Adding IPv6 glue to the root zone

Ronald van der Pol
(Ronald.vanderPol@nlnetlabs.nl)

NLnet Labs
Amsterdam, The Netherlands

Daniel Karrenberg
(Daniel.Karrenberg@ripe.net)

RIPE NCC
Amsterdam, The Netherlands

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ABSTRACT

The experiment described in this document investigates the impact of adding IPv6 glue to the root zone to the number of truncated messages sent by a root server. This was done by replaying real life DNS traffic in a laboratory setup and counting the number of truncated messages. Measurements were done with both BIND 8 and NSD. Real life traffic from L root and K root (from both the AMS−IX and LINX) was used.

1. The problem of dropped glue

RFC 1035 [DOMAIN NAMES] limits the size of UDP DNS messages to 512 octets, not counting the IP and UDP headers. In case the full response to a query is longer than this limit, RR sets will be removed until the response message is less than 512 octets long. At first RR sets from the additinal section will be removed. These records contain the glue information.

In case the response message is still too long after removing the whole additional section, RR sets from the answer section will be removed. Omitting answer section RR sets is called truncation and is indicated by setting the TC bit in the message header.

Omitting glue is especially critical at the root because it is very often required by the DNS client to resolve the user request.

Therefore the delegation data entered in the root zone is carefully engineered such that response sizes for reasonable queries do not exceed the 512 octet limit. The specific queries matter here because the size of the response depends on the question asked, as this question is included in the response message. To make things even more complicated the specific name queried also influences the effectiveness of the name compression algorithm and thus the message size.

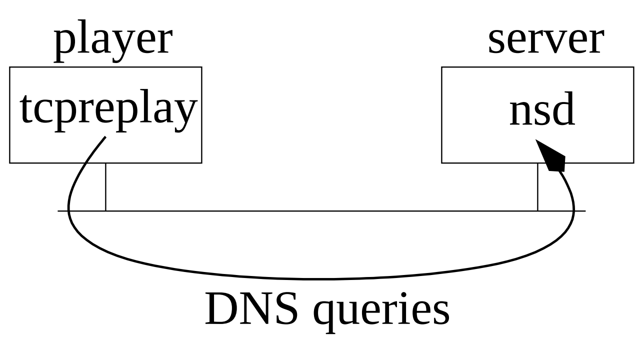
With the advent of IPv6 additional glue information is needed to point to the IPv6 addresses of name servers. The question how much glue can be safely added arises.

Since the queries have an influence on the answer in this work we use real observed queries to root servers. Our results are intended to complement the theoretical work by others [Vixie, Kato].

RFC 2671 [EDNS0] removes the maximum size limitation of UDP DNS messages. The problem of dropped glue will be absent for nameservers and resolvers that support EDNS0. It is expected that nameservers and resolvers that support IPv6 will also support EDNS0.

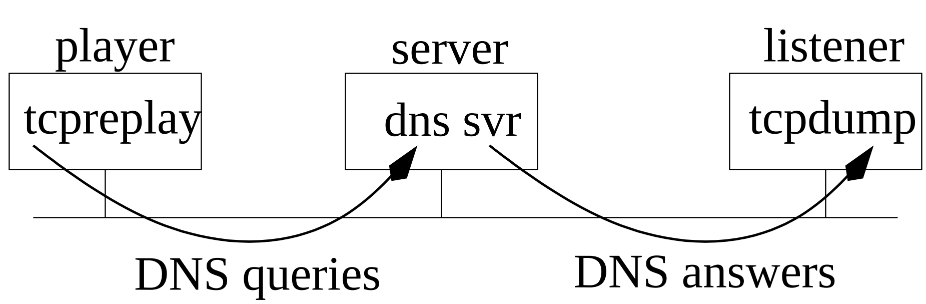
2. The experiment

The laboratory setup consists of an isolated network with two computers (see the picture below). One is the player and sends DNS queries to the the DNS server. The other is the server and acts as a root server.



The player runs a modified version of tcpreplay, a program that replays traffic from a saved tcpdump file. In this case tcpreplay sends real life DNS traffic to the root server running on the server computer. Initially, NSD was used as nameserver. It had some code added so that it could print the total number of queries received and the total number of replies with dropped glue it sent.

To verify the results a third computer, the listener, was added (see picture below). The listener uses tcpdump to capture the DNS replies sent by the root server of the server computer. By analyzing the tcpdump output, the total number of replies and the total number of replies with dropped glue was printed. This result was compared with the result from the internal NSD counters.



The same measurements were also done using BIND 8 as nameserver. In this case only the tcpdump output on the listener computer was analyzed.

3. Description of the real life traffic trace files

The operators of K root and L root provided dumps of real life DNS root traffic by capturing this traffic with tcpdump.

The dump of K root at the AMS-IX was done on 20030815 from 09:18:58 to 09:23:49. It consisted of 999210 packets with traffic from and to port 53 and ICMP traffic. From this dump the first 250,000 packets sent to UDP port 53 of the K root server were selected and written to a file.

The dump of K root at the LINX was done on 20030815 from 09:19:49 to 09:23:32. It consisted of 999452 packets with traffic from and to port 53 and ICMP traffic. From this dump the first 250,000 packets sent to UDP port 53 of the K root server were selected and written to a file.

The dump of L root was done on 20030803 from 20:57:57 to 21:01:57. It consisted of 1895955 packets with traffic from and to port 53 of the L root server. From this dump the first 250,000 packets sent to UDP port 53 of the L root server were selected and written to a file.

To use the traces mentioned above some preparation was needed. To be able to replay the traces with tcpreplay the destination IP and MAC addresses in the packets needed to be changed. The IP and MAC addresses of the K and L root servers were replaced by the IP and MAC addresses of the server computer in the laboratory network.

4. Results

The next sections show the main results of several measurements.

4.1. Adding glue currently in the DNS

Today, several TLDs have already added AAAA resource records to some of their nameservers. In this measurement, this glue was added to the root zone. To get a list of AAAA resource records the following procedure was followed:

(1) for all delegations in the root zone, ask the list of nameservers at a server authoritative for each delegated zone (note that this list may be larger than the list present in the root zone)

(2) for all these nameservers, get the AAAA RRs

This resulted in 39 AAAA RRs (see appendix A).

The AAAA RRs found with the procedure described above were added to the root zone and traces from K root at the LINX and AMS-IX and L root were run in the laboratory. The results were as follows. For a trace of K root at the AMS-IX, 129 out of 249964 replies had dropped glue. This equals to 0.1%. For a trace of K root at the LINX, 139 out of 249977 replies had dropped glue. This equals to 0.1%. For a trace of L root, 192 out of 249880 replies had dropped glue. This equals 0.1%. These results were obtained with the internal counter of NSD.

4.2. Adding one to five AAAA RRs to each zone

For all zones (delegations) IPv6 glue was added by including a AAAA resource record to a nameserver of that zone. All IPv6 addresses used were 8888:7777:6666:5555:4444:3333:2222:1111. The choice of the address does not influence the outcome of the measurements, because IPv6 addresses in DNS messages always take 16 octets of space.

A Perl script was used to cylcle through all domains. For each domain the following loop was performed:

(1) set N=5

(2) add AAAA RRs to N nameservers of this zone

(3) run traces

(4) if there was dropped glue, N--, goto (2)

(5) exit (goto next zone)

The results of this run are shown in the table below. Only the results with a significant number of drops are shown. The full results are shown in appendix B (the table only contains results for TLDs which had non-zero drops). The measurements were done with real life DNS traffic traces from K root at the LINX and AMS-IX and from L root. The first column (zone) shows the zone to which the AAAA resource records were added. The second column (glue) shows the amount of nameservers that had a AAAA resource record added. The next three columns show the results for the three kind of traces. The percentage shown is the amount of replies with dropped glue divided by the total amount of replies. A dash means there was no dropped glue.

		K @ LINX	K @ AMS-IX	L root
zone	# AAAA	drops	drops	drops
.	1	0.1%	-	0.1%
.	2	0.1%	-	0.1%
.	3	21.6%	20.1%	27.5%
.	4	21.6%	20.1%	27.6%
.	5	21.6%	20.1%	27.6%
COM	1	0.1%	0.1%	0.2%
COM	2	16.5%	24.4%	27.9%
COM	3	16.8%	25.2%	28.4%
COM	4	16.8%	25.2%	28.4%
COM	5	16.8%	25.2%	28.4%
DE	1	-	-	-
DE	2	0.7%	0.9%	0.5%
DE	3	0.9%	1.1%	0.6%
DE	4	0.9%	1.1%	0.6%
DE	5	0.9%	1.1%	0.6%
HK	1	-	-	-
HK	2	-	-	-
HK	3	0.1%	-	0.1%
HK	4	0.2%	-	0.1%
HK	5	0.2%	-	0.1%
MIL	1	0.1%	-	0.1%
MIL	2	0.1%	-	0.1%
MIL	3	21.6%	20.1%	27.6%
MIL	4	21.7%	20.4%	27.8%
MIL	5	21.7%	20.4%	27.8%
PL	1	-	-	-
PL	2	-	-	-
PL	3	0.1%	-	0.3%
PL	4	0.1%	-	0.3%
PL	5	0.1%	-	0.3%

5. Verification of the results

Appendix B shows the raw results of measurements with the K root trace at the LINX. The results are obtained in three different ways: the internal counter of NSD, traffic analysis of replies sent by NSD and traffic analysis of replies sent by BIND 8. From the table it is clear that all three measurement meachanisms are consistent with each other.

6. Conclusions

The results described in section 4.1 are about the glue that is currently in the DNS. Several TLD operators have already added IPv6 glue for some of their nameservers. This glue is not yet present in the root zone. The results show that adding this glue to the root zone has no negative effect on the operation of the root servers.

The results described in section 4.2 show that adding IPv6 addresses to up to five nameservers in the root zone has no negative effect for most of the delegations. There are a couple of exceptions. These are the zones that have maximized their glue, like .COM and .MIL. Answers relating to these zones already have a big additional section, leaving no space for IPv6 glue. Operators of these zones need to change their their glue setup. This can be done by choosing a naming scheme that allows for more compression (.MIL) or reducing the number of nameservers and adding IPv6 addresses to the remaining nameservers (.COM).

7. Futher work

We intend to look in more detail to the queries in the trace files.

We also want to look at what glue is removed by nameservers. It looks like they just remove some of the glue, without caring which. It might be better to always start with removing out-of-zone glue.

We invite operators of TLD zones to propose specific sets of glue for their TLD and have us test the drops with root server traces.

8. Acknowledgements.

We thank Gerard Leurs of RIPE NCC for providing us with DNS traces of K root and Steve Conte of ICANN for providing us with DNS traces of L root.

This work made extensive use of the DISTEL DNS Testing Laboratory developed at the RIPE NCC [RIPE 42]. This laboratory is now operational at NLnet Labs.

Some early results of this work were presented at the DNS/DNR working group at RIPE 46 in Amsterdam [RIPE 46]. We thank the working group for their input and suggestions.

References

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RIPE 46.
http://www.ripe.net/ripe/meetings/ripe-46/presentations/ripe46-dn-ipv6-glue/index.html.

Appendix A

Below are the 39 nameservers that currently have an IPv6 address.

a.dns.tw.	IN	AAAA	2001:cd8:800:0:2d0:c9ff:fe38:3527
d.dns.jp.	IN	AAAA	2001:240::53
d.dns.jp.	IN	AAAA	2001:240::53
d.dns.jp.	IN	AAAA	2001:240::53
dns.estpak.ee.	IN	AAAA	2001:7d0:0:e010::1
dns.nic.it.	IN	AAAA	2001:760:600:1::5
dns.ripe.net.	IN	AAAA	2001:610:240:0:53::193
domns1.dotdm.net.	IN	AAAA	::ffff:207.1.103.96
domreg.nic.ch.	IN	AAAA	2001:620:0:3:a00:20ff:fe85:9276
dot.ep.net.	IN	AAAA	2001:478:6:0:230:48ff:fe22:6a29
e.dns.jp.	IN	AAAA	2001:200:0:1::4
f.dns.jp.	IN	AAAA	2001:2f8:0:100::153
f.dns.jp.	IN	AAAA	2001:2f8:0:100::153
f.dns.jp.	IN	AAAA	2001:2f8:0:100::153
flag.ep.net.	IN	AAAA	3ffe:805::2d0:b7ff:fee8:c4d9
merapi.switch.ch.	IN	AAAA	2001:620:0:1:a00:20ff:fe88:a3f8
munnari.oz.au.	IN	AAAA	2001:388:c02:4000::1:21
ns-ext.vix.com.	IN	AAAA	2001:4f8:0:2::13
ns-ext.vix.com.	IN	AAAA	2001:4f8:0:2::13
ns-jp.sinet.ad.jp.	IN	AAAA	2001:2f8:0:100::153
ns.nic.ir.	IN	AAAA	2001:960:618:70::89
ns.nic.ir.	IN	AAAA	2001:960:618:70::89
ns.ripe.net.	IN	AAAA	2001:610:240:0:53::193
ns0.iij.ad.jp.	IN	AAAA	2001:240::53
ns1.dotdm.net.	IN	AAAA	::ffff:207.1.103.96
ns1.london.uk.netdns.com.	IN	AAAA	::ffff:212.62.6.38
ns1.newyork.us.netdns.com.	IN	AAAA	::ffff:216.32.212.86
ns1.sanfrancisco.us.netdns.com.	IN	AAAA	::ffff:207.82.50.166
ns1.sanfrancisco.us.netdns.com.	IN	AAAA	::ffff:207.82.50.166
ns1.seattle.us.netdns.com.	IN	AAAA	::ffff:206.253.214.13
ns1.tokyo.jp.netdns.com.	IN	AAAA	::ffff:64.56.164.118
ns2.free.net.	IN	AAAA	2001:640:1:1:220:edff:fe50:31e8
ns3.apnic.net.	IN	AAAA	2001:dc0:1:0:4777:131::
ns3.nic.fr.	IN	AAAA	2001:660:3006:1::1:1
persia.nic.ir.	IN	AAAA	2001:960:618:70::84
persia.nic.ir.	IN	AAAA	2001:960:618:70::84
scsnms.switch.ch.	IN	AAAA	2001:620::1
sec3.apnic.net.	IN	AAAA	2001:dc0:1:0:4777:140::
server.nordu.net.	IN	AAAA	2001:948:0:f005::42

Appendix B

These are the raw results of measurements with the trace of K root traffic at the LINX. Only the results with drops are shown. In other words: five additional AAAA RRs can be added to all current TLDs not appearing in this table without causing any glue to be dropped in our measurements.

The first column shows the zone, a slash and a number. The number is the amount of AAAA RRs added to the zone.

The second column shows the amount of replies with dropped glue, a slash, the total amount of replies and between parentheses the percentage of drops. These results are for BIND 8 running as nameserver on the server computer. The results were obtained by analyzing the traffic sent by BIND with the help of the listener computer.

The third column shows the amount of replies with dropped glue, a slash, the total amount of replies and between parentheses the percentage of drops. These resuls are for NSD running as nameserver on the server computer. The results were obtained with internal counters in NSD.

The fourth coulumn shows the amount of replies with dropped glue, a slash, the total amount of replies and between parentheses teh percentage of drops. These results are for NSD running as nameserver on the server computer. The results were obtained by analyzing the traffic sent NSD with the help of the listener computer.

	traffic of K root at the LINX (250.000 packets)		
	bind/traffic analysis	nsd/internal counter	nsd/traffic analysis
./1	244/249557 (0.10%)	244/249959 (0.10%)	244/249938 (0.10%)
./2	244/249525 (0.10%)	244/249947 (0.10%)	244/249926 (0.10%)
./3	53847/249520 (21.58%)	54178/249965 (21.67%)	54178/249944 (21.68%)
./4	53863/249492 (21.59%)	54199/249982 (21.68%)	54199/249961 (21.68%)
./5	53871/249530 (21.59%)	54190/249947 (21.68%)	54190/249926 (21.68%)
AN/4	5/249529 (0.00%)	5/249976 (0.00%)	5/249955 (0.00%)
AN/5	5/249512 (0.00%)	5/249981 (0.00%)	5/249960 (0.00%)
AR/5	58/249543 (0.02%)	58/249960 (0.02%)	58/249939 (0.02%)
ARPA/1	243/249556 (0.10%)	244/249930 (0.10%)	244/249909 (0.10%)
ARPA/2	244/249560 (0.10%)	244/249961 (0.10%)	244/249940 (0.10%)
ARPA/3	53847/249517 (21.58%)	54162/249929 (21.67%)	54162/249908 (21.67%)
ARPA/4	53872/249523 (21.59%)	54197/249943 (21.68%)	54197/249922 (21.69%)
ARPA/5	53866/249497 (21.59%)	54193/249938 (21.68%)	54193/249917 (21.68%)
AT/5	1/249479 (0.00%)	2/249922 (0.00%)	2/249901 (0.00%)
AU/5	3/249512 (0.00%)	2/249933 (0.00%)	2/249913 (0.00%)
BT/4	3/249543 (0.00%)	3/249947 (0.00%)	3/249926 (0.00%)
BT/5	3/249541 (0.00%)	3/249931 (0.00%)	3/249910 (0.00%)
CL/4	9/249545 (0.00%)	10/249954 (0.00%)	10/249933 (0.00%)
CL/5	98/249539 (0.04%)	98/249965 (0.04%)	98/249944 (0.04%)
COM/1	139/249524 (0.06%)	129/249929 (0.05%)	129/249908 (0.05%)
COM/2	41082/249523 (16.46%)	40934/249986 (16.37%)	40919/249965 (16.37%)
COM/3	41921/249507 (16.80%)	41942/249920 (16.78%)	41927/249899 (16.78%)
COM/4	41936/249550 (16.80%)	41950/249972 (16.78%)	41935/249951 (16.78%)
COM/5	41240/245559 (16.79%)	41948/249945 (16.78%)	41933/249924 (16.78%)
CZ/5	25/249549 (0.01%)	24/249934 (0.01%)	24/249913 (0.01%)
DE/2	1823/249522 (0.73%)	1827/249943 (0.73%)	1827/249922 (0.73%)
DE/3	2116/249549 (0.85%)	2117/249925 (0.85%)	2117/249904 (0.85%)
DE/4	2116/249548 (0.85%)	2116/249942 (0.85%)	2116/249921 (0.85%)
DE/5	2116/249552 (0.85%)	2117/249942 (0.85%)	2117/249921 (0.85%)
EDU/3	68/249537 (0.03%)	68/249958 (0.03%)	68/249937 (0.03%)
EDU/4	68/249497 (0.03%)	68/249960 (0.03%)	68/249939 (0.03%)
EDU/5	68/249523 (0.03%)	68/249910 (0.03%)	68/249889 (0.03%)
FR/5	63/249541 (0.03%)	61/249949 (0.02%)	61/249928 (0.02%)
GG/5	2/249504 (0.00%)	2/249939 (0.00%)	2/249918 (0.00%)
GOV/3	68/249522 (0.03%)	68/249991 (0.03%)	68/249970 (0.03%)
GOV/4	68/249475 (0.03%)	68/249990 (0.03%)	68/249969 (0.03%)
GOV/5	68/249548 (0.03%)	68/249946 (0.03%)	68/249925 (0.03%)

	traffic of K root at the LINX (250.000 packets) (cont'd)		
	bind/traffic analysis	nsd/internal counter	nsd/traffic analysis
HK/3	218/249534 (0.09%)	218/249941 (0.09%)	218/249920 (0.09%)
HK/4	510/249519 (0.20%)	510/249937 (0.20%)	510/249916 (0.20%)
HK/5	510/249550 (0.20%)	510/249919 (0.20%)	510/249898 (0.20%)
HR/5	21/249539 (0.01%)	21/249905 (0.01%)	21/249884 (0.01%)
IE/3	9/249478 (0.00%)	9/249942 (0.00%)	9/249921 (0.00%)
IE/4	77/249549 (0.03%)	77/249969 (0.03%)	77/249948 (0.03%)
IE/5	80/249486 (0.03%)	80/249964 (0.03%)	80/249943 (0.03%)
IN/3	3/249516 (0.00%)	3/249955 (0.00%)	3/249934 (0.00%)
IN/4	72/249546 (0.03%)	72/249951 (0.03%)	72/249930 (0.03%)
IN/5	72/249553 (0.03%)	72/249954 (0.03%)	72/249933 (0.03%)
IT/5	82/249536 (0.03%)	77/249949 (0.03%)	77/249928 (0.03%)
JE/5	2/249507 (0.00%)	2/249951 (0.00%)	2/249930 (0.00%)
MIL/1	244/249515 (0.10%)	244/249927 (0.10%)	244/249906 (0.10%)
MIL/2	244/249521 (0.10%)	244/249943 (0.10%)	244/249922 (0.10%)
MIL/3	53871/249555 (21.59%)	54193/249912 (21.68%)	54193/249891 (21.69%)
MIL/4	54021/249561 (21.65%)	54346/249971 (21.74%)	54346/249950 (21.74%)
MIL/5	54026/249560 (21.65%)	54341/249962 (21.74%)	54341/249941 (21.74%)
NAME/3	68/249502 (0.03%)	68/249923 (0.03%)	68/249902 (0.03%)
NAME/4	68/249552 (0.03%)	68/249951 (0.03%)	68/249930 (0.03%)
NAME/5	68/249529 (0.03%)	68/249943 (0.03%)	68/249922 (0.03%)
NET/1	139/249557 (0.06%)	129/249896 (0.05%)	129/249875 (0.05%)
NET/2	41089/249530 (16.47%)	40930/249962 (16.37%)	40915/249941 (16.37%)
NET/3	41935/249556 (16.80%)	41949/249974 (16.78%)	41934/249953 (16.78%)
NET/4	41930/249547 (16.80%)	41936/249935 (16.78%)	41921/249914 (16.77%)
NET/5	41936/249558 (16.80%)	41951/249961 (16.78%)	41936/249940 (16.78%)
PH/4	3/249490 (0.00%)	3/249967 (0.00%)	3/249946 (0.00%)
PH/5	3/249528 (0.00%)	3/249929 (0.00%)	3/249908 (0.00%)
PL/3	149/249528 (0.06%)	149/249979 (0.06%)	149/249958 (0.06%)
PL/4	149/249542 (0.06%)	149/249935 (0.06%)	149/249914 (0.06%)
PL/5	149/249532 (0.06%)	149/249980 (0.06%)	149/249959 (0.06%)
PY/5	1/249527 (0.00%)	1/249957 (0.00%)	1/249936 (0.00%)
RO/4	22/249521 (0.01%)	21/249901 (0.01%)	21/249880 (0.01%)
RO/5	22/249548 (0.01%)	21/249961 (0.01%)	21/249940 (0.01%)
SI/5	7/249559 (0.00%)	6/249892 (0.00%)	0/249871 (0.00%)
SK/5	25/249536 (0.01%)	24/249963 (0.01%)	0/249942 (0.00%)
SR/4	68/249485 (0.03%)	68/249966 (0.03%)	0/249945 (0.00%)
SR/5	68/249549 (0.03%)	68/249882 (0.03%)	0/249862 (0.00%)
UY/4	3/249524 (0.00%)	3/249931 (0.00%)	0/249910 (0.00%)
UY/5	81/249563 (0.03%)	81/249962 (0.03%)	0/249941 (0.00%)

Appendix B

These are the raw results for the measurements with the traces of K root at the LINX and the AMS-IX and of L root. The first column shows the zone, a slash and a number indicating the amount of AAAA RRs added to the zone.

The second column shows the results of the internal counters of NSD. It shows the amount of replies with dropped glue, a slash, the total amount of replies and between parentheses the percentage of drops. These results are for the trace of K root at the LINX.

The third column shows the same results, but for the trace of K root at the AMS−IX.

The fourth column shows the same results, but for the trace of L root.

	K @ LINX drops	K @ AMS-IX drops	L root drops
./1	244/249959 (0.10%)	82/249960 (0.03%)	347/249893 (0.14%)
./2	244/249947 (0.10%)	82/249860 (0.03%)	347/249876 (0.14%)
./3	54178/249965 (21.67%)	50130/249972 (20.05%)	68781/249957 (27.52%)
./4	54199/249982 (21.68%)	50156/249971 (20.06%)	68907/249855 (27.58%)
./5	54190/249947 (21.68%)	50114/249824 (20.06%)	68921/249919 (27.58%)
AC/5	-	-	1/249785 (0.00%)
AN/4	5/249976 (0.00%)	2/249926 (0.00%)	4/249893 (0.00%)
AN/5	5/249981 (0.00%)	2/249923 (0.00%)	4/249859 (0.00%)
AR/5	58/249960 (0.02%)	69/249961 (0.03%)	178/249830 (0.07%)
ARPA/1	244/249930 (0.10%)	82/249956 (0.03%)	347/249879 (0.14%)
ARPA/2	244/249961 (0.10%)	82/249827 (0.03%)	347/249946 (0.14%)
ARPA/3	54162/249929 (21.67%)	50130/249972 (20.05%)	68769/249905 (27.52%)
ARPA/4	54197/249943 (21.68%)	50157/249966 (20.07%)	68919/249935 (27.57%)
ARPA/5	54193/249938 (21.68%)	50155/249931 (20.07%)	68884/249842 (27.57%)
AT/5	2/249922 (0.00%)	16/249972 (0.01%)	6/249886 (0.00%)
AU/5	2/249933 (0.00%)	-	-
BT/4	3/249947 (0.00%)	-	2/249843 (0.00%)
BT/5	3/249931 (0.00%)	-	2/249911 (0.00%)
CL/4	10/249954 (0.00%)	9/249959 (0.00%)	82/249880 (0.03%)
CL/5	98/249965 (0.04%)	187/249957 (0.07%)	483/249897 (0.19%)
COM/1	129/249929 (0.05%)	359/249959 (0.14%)	567/249801 (0.23%)
COM/2	40934/249986 (16.37%)	60995/249952 (24.40%)	69731/249919 (27.90%)
COM/3	41942/249920 (16.78%)	62883/249963 (25.16%)	71010/249904 (28.41%)
COM/4	41950/249972 (16.78%)	62886/249972 (25.16%)	71018/249896 (28.42%)
COM/5	41948/249945 (16.78%)	62871/249903 (25.16%)	70924/249624 (28.41%)
CZ/3	-	1/249920 (0.00%)	2/249860 (0.00%)
CZ/4	-	9/249943 (0.00%)	2/249890 (0.00%)
CZ/5	24/249934 (0.01%)	90/248853 (0.04%)	117/249843 (0.05%)
DE/2	1827/249943 (0.73%)	2117/249923 (0.85%)	1137/249939 (0.45%)
DE/3	2117/249925 (0.85%)	2674/249905 (1.07%)	1404/249734 (0.56%)
DE/4	2116/249942 (0.85%)	2674/249972 (1.07%)	1404/249883 (0.56%)
DE/5	2117/249942 (0.85%)	2673/249939 (1.07%)	1404/249929 (0.56%)
EDU/3	68/249958 (0.03%)	83/249960 (0.03%)	7/249963 (0.00%)
EDU/4	68/249960 (0.03%)	83/249972 (0.03%)	7/249773 (0.00%)
EDU/5	68/249910 (0.03%)	83/249948 (0.03%)	7/249923 (0.00%)
ES/5	-	1/249965 (0.00%)	1/249888 (0.00%)
FR/5	61/249949 (0.02%)	1/249886 (0.00%)	20/249692 (0.01%)

	K @ LINX drops	K @ AMS-IX drops	L root drops
GE/3	-	1/249969 (0.00%)	2/249803 (0.00%)
GE/4	-	9/249967 (0.00%)	2/249817 (0.00%)
GE/5	-	9/249972 (0.00%)	2/249832 (0.00%)
GG/5	2/249939 (0.00%)	7/249933 (0.00%)	6/249803 (0.00%)
GOV/3	68/249991 (0.03%)	83/249926 (0.03%)	7/249935 (0.00%)
GOV/4	68/249990 (0.03%)	83/249921 (0.03%)	7/249818 (0.00%)
GOV/5	68/249946 (0.03%)	83/249972 (0.03%)	7/249952 (0.00%)
HK/3	218/249941 (0.09%)	62/249914 (0.02%)	193/249887 (0.08%)
HK/4	510/249937 (0.20%)	80/249960 (0.03%)	233/249908 (0.09%)
HK/5	510/249919 (0.20%)	80/249860 (0.03%)	233/249916 (0.09%)
HR/4	-	8/249968 (0.00%)	-
HR/5	21/249905 (0.01%)	90/249960 (0.04%)	113/249937 (0.05%)
IE/3	9/249942 (0.00%)	22/249894 (0.01%)	6/249816 (0.00%)
IE/4	77/249969 (0.03%)	154/249945 (0.06%)	167/249876 (0.07%)
IE/5	80/249964 (0.03%)	154/249951 (0.06%)	169/249809 (0.07%)
IN/3	3/249955 (0.00%)	-	2/249898 (0.00%)
IN/4	72/249951 (0.03%)	357/249896 (0.14%)	230/249879 (0.09%)
IN/5	72/249954 (0.03%)	357/249940 (0.14%)	230/249832 (0.09%)
IS/3	-	1/249970 (0.00%)	2/249853 (0.00%)
IS/4	-	9/249972 (0.00%)	2/249897 (0.00%)
IS/5	-	9/249972 (0.00%)	2/248611 (0.00%)
IT/5	77/249949 (0.03%)	56/249972 (0.02%)	116/249899 (0.05%)
JE/5	2/249951 (0.00%)	7/249971 (0.00%)	6/249911 (0.00%)
LV/2	-	1/249845 (0.00%)	2/249842 (0.00%)
LV/3	-	9/249960 (0.00%)	2/249933 (0.00%)
LV/4	-	9/249965 (0.00%)	2/249898 (0.00%)
LV/5	-	9/249951 (0.00%)	2/249885 (0.00%)
MIL/1	244/249927 (0.10%)	82/249972 (0.03%)	347/249870 (0.14%)
MIL/2	244/249943 (0.10%)	82/249964 (0.03%)	347/249901 (0.14%)
MIL/3	54193/249912 (21.68%)	50152/249931 (20.07%)	68862/249768 (27.57%)
MIL/4	54346/249971 (21.74%)	50921/249960 (20.37%)	69393/249958 (27.76%)
MIL/5	54341/249962 (21.74%)	50923/249960 (20.37%)	69360/249864 (27.76%)
MT/5	-	1/249795 (0.00%)	2/249924 (0.00%)
NAME/3	68/249923 (0.03%)	83/249939 (0.03%)	7/249901 (0.00%)
NAME/4	68/249951 (0.03%)	83/249972 (0.03%)	7/249663 (0.00%)
NAME/5	68/249943 (0.03%)	83/249888 (0.03%)	7/249908 (0.00%)

	K @ LINX drops	K @ AMS-IX drops	L root drops
NET/1	129/249896 (0.05%)	359/249972 (0.14%)	567/249890 (0.23%)
NET/2	40930/249962 (16.37%)	61002/249972 (24.40%)	69729/249910 (27.90%)
NET/3	41949/249974 (16.78%)	62886/249972 (25.16%)	71009/249914 (28.41%)
NET/4	41936/249935 (16.78%)	62882/249956 (25.16%)	70993/249907 (28.41%)
NET/5	41951/249961 (16.78%)	62852/249927 (25.15%)	71008/249911 (28.41%)
NL/5	-	1/249952 (0.00%)	2/249756 (0.00%)
PH/4	3/249967 (0.00%)	-	2/249793 (0.00%)
PH/5	3/249929 (0.00%)	-	2/249833 (0.00%)
PL/2	-	1/249967 (0.00%)	2/249657 (0.00%)
PL/3	149/249979 (0.06%)	82/249972 (0.03%)	695/249958 (0.28%)
PL/4	149/249935 (0.06%)	82/249959 (0.03%)	695/249841 (0.28%)
PL/5	149/249980 (0.06%)	82/249939 (0.03%)	695/249950 (0.28%)
PY/5	1/249957 (0.00%)	-	-
RO/3	-	8/249972 (0.00%)	-
RO/4	21/249901 (0.01%)	91/249937 (0.04%)	115/249954 (0.05%)
RO/5	21/249961 (0.01%)	91/249965 (0.04%)	115/249795 (0.05%)
SI/5	6/249892 (0.00%)	7/249959 (0.00%)	2/249858 (0.00%)
SK/3	-	1/249928 (0.00%)	2/249890 (0.00%)
SK/4	-	9/249972 (0.00%)	2/249890 (0.00%)
SK/5	24/249963 (0.01%)	91/249954 (0.04%)	117/249896 (0.05%)
SR/4	68/249966 (0.03%)	83/249900 (0.03%)	7/249893 (0.00%)
SR/5	68/249882 (0.03%)	83/249919 (0.03%)	7/249927 (0.00%)
TM/5	-	-	1/249825 (0.00%)
UY/4	3/249931 (0.00%)	-	2/249852 (0.00%)
UY/5	81/249962 (0.03%)	379/249918 (0.15%)	236/249899 (0.09%)
ZA/4	-	120/249855 (0.05%)	108/249716 (0.04%)
ZA/5	-	180/249972 (0.07%)	1038/249864 (0.42%)