connections i.e. there is no mobility and established connections remain unaffected.
- The GGSN may also remove itself from default routers and then no traffic except those with more specific routes are routed to it. (next slide)

ping6 www.google.com and www.kame.net and switch between 3G and WLAN

Both google and kame are ping6:ed happily over 3G

RA from GGSN:
• Removes itself from default routers (NO traffic will be routed to in unless..)
• GGSN adds a more specific route for kame

Google's traffic moves to other interface (WLAN)

The image shows a Wireshark capture of ICMPv6 traffic. The main pane displays a list of packets with the following columns: No., Time, Source, Destination, Protocol, and Info. The selected packet (No. 46) is a Router Advertisement from source fe80::1 to destination 2001:6e8:2100:188::2. The details pane below shows the structure of the Router Advertisement, including the Router Lifetime (0s), Reachable time (12000ms), Retrans timer (3000ms), and an ICMPv6 Option (Route Information) with a Prefix of 2001:200:dff:fff1::(2001:200:dff:fff1::).

No.	Time	Source	Destination	Protocol	Info
36	10.200340	2001:6e8:2100:188::2	2001:200:dff:fff1:216:3eff:feb1:44d7	ICMPv6	Echo (ping) request id=0x7507, seq=26
37	10.873198	2001:200:dff:fff1:216:3eff:feb1:44d7	2001:6e8:2100:188::2	ICMPv6	Echo (ping) reply id=0x7507, seq=26
40	12.001709	2001:6e8:2100:188::2	2a00:1450:8007::93	ICMPv6	Echo (ping) request id=0x7407, seq=29
41	12.433203	2a00:1450:8007::93	2001:6e8:2100:188::2	ICMPv6	Echo (ping) reply id=0x7407, seq=29
44	13.202333	2001:6e8:2100:188::2	2001:200:dff:fff1:216:3eff:feb1:44d7	ICMPv6	Echo (ping) request id=0x7507, seq=27
46	13.597180	fe80::1	2001:6e8:2100:188::2	ICMPv6	Router Advertisement
51	13.873215	2001:200:dff:fff1:216:3eff:feb1:44d7	2001:6e8:2100:188::2	ICMPv6	Echo (ping) reply id=0x7507, seq=27
60	16.203022	2001:6e8:2100:188::2	2001:200:dff:fff1:216:3eff:feb1:44d7	ICMPv6	Echo (ping) request id=0x7507, seq=28
61	16.877199	2001:200:dff:fff1:216:3eff:feb1:44d7	2001:6e8:2100:188::2	ICMPv6	Echo (ping) reply id=0x7507, seq=28
66	19.204356	2001:6e8:2100:188::2	2001:200:dff:fff1:216:3eff:feb1:44d7	ICMPv6	Echo (ping) request id=0x7507, seq=29
67	19.957210	2001:200:dff:fff1:216:3eff:feb1:44d7	2001:6e8:2100:188::2	ICMPv6	Echo (ping) reply id=0x7507, seq=29
72	22.205760	2001:6e8:2100:188::2	2001:200:dff:fff1:216:3eff:feb1:44d7	ICMPv6	Echo (ping) request id=0x7507, seq=30
73	22.913188	2001:200:dff:fff1:216:3eff:feb1:44d7	2001:6e8:2100:188::2	ICMPv6	Echo (ping) reply id=0x7507, seq=30

Router Advertisement details:
Router Lifetime (s): 0
Reachable time (ms): 12000
Retrans timer (ms): 3000
ICMPv6 Option (Route Information : Low 2001:200:dff:fff1::/64)
Type: Route Information (24)
Length: 2 (16 bytes)
Prefix Length: 64
Flag: 0x18
Route Lifetime: 100
Prefix: 2001:200:dff:fff1::(2001:200:dff:fff1::)

ping6 www.google.com and www.kame.net and switch between 3G and WLAN

Google's traffic appeared to WLAN interface..

LANcase3.pcap [Wireshark 1.6.8 (SVN Rev 42761 from /trunk-1.6)]

Filter: icmpv6

No.	Time	Source	Destination	Protocol	Info
2	12.248163	2001:6e8:2100:100:211:25ff:fe44:555b	2a00:1450:8007::93	ICMPv6	Echo (ping) request id=0x7407, seq=30
3	12.279707	2a00:1450:8007::93	2001:6e8:2100:100:211:25ff:fe44:555b	ICMPv6	Echo (ping) reply id=0x7407, seq=30
5	15.248549	2001:6e8:2100:100:211:25ff:fe44:555b	2a00:1450:8007::93	ICMPv6	Echo (ping) request id=0x7407, seq=31
6	15.280241	2a00:1450:8007::93	2001:6e8:2100:100:211:25ff:fe44:555b	ICMPv6	Echo (ping) reply id=0x7407, seq=31
7	16.918293	fe80::2a0:8eff:fe07:bda2	ff02::1	ICMPv6	Router Advertisement From 00:a0:8e:07:bd:a2
8	17.138157	fe80::2a0:8eff:fe07:bda2	2001:6e8:2100:100:211:25ff:fe44:555b	ICMPv6	Neighbor Solicitation for 2001:6e8:2100:100:211:25ff:fe44:555b
9	17.138201	2001:6e8:2100:100:211:25ff:fe44:555b	fe80::2a0:8eff:fe07:bda2	ICMPv6	Neighbor Advertisement 2001:6e8:2100:100:211:25ff:fe44:555b
10	18.248944	2001:6e8:2100:100:211:25ff:fe44:555b	2a00:1450:8007::93	ICMPv6	Echo (ping) request id=0x7407, seq=32
11	18.280526	2a00:1450:8007::93	2001:6e8:2100:100:211:25ff:fe44:555b	ICMPv6	Echo (ping) reply id=0x7407, seq=32
12	21.249345	2001:6e8:2100:100:211:25ff:fe44:555b	2a00:1450:8007::93	ICMPv6	Echo (ping) request id=0x7407, seq=33
15	21.280786	2a00:1450:8007::93	2001:6e8:2100:100:211:25ff:fe44:555b	ICMPv6	Echo (ping) reply id=0x7407, seq=33
16	24.249761	2001:6e8:2100:100:211:25ff:fe44:555b	2a00:1450:8007::93	ICMPv6	Echo (ping) request id=0x7407, seq=34
24	24.281336	2a00:1450:8007::93	2001:6e8:2100:100:211:25ff:fe44:555b	ICMPv6	Echo (ping) reply id=0x7407, seq=34
18	27.251278	2001:6e8:2100:100:211:25ff:fe44:555b	2a00:1450:8007::93	ICMPv6	Echo (ping) request id=0x7407, seq=35
19	30.251295	2001:6e8:2100:100:211:25ff:fe44:555b	2a00:1450:8007::93	ICMPv6	Echo (ping) request id=0x7407, seq=36
20	30.285887	2a00:1450:8007::93	2001:6e8:2100:100:211:25ff:fe44:555b	ICMPv6	Echo (ping) reply id=0x7407, seq=36
21	33.254332	2001:6e8:2100:100:211:25ff:fe44:555b	2a00:1450:8007::93	ICMPv6	Echo (ping) request id=0x7407, seq=37
22	33.288908	2a00:1450:8007::93	2001:6e8:2100:100:211:25ff:fe44:555b	ICMPv6	Echo (ping) reply id=0x7407, seq=37
24	36.255286	2001:6e8:2100:100:211:25ff:fe44:555b	2a00:1450:8007::93	ICMPv6	Echo (ping) request id=0x7407, seq=38
25	36.289949	2a00:1450:8007::93	2001:6e8:2100:100:211:25ff:fe44:555b	ICMPv6	Echo (ping) reply id=0x7407, seq=38
26	37.456577	2001:6e8:2100:100:211:25ff:fe44:555b	2001:200:dff:fff1:216:3eff:feb1:44d7	ICMPv6	Echo (ping) request id=0x7507, seq=36
27	37.762339	2001:200:dff:fff1:216:3eff:feb1:44d7	2001:6e8:2100:100:211:25ff:fe44:555b	ICMPv6	Echo (ping) reply id=0x7507, seq=36
28	39.258391	2001:6e8:2100:100:211:25ff:fe44:555b	2a00:1450:8007::93	ICMPv6	Echo (ping) request id=0x7407, seq=39
29	39.289959	2a00:1450:8007::93	2001:6e8:2100:100:211:25ff:fe44:555b	ICMPv6	Echo (ping) reply id=0x7407, seq=39
30	40.456827	2001:6e8:2100:100:211:25ff:fe44:555b	2001:200:dff:fff1:216:3eff:feb1:44d7	ICMPv6	Echo (ping) request id=0x7507, seq=37
31	40.762360	2001:200:dff:fff1:216:3eff:feb1:44d7	2001:6e8:2100:100:211:25ff:fe44:555b	ICMPv6	Echo (ping) reply id=0x7507, seq=37
33	42.261344	2001:6e8:2100:100:211:25ff:fe44:555b	2a00:1450:8007::93	ICMPv6	Echo (ping) request id=0x7407, seq=40
34	42.292986	2a00:1450:8007::93	2001:6e8:2100:100:211:25ff:fe44:555b	ICMPv6	Echo (ping) reply id=0x7407, seq=40
35	43.458737	2001:6e8:2100:100:211:25ff:fe44:555b	2001:200:dff:fff1:216:3eff:feb1:44d7	ICMPv6	Echo (ping) request id=0x7507, seq=38
36	43.764386	2001:200:dff:fff1:216:3eff:feb1:44d7	2001:6e8:2100:100:211:25ff:fe44:555b	ICMPv6	Echo (ping) reply id=0x7507, seq=38

Frame (frame), 110 bytes | Packets: 95 Displayed: 58 Marked: 0 Load ti... | Profile: Default

ping6 www.google.com and www.kame.net and switch between 3G and WLAN

Only kame is over 3G.. google moved to WLAN..

RA from GGSN:
• Removes the more specific route for kame

All traffic moves to WLAN. GGSN is not a default router and all new connections go to other accesses..

The image shows a Wireshark capture of ICMPv6 traffic. The main pane displays a list of packets with the following columns: No., Time, Source, Destination, Protocol, and Info. The selected packet (No. 125) is a Router Advertisement (RA) message from source fe80::1 to destination 2001:6e8:2100:188::2. The packet details pane shows the RA message structure, including the Router Lifetime (0), Reachable time (12000), Retrans timer (3000), and an ICMPv6 Option (Route Information) with a Prefix Length of 64 and a Prefix of 2001:200:dff:fff1::(2001:200:dff:fff1::). The hex dump at the bottom shows the raw bytes of the packet.

No.	Time	Source	Destination	Protocol	Info
73	22.913188	2001:200:dff:fff1:216:3eff:feb1:44d7	2001:6e8:2100:188::2	ICMPv6	Echo (ping) request id=0x7507, seq=30
81	25.208318	2001:6e8:2100:188::2	2001:200:dff:fff1:216:3eff:feb1:44d7	ICMPv6	Echo (ping) reply id=0x7507, seq=30
83	25.913194	2001:200:dff:fff1:216:3eff:feb1:44d7	2001:6e8:2100:188::2	ICMPv6	Echo (ping) request id=0x7507, seq=31
90	28.209211	2001:6e8:2100:188::2	2001:200:dff:fff1:216:3eff:feb1:44d7	ICMPv6	Echo (ping) reply id=0x7507, seq=31
94	28.953218	2001:200:dff:fff1:216:3eff:feb1:44d7	2001:6e8:2100:188::2	ICMPv6	Echo (ping) request id=0x7507, seq=32
97	31.210218	2001:6e8:2100:188::2	2001:200:dff:fff1:216:3eff:feb1:44d7	ICMPv6	Echo (ping) reply id=0x7507, seq=32
103	34.209231	2001:6e8:2100:188::2	2001:200:dff:fff1:216:3eff:feb1:44d7	ICMPv6	Echo (ping) request id=0x7507, seq=33
110	36.341202	2001:200:dff:fff1:216:3eff:feb1:44d7	2001:6e8:2100:188::2	ICMPv6	Echo (ping) reply id=0x7507, seq=33
113	36.741171	2001:200:dff:fff1:216:3eff:feb1:44d7	2001:6e8:2100:188::2	ICMPv6	Echo (ping) request id=0x7507, seq=34
116	37.208799	2001:6e8:2100:188::2	2001:200:dff:fff1:216:3eff:feb1:44d7	ICMPv6	Echo (ping) reply id=0x7507, seq=34
117	37.665203	2001:200:dff:fff1:216:3eff:feb1:44d7	2001:6e8:2100:188::2	ICMPv6	Echo (ping) request id=0x7507, seq=35
125	39.401195	fe80::1	2001:6e8:2100:188::2	ICMPv6	Router Advertisement

ping6 www.google.com and www.kame.net and switch between 3G and WLAN

Now also Kame's traffic appeared to WLAN interface.. both google & kame are over WLAN.

LANcase3.pcap [Wireshark 1.6.8 (SVN Rev 42761 from /trunk-1.6)]

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5	15.248549	2001:6e8:2100:100:211:25ff:fe44:555b	2a00:1450:8007::93	ICMPv6	Echo (ping) request id=0x7407, seq=31
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9	17.138201	2001:6e8:2100:100:211:25ff:fe44:555b	fe80::2a0:8eff:fe07:bda2	ICMPv6	Neighbor Advertisement 2001:6e8:2100:100:211:25ff:fe44:555b
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16	24.249761	2001:6e8:2100:100:211:25ff:fe44:555b	2a00:1450:8007::93	ICMPv6	Echo (ping) request id=0x7407, seq=34
17	24.281336	2a00:1450:8007::93	2001:6e8:2100:100:211:25ff:fe44:555b	ICMPv6	Echo (ping) reply id=0x7407, seq=34
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20	30.285887	2a00:1450:8007::93	2001:6e8:2100:100:211:25ff:fe44:555b	ICMPv6	Echo (ping) reply id=0x7407, seq=36
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22	33.288908	2a00:1450:8007::93	2001:6e8:2100:100:211:25ff:fe44:555b	ICMPv6	Echo (ping) reply id=0x7407, seq=37
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27	37.762339	2001:200:dff:fff1:216:3eff:feb1:44d7	2001:6e8:2100:100:211:25ff:fe44:555b	ICMPv6	Echo (ping) reply id=0x7507, seq=36
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31	40.762360	2001:200:dff:fff1:216:3eff:feb1:44d7	2001:6e8:2100:100:211:25ff:fe44:555b	ICMPv6	Echo (ping) reply id=0x7507, seq=37
33	42.261344	2001:6e8:2100:100:211:25ff:fe44:555b	2a00:1450:8007::93	ICMPv6	Echo (ping) request id=0x7407, seq=40
34	42.292986	2a00:1450:8007::93	2001:6e8:2100:100:211:25ff:fe44:555b	ICMPv6	Echo (ping) reply id=0x7407, seq=40
35	43.458737	2001:6e8:2100:100:211:25ff:fe44:555b	2001:200:dff:fff1:216:3eff:feb1:44d7	ICMPv6	Echo (ping) request id=0x7507, seq=38
36	43.764386	2001:200:dff:fff1:216:3eff:feb1:44d7	2001:6e8:2100:100:211:25ff:fe44:555b	ICMPv6	Echo (ping) reply id=0x7507, seq=38

Frame (frame), 110 bytes | Packets: 95 Displayed: 58 Marked: 0 Load ti... | Profile: Default

Issues – what next

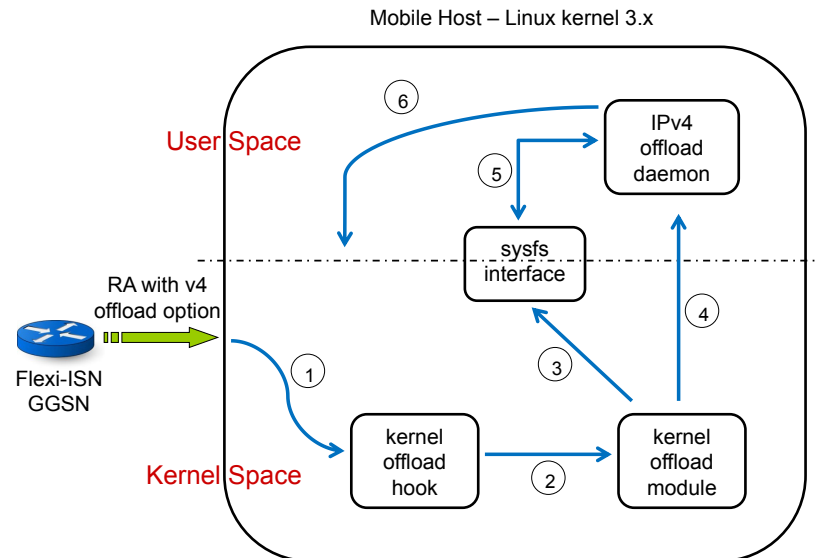
- That worked as expected with unmodified end host. All we did was end host configuration.
- Alternatively GGSN could have lowered its preference to LOW and have the same effect but still keeping itself as a default router.
 - We do not accept RFC 4191 from WLAN so its default router is implicitly always has a MEDIUM preference.
- BUT! This works only for IPv6! WHAT ABOUT IPv4?
 - You can specify IPv4-mapped IPv6 routes in RFC 4191 but those routes get installed into IPv6 routing table not IPv4.

Implement RFC 4191 equivalent for IPv4 and piggyback it on the Neighbor Discovery

- Solution described in:
 - J. Korhonen, T. Savolainen, A. Y. Ding, "Controlling Traffic Offloading Using Neighbor Discovery Protocol", Internet-Draft "draft-korhonen-mif-ra-offload-05.txt", August 31, 2012 (work in progress).
 - Aaron Yi Ding, Jouni Korhonen, Pan Hui, Teemu Savolainen, Sasu Tarkoma, Markku Kojo, "NAO: A Framework to Enable Efficient Mobile Offloading", In Proc. ACM/IFIP/USENIX International Middleware Conference - Middleware PDT Workshop, Lisbon, Portugal, December 2011.
 - Jouni Korhonen, Teemu Savolainen, Aaron Yi Ding, Markku Kojo, "Towards Network Controlled IP Traffic Offloading", IEEE Communication Magazine COMMAG. (submitted for review)
- Adds IPv4 more specific routes (old) using IPv4-Mapped IPv6 addresses or (new) as its own options; also adds IPv4 default gateway address, which must point to the sending router.

IPv6 and IPv4 offloading implementation

- Modifies the end host, which is generally bad.. but..
- Implementation mainly in user space with a kernel hook.
- Kernel pushes new RA options to (3) via sysfs to user space and/or (4) using netlink to the listening daemon (we could have just hook into `ndisc_is_useropt()` but this was a generic exercise anyway.. ;-)
- Daemon takes care of installing and handling IPv4 routes (scripting mostly..)



Test case and example of a RA

- For mixed a test sequence: 6 flows (pings)
 - IPv6/IPv4 to google.com, kame.net, funet.fi
- All traffic go over 3G (IPv6 and IPv4)
 - This is done by sending RAs to client, to add specific routes for each destination, lifetime 500s, preference as high (could be all in one RA) .
 - Router pref is MED but Linux prefers WLAN over 3G as a default.. to be sure router pref should be LOW.
- Move all IPv4 to WLAN and keep all IPv6 in 3G
 - 3 RAs to change the routes for IPv4 traffic, by setting lifetime to 0 -
- Move IPv6 funet.fi from 3G to WLAN
 - 1 RA to change the route to wlan, by setting lifetime to 0
- Move IPv6 kame.net from 3G to WLAN
 - 1 RA to change the route to wlan, by setting lifetime to 0
- Move IPv4 funet.fi back to 3G
 - 1 RA to add specific route to 3G, lifetime 500s, preference as high
- Now we should have the following:
 - IPv6 google.com over 3G
 - IPv6 kame.net and funet.fi over WLAN
 - IPv4 google.com and kame.net over WLAN
 - IPv4 funet.fi over 3G

885 0.010017 fe80::214:4fff:fe96:f24e 2001:6e8:2100:188: ICMPv6

1322 0.029705 fe80::214:4fff:fe96:f24e 2001:6e8:2100:188: ICMPv6

1768 0.129486 fe80::214:4fff:fe96:f24e 2001:6e8:2100:188: ICMPv6

2126 0.403105 fe80::214:4fff:fe96:f24e 2001:6e8:2100:188: ICMPv6

2339 0.359960 fe80::214:4fff:fe96:f24e 2001:6e8:2100:188: ICMPv6

Frame 1322: 112 bytes on wire (896 bits), 112 bytes captured (896 bits)

Linux cooked capture

Internet Protocol Version 6, Src: fe80::214:4fff:fe96:f24e (fe80::214:4fff:fe96:f24e)

Internet Control Message Protocol v6

Type: Router Advertisement (134)

Code: 0

Checksum: 0xbc58 [correct]

Cur hop limit: 64

Flags: 0x00

Router lifetime (s): 1800

Reachable time (ms): 12000

Retrans timer (ms): 3000

ICMPv6 Option (Route Information : High ::ffff:203.178.141.0/120)

ICMPv6 Option (Mobile Node Identifier Option)

0010 60 00 00 00 00 38 3a ff fe 80 00 00 00 00 00 008:.....

0020 02 14 4f ff fe 96 f2 4e 20 01 06 e8 21 00 01 88 ...0...N.....

0030 00 00 00 00 00 00 02 86 00 bc 58 40 00 07 08x@....

0040 00 00 2e e0 00 0b b8 18 03 78 08 00 00 00 00x.....

0050 00 00 00 00 00 00 00 00 00 ff ff cb b2 8d 00x.....

0060 1e 02 00 00 0a 06 06 06 00 00 30 77 69 62 00 000wib....

Option (icmpv6.opt), 16 bytes : Packets: 2501 Displayed: 12 Marked:

ping6 and switch between 3G and WLAN – move the last IPv4 flow to WLAN

IPv6 google & kame over 3G.. IPv4 funet also over 3G

RA from GGSN:
• removes more specific route for www.funet.fi

Only IPv6 left on 3G.

The image shows a Wireshark capture of ICMPv6 traffic. The main pane displays a list of packets, with packet 1768 highlighted. The details pane shows the structure of the Router Advertisement (RA) packet, including the ICMPv6 Option (Route Information) field. The route information is expanded, showing a specific route with a prefix length of 120 and a route lifetime of 0. The prefix is ::ffff:81.90.77.0 (::ffff:81.90.77.0). The packet bytes pane shows the raw data of the packet, including the ICMPv6 Option (Route Information) field.

No.	Time	Source	Destination	Protocol	Info
1761	575.878366	2a00:1450:400f:800::1012	2001:6e8:2100:188::2	ICMPv6	Echo (ping) reply id=0x1a29, seq=184
1762	575.888212	2001:200:dff:fff1:216:3eff:feb1:44d7	2001:6e8:2100:188::2	ICMPv6	Echo (ping) reply id=0x2a29, seq=167
1763	576.272375	2001:6e8:2100:188::2	2a00:16a0:0:100::21:3	ICMPv6	Echo (ping) request id=0x2c29, seq=153
1764	576.318346	2a00:16a0:0:100::21:3	2001:6e8:2100:188::2	ICMPv6	Echo (ping) reply id=0x2c29, seq=153
1765	576.432957	93.106.136.181	81.90.77.32	ICMP	Echo (ping) request id=0x2b29, seq=162/41472, ttl=64
1766	576.486723	81.90.77.32	93.106.136.181	ICMP	Echo (ping) reply id=0x2b29, seq=162/41472, ttl=52
1767	576.487403	2001:6e8:2100:188::2	2001:200:dff:fff1:216:3eff:feb1:44d7	ICMPv6	Echo (ping) request id=0x2a29, seq=168
1768	576.616885	fa80::214:4fff:fe96:f24e	2001:6e8:2100:188::2	ICMPv6	Router Advertisement
1769	576.812491	2001:6e8:2100:188::2	2a00:1450:400f:800::1012	ICMPv6	Echo (ping) request id=0x1a29, seq=185
1770	576.878472	2a00:1450:400f:800::1012	2001:6e8:2100:188::2	ICMPv6	Echo (ping) reply id=0x1a29, seq=185
1771	576.891376	2001:200:dff:fff1:216:3eff:feb1:44d7	2001:6e8:2100:188::2	ICMPv6	Echo (ping) reply id=0x2a29, seq=168
1772	577.273286	2001:6e8:2100:188::2	2a00:16a0:0:100::21:3	ICMPv6	Echo (ping) request id=0x2c29, seq=154
1773	577.326725	2a00:16a0:0:100::21:3	2001:6e8:2100:188::2	ICMPv6	Echo (ping) reply id=0x2c29, seq=154

Router Lifetime (s): 1800
Reachable time (ms): 12000
Retrans timer (ms): 3000

ICMPv6 Option (Route Information : High ::ffff:81.90.77.0/120)
Type: Route Information (24)
Length: 3 (24 bytes)
Prefix Length: 120
Flag: 0x08
Route Lifetime: 0
Prefix: ::ffff:81.90.77.0 (::ffff:81.90.77.0)

ICMPv6 Option (Route Information : High ::ffff:81.90.77.0/120)

Option (icmpv6.opt), 16 bytes | Packets: 2501 Displayed: 2501 Marked: 0 L... | Profile: Default

GGSN moved one IPv4 flow from 3G to WLAN

The image shows a Wireshark capture of network traffic. The filter is set to 'icmpv6 || icmp'. The capture shows a series of ICMP Echo (ping) requests and replies. The source IP address is 192.168.2.3 and the destination is 209.85.137.147. The capture shows a flow of traffic that is initially identified as 3G and then moves to WLAN.

No.	Time	Source	Destination	Protocol	Info
4674	624.953148	fe80::20e:35ff:fe7:eda1	fe80::212:f0ff:fe28:d397	ICMPv6	Neighbor Advertisement fe80::20e:35ff:fe7:eda1 (sol)
4689	631.961824	fe80::20e:35ff:fe7:eda1	2001:708:160:802::2	ICMPv6	Neighbor Solicitation for 2001:708:160:802::2 from 00
4690	631.963802	2001:708:160:802::2	fe80::20e:35ff:fe7:eda1	ICMPv6	Neighbor Advertisement 2001:708:160:802::2 (rtr, sol)
4865	653.514815	fe80::212:f0ff:fe28:d397	2001:708:160:802::3	ICMPv6	Neighbor Solicitation for 2001:708:160:802::3 from 00
4866	653.514866	2001:708:160:802::3	fe80::212:f0ff:fe28:d397	ICMPv6	Neighbor Advertisement 2001:708:160:802::3 (sol)
4973	658.521835	fe80::20e:35ff:fe7:eda1	fe80::212:f0ff:fe28:d397	ICMPv6	Neighbor Solicitation for fe80::212:f0ff:fe28:d397 fr
4974	658.522550	fe80::212:f0ff:fe28:d397	fe80::20e:35ff:fe7:eda1	ICMPv6	Neighbor Advertisement fe80::212:f0ff:fe28:d397 (rtr,
5105	688.094604	192.168.2.3	209.85.137.147	ICMP	Echo (ping) request id=0x1929, seq=96/24576, ttl=64
5106	688.114415	209.85.137.147	192.168.2.3	ICMP	Echo (ping) reply id=0x1929, seq=96/24576, ttl=51
5109	689.091644	192.168.2.3	209.85.137.147	ICMP	Echo (ping) request id=0x1929, seq=97/24832, ttl=64
5110	689.112573	209.85.137.147	192.168.2.3	ICMP	Echo (ping) reply id=0x1929, seq=97/24832, ttl=51
5113	690.092378	192.168.2.3	209.85.137.147	ICMP	Echo (ping) request id=0x1929, seq=98/25088, ttl=64
5114	690.110424	209.85.137.147	192.168.2.3	ICMP	Echo (ping) reply id=0x1929, seq=98/25088, ttl=51
5117	691.092927	192.168.2.3	209.85.137.147	ICMP	Echo (ping) request id=0x1929, seq=99/25344, ttl=64
5118	691.111018	209.85.137.147	192.168.2.3	ICMP	Echo (ping) reply id=0x1929, seq=99/25344, ttl=51
5121	692.093845	192.168.2.3	209.85.137.147	ICMP	Echo (ping) request id=0x1929, seq=100/25600, ttl=64
5122	692.114212	209.85.137.147	192.168.2.3	ICMP	Echo (ping) reply id=0x1929, seq=100/25600, ttl=51
5125	693.095174	192.168.2.3	209.85.137.147	ICMP	Echo (ping) request id=0x1929, seq=101/25856, ttl=64
5126	693.114141	209.85.137.147	192.168.2.3	ICMP	Echo (ping) reply id=0x1929, seq=101/25856, ttl=51
5131	694.096314	192.168.2.3	209.85.137.147	ICMP	Echo (ping) request id=0x1929, seq=102/26112, ttl=64
5132	694.114500	209.85.137.147	192.168.2.3	ICMP	Echo (ping) reply id=0x1929, seq=102/26112, ttl=51
5135	695.097645	192.168.2.3	209.85.137.147	ICMP	Echo (ping) request id=0x1929, seq=103/26368, ttl=64
5136	695.115875	209.85.137.147	192.168.2.3	ICMP	Echo (ping) reply id=0x1929, seq=103/26368, ttl=51
5139	696.099017	192.168.2.3	209.85.137.147	ICMP	Echo (ping) request id=0x1929, seq=104/26624, ttl=64
5140	696.117560	209.85.137.147	192.168.2.3	ICMP	Echo (ping) reply id=0x1929, seq=104/26624, ttl=51
5143	697.100710	192.168.2.3	209.85.137.147	ICMP	Echo (ping) request id=0x1929, seq=105/26880, ttl=64
5144	697.118687	209.85.137.147	192.168.2.3	ICMP	Echo (ping) reply id=0x1929, seq=105/26880, ttl=51
5147	698.101865	192.168.2.3	209.85.137.147	ICMP	Echo (ping) request id=0x1929, seq=106/27136, ttl=64
5148	698.127220	209.85.137.147	192.168.2.3	ICMP	Echo (ping) reply id=0x1929, seq=106/27136, ttl=51

File: "/Users/jounkorh/resea... : Packets: 9630 Displayed: 2233 Marked: 0 L... : Profile: Default

GGSN moved second IPv4 flow from 3G to WLAN

Filter: icmpv6 || icmp

No.	Time	Source	Destination	Protocol	Info
5549	727.155682	209.85.137.147	192.168.2.3	ICMP	Echo (ping) reply id=0x1929, seq=135/34560, ttl=51
5552	728.138045	192.168.2.3	209.85.137.147	ICMP	Echo (ping) request id=0x1929, seq=136/34816, ttl=64
5553	728.156264	209.85.137.147	192.168.2.3	ICMP	Echo (ping) reply id=0x1929, seq=136/34816, ttl=51
5556	729.139405	192.168.2.3	209.85.137.147	ICMP	Echo (ping) request id=0x1929, seq=137/35072, ttl=64
5557	729.157876	209.85.137.147	192.168.2.3	ICMP	Echo (ping) reply id=0x1929, seq=137/35072, ttl=51
5560	730.141015	192.168.2.3	209.85.137.147	ICMP	Echo (ping) request id=0x1929, seq=138/35328, ttl=64
5561	730.159095	209.85.137.147	192.168.2.3	ICMP	Echo (ping) reply id=0x1929, seq=138/35328, ttl=51
5575	731.141865	192.168.2.3	209.85.137.147	ICMP	Echo (ping) request id=0x1929, seq=139/35584, ttl=64
5576	731.161785	209.85.137.147	192.168.2.3	ICMP	Echo (ping) reply id=0x1929, seq=139/35584, ttl=51
5577	731.404307	192.168.2.3	203.178.141.194	ICMP	Echo (ping) request id=0x2929, seq=119/30464, ttl=64
5578	731.714096	203.178.141.194	192.168.2.3	ICMP	Echo (ping) reply id=0x2929, seq=119/30464, ttl=44
5581	732.142941	192.168.2.3	209.85.137.147	ICMP	Echo (ping) request id=0x1929, seq=140/35840, ttl=64
5582	732.162346	209.85.137.147	192.168.2.3	ICMP	Echo (ping) reply id=0x1929, seq=140/35840, ttl=51
5583	732.405846	192.168.2.3	203.178.141.194	ICMP	Echo (ping) request id=0x2929, seq=120/30720, ttl=64
5584	732.717306	203.178.141.194	192.168.2.3	ICMP	Echo (ping) reply id=0x2929, seq=120/30720, ttl=44
5587	733.144476	192.168.2.3	209.85.137.147	ICMP	Echo (ping) request id=0x1929, seq=141/36096, ttl=64
5588	733.162645	209.85.137.147	192.168.2.3	ICMP	Echo (ping) reply id=0x1929, seq=141/36096, ttl=51
5589	733.407206	192.168.2.3	203.178.141.194	ICMP	Echo (ping) request id=0x2929, seq=121/30976, ttl=64
5590	733.717366	203.178.141.194	192.168.2.3	ICMP	Echo (ping) reply id=0x2929, seq=121/30976, ttl=44
5593	734.145805	192.168.2.3	209.85.137.147	ICMP	Echo (ping) request id=0x1929, seq=142/36352, ttl=64
5594	734.167676	209.85.137.147	192.168.2.3	ICMP	Echo (ping) reply id=0x1929, seq=142/36352, ttl=51
5595	734.408255	192.168.2.3	203.178.141.194	ICMP	Echo (ping) request id=0x2929, seq=122/31232, ttl=64
5596	734.720334	203.178.141.194	192.168.2.3	ICMP	Echo (ping) reply id=0x2929, seq=122/31232, ttl=44
5599	735.146925	192.168.2.3	209.85.137.147	ICMP	Echo (ping) request id=0x1929, seq=143/36608, ttl=64
5600	735.165126	209.85.137.147	192.168.2.3	ICMP	Echo (ping) reply id=0x1929, seq=143/36608, ttl=51
5601	735.409215	192.168.2.3	203.178.141.194	ICMP	Echo (ping) request id=0x2929, seq=123/31488, ttl=64
5602	735.719137	203.178.141.194	192.168.2.3	ICMP	Echo (ping) reply id=0x2929, seq=123/31488, ttl=44
5605	736.147411	192.168.2.3	209.85.137.147	ICMP	Echo (ping) request id=0x1929, seq=144/36864, ttl=64
5606	736.165446	209.85.137.147	192.168.2.3	ICMP	Echo (ping) reply id=0x1929, seq=144/36864, ttl=51

File: "/Users/jounkorh/resea... : Packets: 9630 Displayed: 2233 Marked: 0 L... : Profile: Default

GGSN moved third IPv4 flow from 3G to WLAN

Filter: icmpv6 || icmp

No.	Time	Source	Destination	Protocol	Info
6282	784.217423	192.168.2.3	209.85.137.147	ICMP	Echo (ping) request id=0x1929, seq=192/49152, ttl=64
6284	784.240055	209.85.137.147	192.168.2.3	ICMP	Echo (ping) reply id=0x1929, seq=192/49152, ttl=51
6299	784.465046	192.168.2.3	203.178.141.194	ICMP	Echo (ping) request id=0x2929, seq=172/44032, ttl=64
6318	784.779172	203.178.141.194	192.168.2.3	ICMP	Echo (ping) reply id=0x2929, seq=172/44032, ttl=44
6327	785.219206	192.168.2.3	209.85.137.147	ICMP	Echo (ping) request id=0x1929, seq=193/49408, ttl=64
6328	785.237302	209.85.137.147	192.168.2.3	ICMP	Echo (ping) reply id=0x1929, seq=193/49408, ttl=51
6329	785.466044	192.168.2.3	203.178.141.194	ICMP	Echo (ping) request id=0x2929, seq=173/44288, ttl=64
6341	785.778685	203.178.141.194	192.168.2.3	ICMP	Echo (ping) reply id=0x2929, seq=173/44288, ttl=44
6344	786.220473	192.168.2.3	209.85.137.147	ICMP	Echo (ping) request id=0x1929, seq=194/49664, ttl=64
6345	786.238616	209.85.137.147	192.168.2.3	ICMP	Echo (ping) reply id=0x1929, seq=194/49664, ttl=51
6357	786.467294	192.168.2.3	203.178.141.194	ICMP	Echo (ping) request id=0x2929, seq=174/44544, ttl=64
6358	786.777256	203.178.141.194	192.168.2.3	ICMP	Echo (ping) reply id=0x2929, seq=174/44544, ttl=44
6361	787.129306	192.168.2.3	81.90.77.32	ICMP	Echo (ping) request id=0x2b29, seq=163/41728, ttl=64
6362	787.135845	81.90.77.32	192.168.2.3	ICMP	Echo (ping) reply id=0x2b29, seq=163/41728, ttl=55
6363	787.221795	192.168.2.3	209.85.137.147	ICMP	Echo (ping) request id=0x1929, seq=195/49920, ttl=64
6364	787.242006	209.85.137.147	192.168.2.3	ICMP	Echo (ping) reply id=0x1929, seq=195/49920, ttl=51
6365	787.468156	192.168.2.3	203.178.141.194	ICMP	Echo (ping) request id=0x2929, seq=175/44800, ttl=64
6366	787.778298	203.178.141.194	192.168.2.3	ICMP	Echo (ping) reply id=0x2929, seq=175/44800, ttl=44
6369	788.131004	192.168.2.3	81.90.77.32	ICMP	Echo (ping) request id=0x2b29, seq=164/41984, ttl=64
6370	788.132938	81.90.77.32	192.168.2.3	ICMP	Echo (ping) reply id=0x2b29, seq=164/41984, ttl=55
6371	788.223201	192.168.2.3	209.85.137.147	ICMP	Echo (ping) request id=0x1929, seq=196/50176, ttl=64
6372	788.241282	209.85.137.147	192.168.2.3	ICMP	Echo (ping) reply id=0x1929, seq=196/50176, ttl=51
6373	788.469167	192.168.2.3	203.178.141.194	ICMP	Echo (ping) request id=0x2929, seq=176/45056, ttl=64
6374	788.780286	203.178.141.194	192.168.2.3	ICMP	Echo (ping) reply id=0x2929, seq=176/45056, ttl=44
6377	789.132104	192.168.2.3	81.90.77.32	ICMP	Echo (ping) request id=0x2b29, seq=165/42240, ttl=64
6378	789.134191	81.90.77.32	192.168.2.3	ICMP	Echo (ping) reply id=0x2b29, seq=165/42240, ttl=55
6379	789.224426	192.168.2.3	209.85.137.147	ICMP	Echo (ping) request id=0x1929, seq=197/50432, ttl=64
6380	789.242853	209.85.137.147	192.168.2.3	ICMP	Echo (ping) reply id=0x1929, seq=197/50432, ttl=51
6381	789.470056	192.168.2.3	203.178.141.194	ICMP	Echo (ping) request id=0x2929, seq=177/45312, ttl=64

File: "/Users/jounkorh/resea... | Packets: 9630 Displayed: 2233 Marked: 0 L... | Profile: Default

Last comments..

- Both IPv4 and IPv6 offloading is doable.. but requires end host modification and standards push due the lack of IPv4 support. (it is there but not quite..)
- Note that the GGSN/PGW can only speak for itself. It cannot directly point traffic to other node/router. **The implicit “I don’t want traffic” approach only available.**
- Opposition in IETF due mixing IPv4 into IPv6..
- DHCP not that much better since there are own version for both IPv4 and IPv6; and lacks easy push semantics.
- There is no ANDSF/DM/MOs/etc in these experiments/solutions..
- GGSN/PGW would require a policy/configuration interface for dynamic triggering of RAs with routing information.