Analysis of IPv6 deployment survey responses

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Introduction

In 2012, CAIDA published a survey of 23 questions to operational venues (i.e., NANOG, RIPE) for network operators, soliciting information regarding the status of their IPv4 pool and their plans for the IPv4 address run-out. More specifically the questions inquired about the networks type of activity, address space usage, future needs for IPv4 addresses, size and overhead of Carrier Grade NAT (CGN) deployment and their plans to adapt to the IPv4 address space run-out. Appendix A lists the questions published in the survey.
We collected responses from *65 network operators*, that we analyze and extract our understanding of the networks future plans for the IPv6 adoption process.

Primary activity of the networks

In question 1 we ask operators to choose a primary activity from a set of eight pre-defined categories. Using these categories, we devise the following five bussines classes: *Transit providers*, *Enterprise customers*, *Content providers*, *Hostng providers* and *Access providers*:

- Access Providers (AP): Access Provider (e.g., Cable, DSL, Wireless);
- Content Providers (CP) : Content Provider;
- Enterprise Customers(EC) : Enterprise Network, Research and Education Network, Other;
- Hosting Providers (HP) : Hosting/data center;
- Transit Providers (TP) : Transit Provider;

We count how many of the responding networks are in each bussiness class and list the numbers in table 1. 42% of the responses come from EC networks, while 6.25% are Transit networks.

Table 1: Network Bussiness Types

No	Type	Number of networks	Primary Activity (Number of networks)
1	Access Providers (AP)	14	Access Provider (14)
2	Content Providers (CP)	7	Content Provider (7)
3	Enterprise Customers(EC)	27	Enterprise Network (13) Research and Education Network (9) Other (5)
4	Hosting Providers (HP)	12	Hosting/data cente (12)
5	Transit Providers (TP)	4	Transit Provider (4)
	Total	64	

Usage of IPv4 addresses

For a given network, we define the *usage fraction (f)* as the ratio between the number of devices (entities) that require an IPv4 address in order to communicate with the public Internet and the total size of the IPv4 address pool. Based on the value of *f*, we group the networks into three classes:

- Organizations with surplus of IPv4 addresses: $0 \leq f < 1$:
- Organization that use all their available IPv4 addresses: $f = 1$;
- Organization with a deficit of IPv4 addresses: $1 < f$;

We exclude from this analysis 10 networks from the total of 65; for eight networks, the responses did not comprise both values necessary for computing *f*, and for the two networks, the values provided are not accurate (i.e., network 111 - the number of addresses in the IPv4 pool is equal to 0, and network 123 - the fraction is equal to 250). Table 2 details the excluded networks; N is the number of devices that require an IPv4 address, and M is the number of addresses allocated.
For the remaning 55 networks, we compute the *usage fraction*, and plot the distribution of the fraction in figure 1. We find: 45 (i.e., 81.81%) and 7 (i.e., 12.72%) networks have a IP address suplus ($f < 1$) and deficit ($f > 1$), respectively; for 4 networks the fractions is equal to one.We conclude that for most of the network have a suplus of IP addresses. Further, we analyze the usage fraction for each bussiness type; Table 3 lists for each bussiness class, the 1Q, mean, median and 3Q of the fractions of networks within that class.

As expected, the 3Q for all the bussiness types are below 1. We observe the highest value for Enterprise Customers(EC) and Hosting Providers (HP). Moreover, the media value of the fraction for these network classes is above 1. Thus, within these two classes existis a few networks that have IPv4 address deficit.

Table 2: Networks excluded from computing the usage of IPv4 addresses

Network ID	Primary activity	N	M	f	ASN	Organization
111	Hosting/data center	2000	8	250	16206	Pittsburgh Supercomputing Center
123	Access Provider	25000	0	NA	40328	Ace Communications Group
105	Other	NA	NA	NA	21502	NC Numericable S.A.
123	Research&Education Network	0	NA	NA	2637	Georgia Institute of Technology
125	Other	NA	NA	NA	20357	Baja Broadband
128	Hosting/data center	100000	NA	NA	NA	NA
130	Enterprise Network	2048	NA	NA	19907	NeuStar, Inc.
142	Enterprise Network	NA	NA	NA	3215	France Telecom S.A.
144	Enterprise Network	30000	NA	NA	6067	Onyx Internet Ltd
161	Hosting/data center	1000	NA	NA	55850	TrustPower Ltd

Table 3: Usage fraction statistics of each bussiness type of network

No	Type	Number of networks	1Q	3Q	Median	Mean
1	Access Providers (AP)	12	0.097	0.71	0.52	0.48
2	Content Providers (CP)	7	0.24	0.81	0.488	0.53
3	Enterprise Customers(EC)	22	0.14	0.94	0. 4	1.39
4	Hosting Providers (HP)	10	0.08	0.94	0.75	25.55
5	Transit Providers (TP)	4	0.12	0.34	0.20	0.26

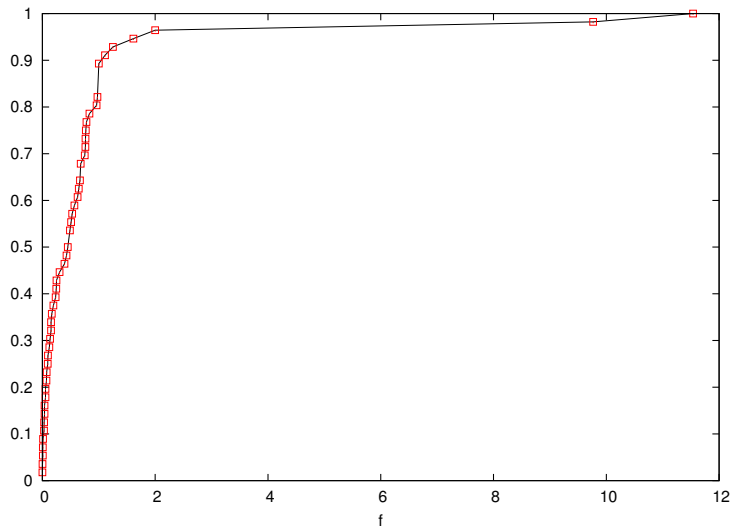

Figure 1: CDF of the usage fraction

Table 4: Excluded networks: not valid

Network ID	Primary activity	Usage fraction (f)	ASN	Organisation
102	Content Provider	0.054	12637	Seeweb s.r.l.
103	Other	0.781	31019	Meanie
104	Other	1	1955	Nemzeti Informacios Infrastruktura Fejlesztesi Iroda
105	Other	NA	21502	NC Numericable S.A.
106	Access Provider	0.625	4181	TDS TELECOM
107	Hosting/data center	0.762	6734	Spin s.r.l.
142	Enterprise Network	NA	3215	France Telecom S.A

Address Mix of the Networks

In question 3 from the survey we ask networks to provide the percentage of devices (end users) in each of the following categories:

- Duat-stack (DS): Devices have assigned public IPv4 and IPv6 addresses;
- IPv4 addresses (IPv4): Devices have assigned public IPv4 addresses, and use transition technologies to access the IPv6 Internet;
- IPv6 addresses (IPv6): Devices have assigned public IPv6 addresses, and use transition technologies to access the IPv4 Internet; (e.g., DS-Lite, DNS64/NAT64);
- only IPv4 addresses (oIPv4): Devices that can access only the IPv4 Internet;
- only IPv6 addresses (oIPv6): Devices that can access only the IPv6 Internet;

Seven networks did not provide information about their end users (see table 4). Consequently, we exclude these network from the analysis. For the remaining 58 networks, we extract the statistics of the percentage for each categories and list these values in table 5. As expected, we observe the highest 3Q values for *DS* and *oIPv4* categories. Moreover, for the latter category we also obtain the highest median value. We show in figure 2 the CDF for each type of address class; we represent each bussiness type with a diffrent symbol. Across all networks, we observe that most of the devices are group in one of the defined classes.

Table 5: Statistics of each type of network

Nr.crt.	Type	Min	Max	1Q	3Q	Median	Mean
1	DS	0	100	1	50	5	29.17
2	IPv4	0	100	0	0.09	0	10.066
3	IPv6	0	97	0	0	0	2.49
4	oIPv4	0	100	8.58	99	90	63.36
5	oIPv6	0	5	0	0	0	0.14

Table 6: Summary address mix for percentage equal to approx. 100%

Type	AP	CP	EC	HP	TP
DS	1	2	3	4	2
IPv4	1	0	1	1	0
IPv6	0	0	0	1	0
oIPv4	10	4	11	4	1
oIPv6	0	0	0	0	0

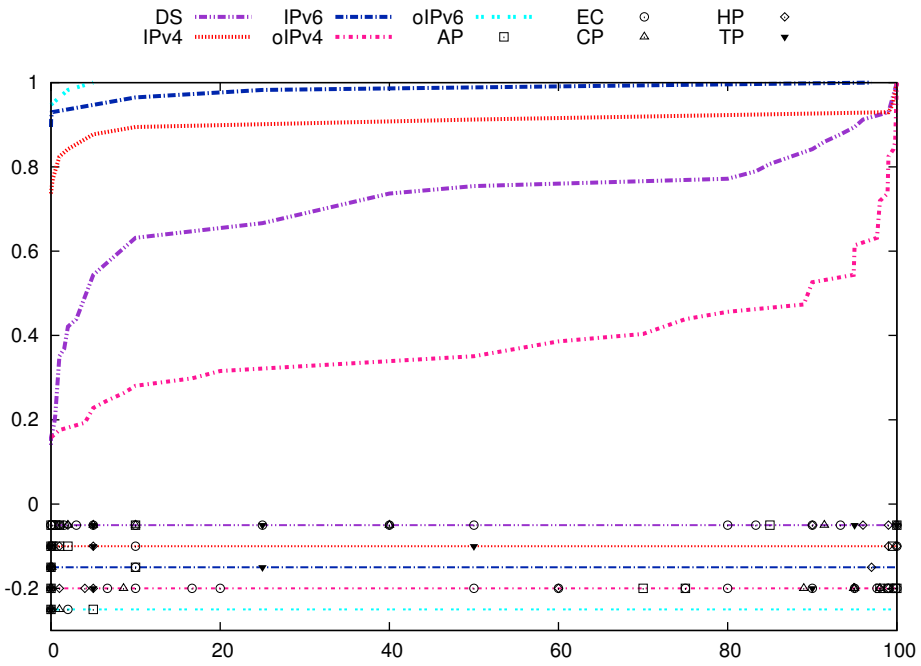

Figure 2: CDF of percentages for each address class (DS, IPv4, IPv6, oIPv4, oIPv6)

IPv4 address space

For each network, we count the number of /24 IPv4 address block and show the distribution of these values in figure 3. Table 7 lists statistics of the number of /24s for each bussiness class. We exclude network 166 from our analysis. Our analysis shows that *EC*, *AP* and *HP* have the highest number of /24s; the median value for these types of networks is EC - 254.95, AP - 140.62 and HP - 105.42.

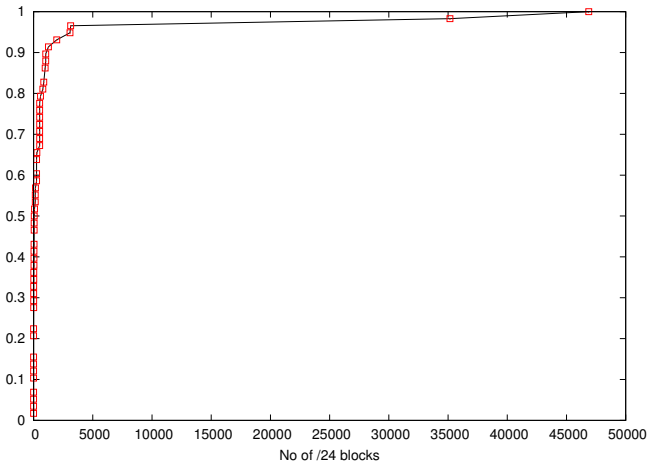

Figure 3: Number of /24 blocks

Table 7: Statistics of each type of network

No	Type	Number of networks	1Q	3Q	Median	Mean
1	Access Providers (AP)	13	46.87	1024	140.62	4281.08
2	Content Providers (CP)	7	0.77	88	17.57	139.51
3	Enterprise Customers(EC)	22	1.25	515.21	254.95	399.57
4	Hosting Providers (HP)	10	24.41	447.78	105.46	3671.35
5	Transit Providers (TP)	4	9.04	103.51	29.3	83.25

Address utilisation

In question 5 we ask networks to provide percentages of IPv4 addresses assigned from their IPv4 address pool assigned to the following categories:

- Servers/services that need a public IPv4 address ;
- Hosts that can potentially be put behind a NAT44 ;
- Used for the public side of a NAT44 ;
- Used for the public side of a NAT64;
- Uncommitted;

The Table 8 lists the excluded networks. We analyze the responses from 51 networks that provided the percentages for the above categories are given.
Table 9 lists statistics for the above categories. We compute the same statistics for each of the five bussiness types. We find that for CP, HP and TP networks use most of the IPs for *Services* that need a public IPv4 address. In the case of AP networks, most of the IPs are assigned to *Private* class - hosts that can potentially be put behind the a NAT device. In the case of EC network, most of the IPs are assigned to the *Uncommitted* category.

Table 8: Excluded networks

Network ID	Primary activity	Servers/Services	Private	PublNAT44	PubNAT64	Uncommited
105	Other	NA	NA	NA	NA	NA
106	Access Provider	6.25	56.25	NA	12.5	NA
110	Transit Provider	90	NA	NA	NA	NA
114	Content Provider	40	NA	NA	NA	22
115	Research&Education	1	NA	NA	NA	NA
120	Research&Education	NA	NA	NA	NA	NA
125	Other	NA	NA	NA	NA	NA
126	Enterprise Network	5	5	2	0	NA
128	Hosting/data center	NA	NA	NA	NA	NA
137	Enterprise Network	NA	NA	NA	NA	6.81
142	Enterprise Network	NA	NA	NA	NA	NA
144	Enterprise Network	NA	NA	NA	NA	NA
161	Hosting/data center	NA	NA	NA	NA	NA
163	Access Provider	NA	NA	NA	NA	NA
168	Access Provider	NA	NA	NA	NA	NA

Table 9: Statistics IPv4 address utilisation

No	Type	Min	Max	1Q	3Q	Median	Mean
1	Services	0.07	100	10	73.75	50	42.653
2	Private	0	100	0	32.5	10	20.874
3	Public NAT44	0	90	0	5	0	6.53
4	Public NAT64	0	30	0	0	0	1.53
5	Uncommitted	0	99	0.25	38.75	22.5	28.54

Table 10: Statistics IPv4 address utilisation per network type

No	Type	Median	Mean
	Access Providers	Total	10
1	Services	10	26.8
2	Private	24.5	39.5
3	Public NAT44	0	14
4	Public NAT64	0	0
5	Uncommitted	17.5	20.7
	Content Providers	Total	6
1	Services	56.05	54.51
2	Private	0	16.66
3	Public NAT44	0	2.6
4	Public NAT64	0	1.91
5	Uncommitted	22.91	20.97
	Enterprise Customers	Total	21
1	Services	16.7	36.41
2	Private	0	19.79
3	Public NAT44	0	5.19
4	Public NAT64	0	2.14
5	Uncommitted	25	37.25
	Hosting Providers	Total	9
1	Services	70	66.77
2	Private	10	12
3	Public NAT44	0	0.77
4	Public NAT64	0	2.22
5	Uncommitted	10	18.22
	Transit Providers	Total	3
1	Services	66.67	55.55
2	Private	0	8.3
3	Public NAT44	0	16.66
4	Public NAT64	0	0
5	Uncommitted	25	19.44

IPv4 address depletion

We consider question 9 from the surve - near term plans (i.e,. within 18 months) on dealing with the depletion of the IPv4 address pool. Out of the total 65 networks, 58 provided a valid answer for this question. Table 11 lists the networks that do not provide an answer for this question.

Table 11: Excluded networks: no near term plans

Network ID	Primary activity	ASN	Organization
105	Other	21502	NC Numericable S.A.
115	Research and Education Network	5739	University of California, Santa Cruz
120	Research and Education Network	2637	Georgia Institute of Technology
128	Hosting/data center	NA	NA
144	Enterprise Network	6067	Onyx Internet Ltd
161	Hosting/data center	55850	TrustPower Ltd
163	Access Provider	4768	TelstraClear Ltd

For the remaining 58 network, we detail the near term plans regarding the IPv4 address depletion in table 12. A network could have provided multiple answers. We count how many actions each networks providedr, and group the networks based on this number (see Table 13; most of the networks responded in the survey with either one or two possible such actions. Among the networks that offered only one possible action, we find two networks that replied *Do nothing*: network 125 and network 152. We hypothesis that these networks have either *sufficient* IPv4 addresses, or they have IPv6 deployed in a large part of their network. Also, 14 and 7 networks consider *Deploy IPv6* and *Transfer IPv4 addresses from elsewhere to my organization* as the only possible actions. Most networks that provided two actions as their near term plan for the IPv4 depletion, consider *Deploy IPv6* as one these action. Also, approx. 30% of the networks consider the other actions to be *Transfer IPv4 addresses from elsewhere to my organization*.

Table 12: IPv4 depletion actions

Nr.crt.	Action	Number of networks
1	Do nothing	14
2	Deploy IPv6	39
3	Deploy Carrier Grade NAT	6
4	Deploy DS-Lite	0
5	Deploy other IPv6/IPv4 protocol translation technology	8
6	We have enough IPv4 addresses	4
7	Transfer IPv4 addresses from elsewhere to my organization	25
8	Other	10

Question 10 targeted the IPv4 address need of the networks. For this question, we obtained valid answers from 51 networks. Out of these network, three expect to reduce their address need; all of these considered *Deploy IPv6* as a future action to the IPv4 address space depletion. This hints that these networks are have already started the process of IPv6 adoption.
Further, we consider network that provided non-negative replies to our question; half of the network replied zero - these networks do not need more address space, while the other half provided a positive value - thesse networks do not appear to satidfy their current IPv4 address need. For networks in the former categorty, we find the median usage fraction (f) to be 0.42. However, for 25% of these networks the fraction greater than 0.70. As expected, networks in the latter category have a higher value of the usage fraction; i.e., median value is 0.64 and 3Q is 0.99. We note that this analysis does not comprises network 111 and network 123 as these do not provide the required precentage for this analysis.
85% of the considered networks have need less that 6000 addresses.

Table 13: IPv4 depletion actions

Actions	Actions	No of networks
1	Do nothing	2
	Deploy IPv6	14
	Transfer IPv4 addresses from elsewhere to my organization	7
	Other	1
	Total	24
2	Do nothing,Deploy IPv6	1
	Do nothing, Transfer IPv4 addresses from elsewhere to my organization	3
	Do nothing,Other	2
	Deploy IPv6,Deploy Carrier Grade NAT	4
	Deploy IPv6 ,We have enough IPv4 addresses	1
	Deploy IPv6, Deploy other IPv6/IPv4 protocol translation technology	2
	Deploy IPv6 ,Transfer IPv4 addresses from elsewhere to my organization	7
	Deploy IPv6 ,Other	1
	Deploy other IPv6/IPv4 protocol translation technology, Other	1
	Other, Transfer IPv4 addresses from elsewhere to my organization	1
	Total	23
3	Deploy IPv6 ,Do nothing,We have enough IPv4 addresses	1
	Deploy IPv6 ,Do nothing,Transfer IPv4 addresses from elsewhere to my organization	3
	Do nothing, Deploy other IPv6/IPv4 protocol translation technology, Other	1
	Deploy IPv6, Transfer IPv4 addresses from elsewhere to my organization , We have enough IPv4 addresses	1
	Deploy IPv6 ,Deploy IPv6/IPv4 protocol translation technology,Transfer IPv4 addresses from elsewhere to my organization	2
	Deploy Carrier Grade NAT ,Deploy IPv6/IPv4 protocol translation technology,Other	1
	Total	9
4	Deploy IPv6,Do nothing,Other ,Transfer IPv4 addresses from elsewhere to my organization	1
5	Deploy Carrier Grade NAT ,Deploy IPv6 ,Deploy IPv6/IPv4 protocol translation technology,Other,We have enough IPv4 addresses	1

Table 14: Networks that expect to reduce their address needs

Network	Primary activity	Fraction	ASN	Organization
109	Hosting/data center	0.027	3561	Savvis
116	Enterprise Network	1	1312	Virginia Polytechnic Institute and State Univ.
126	Enterprise Network	0.13	1798	State of Oregon

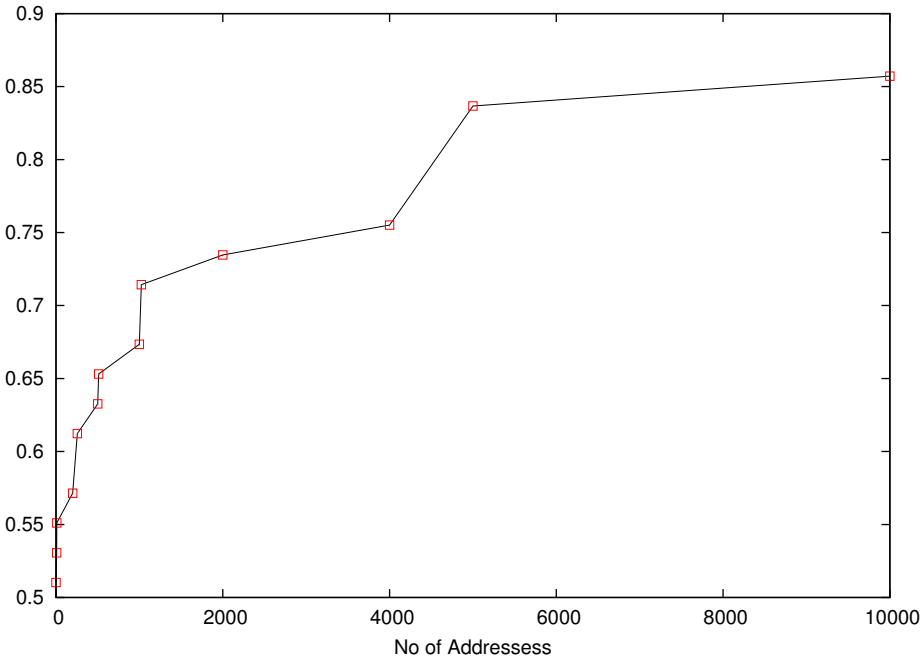

Figure 4: Number of IPv4 Addresses(zoom)

CGN

We further analyse questions regarding Carrie Grade NAT (CGN) (i.e., Question 15, 16 and 17). First, we analyze the percentage of customers that are expected within 18 months to be behind a CGN. We consider for our analysis 37 network; 73% do not expect to have any customer behind CGN, while for 95% the percentage of customers that are expected to be behind a CGN is less than 30. Network 155 provided 100 as answer 100, i.e., this network expects that within 18 months to have all the customers behind CGN (see table **??**). From the 37 networks, 28 expect not to have any customer behind CGN within 18 months; table 16 list the basic statistics for the fraction of address usage for these networks except network 27, that does not give the information to compute the fraction of address usage. We observe that 25% of the selected networks have the usage fraction higher than 0.89. Out of the 27 network, 20 consider as a valid action for the IPv4 depletion the deployment of IPv6; 15 networks claim, however that they have enough IPv4 addresses. Table 17 lists the future action for the 27 networks.

Table 15: Percentage of customers behind CGN in 18 months equal to 100

Network	Primary activity	Fraction	ASN	Organization
155	Research and Education Network	9.7	40335	Watchtower Bible and Tract Society of New York, Inc

Table 16: Percentage of customers behind CGN in 18 months equal to 0

Number of networks	1Q	3Q	Median	Mean
27	0.11	0.89	0.50	0.58

Number of networks	Type
6	AP
2	CP
13	EC
4	HP
1	TP

Table 17: IPv4 depletion actions for networks that will have nocustomer behind CGN within 18 months

No	Action	Number of networks
1	Do nothing	9
2	Deploy IPv6	19
3	Deploy Carrier Grade NAT	0
4	Deploy DS-Lite	2
5	Deploy other IPv6/IPv4 protocol translation technology	2
6	We have enough IPv4 addresses	15
7	Transfer IPv4 addresses from elsewhere to my organization	3
8	Other	2

In question 16 we ask the ratio between private and public address use for the CGN i.e., ***CGN compression factor***. 24 networks provide this information; 11 networks set this value to zero and thus these network do assign private addresses behind, and 4 network have values that are greater or equal to 100. Details for the latter networks are provided in table 18.
From the total of 66 networks, only 11 give information about the expected ratio between private and public address use for the DS-Lite device. Out of 11 networks 9 have the ratio equal to 0 and 1 have the value equal to 100 (network 155 ,Table 18)

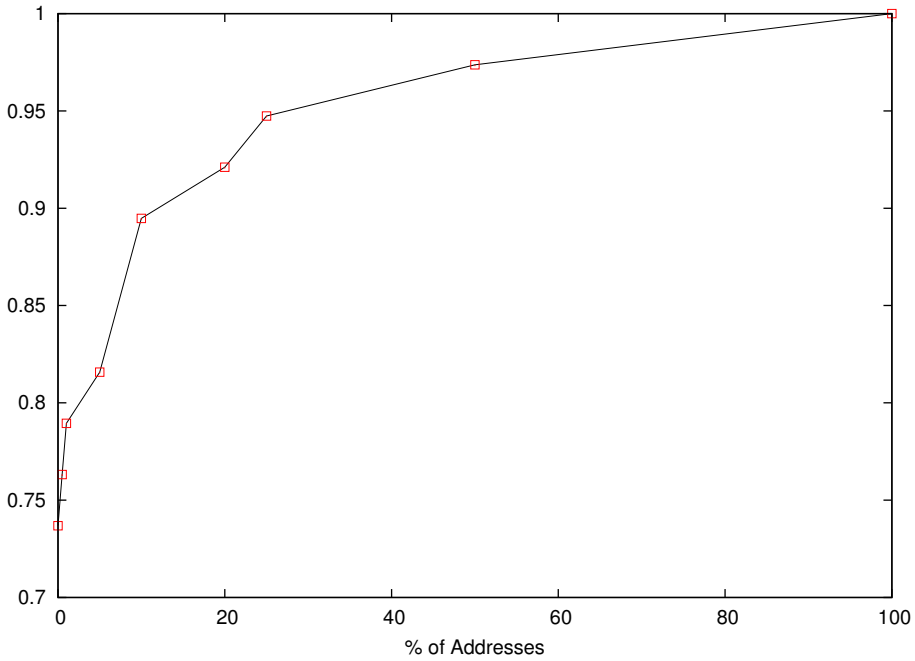

Figure 5: CDF of the users expected to be behind CGN wtihin 18 months

Table 18: Networks for which the compression factor is greater than 100

Network ID	Primary activity	Factor	Fraction	ASN	Organization
124	Content Provider	250	1.11	39905	Emailvision
135	Research and Education Network	100	1.25	36375	University of Michigan
153	Access Provider	256	0.076	30036	Mediacom Communications Corp
155	Research and Education Network	100	9.76	40335	WBTSNY

Summary

We presented in this report an analysis of the responses provided by netwrok operators regarding their plans for the IPv4 address run-out. 82% of the network report that they have a surplus of IPv4 addresses, that are assigned to devices that have assigned either only IPv4 addresses (i.e., *oIPv4* – only IPv4 addresses) or both IPv4 and IPv6 addresses (i.e., *DS* - Duat-stack devices). In terms of future plans regarding the IPv4 depletion, 74% networks consider purchasing addresses on the IPv4 market and 65.51% included deploying IPv6; *CGN deplyment* appears viable solution for few networks. Those networks that do deploy *CGN* report to have at least 100 users behind their CGN devices.

A IPv6 Survey Questions

Section 1: Demographics

1. How would you classify the primary activity of your network? (Select one)

- Fixed Access Provider (e.g., Cable, DSL, Wireless)
- Mobile Access Provider (e.g., cellular)
- Transit Provider
- Research and Education Network
- Content Provider
- Enterprise Network
- Internet exchange point
- Content Distribution Network
- Hosting data
- Other (please specify) Please enter an 'other' value for this selection.

Section 2: Address usage and needs

2. Approximately how many "devices" in your network (entities that require an IP address, so most likely this maps to interfaces that you directly maintain) need to communicate with the public Internet, i.e., either using a publicly reachable IP address or from behind a NAT? (e.g., 50, 2000, 30000, etc.)

3. Of these devices, what percentage:

- are native dual-stack
- access the IPv4 Internet natively, use transition technologies to
- access the IPv6 Internet (e.g., 6RD, 6to4)
- access the IPv6 Internet natively, use transition technologies to
- access the IPv4 Internet (e.g., DS-Lite, DNS64/NAT64)
- can access only the IPv4 Internet
- can access only the IPv6 Internet

4. What is the approximate total size (in whole numbers) of your (non-RFC1918) IPv4 address pool (allocated, assigned, or acquired by transfer)?

5. Of the pool mentioned in question (4), what percentage is:

- servers or services that need a public IPv4 address (e.g., www, ftp, smtp, routing infrastructure)
- hosts that can potentially be put behind a NAT44 (e.g., end users)
- used for the public side of a NAT44 (e.g., firewall with NAT capability, CGN) used for the public side of a NAT64 (e.g., DS-Lite, DNS64/NAT64)
- uncommitted (free, usable)

6. In network notation (e.g., /32), what size is your allocated IPv6 prefix? (Separate multiple prefixes with commas. Put zero if you do not have an IPv6 prefix.)

7. If you have deployed IPv6 in production, please state the size (in network notation) of the deployed IPv6 address space (e.g., /48, /32 etc.)

8. What size(s) prefix do you assign to end sites?

- /48
- /56
- /60
- /64
- /128 (e.g., for hosting/cloud providers)

- Other (please specify) Please enter an 'other' value for this selection.

9. What are your near term plans (18 months) to deal with IPv4 free address pool depletion (more then one may apply)?

- Do nothing
- Deploy IPv6
- Deploy Carrier Grade NAT (please answer Section 4: CGN deployment below)
- Deploy DS-Lite (please answer Section 5: DS-Lite deployment below)
- Deploy other IPv6/IPv4 protocol translation technology
- We have enough IPv4 addresses
- Transfer IPv4 addresses from elsewhere to my organization.Please enter an 'other' value for this selection.
- Other (please specify): Please enter an 'other' value for this selection.

10. Approximately how many IPv4 addresses do you expect to need in the next 18 months in addition to what has already been allocated to you? Fill in a negative number if you expect to reduce your needs.

Section 3: Access Providers (Fixed, Wireless, Mobile, Enterprise)

11. What is the approximate number of CPE units in your network?

12. What is the average turnover of your CPE devices (i.e., how long between replacement of devices)? (e.g., 6 months, 5 years, 12 years, etc.)

13. Approximately what percentage of these CPE units do you provide with an IPv6 address now?

14. Approximately what percentage of your CPE units will you provide with an IPv6 address within 18 months?

Section 4: CGN (NAT444) deployment

15. In 18 months what percentage of your customers do you expect to be behind CGN?

16. What do you expect your "compression factor" to be? (compression factor is the ratio between private and public address use for the CGN) For instance, if 3 customers are behind a single public IPv4 address, the compression factor is 3.

Section 5: DS-Lite

17. What do you expect your "compression factor" to be? (compression factor is the ratio between private and public address use for the DS-Lite device) For instance, if 3 customers are behind a single public IPv4 address, the compression factor is 3.

Section 6: Costs

18. What's the average cost to replace a CPE device in your network?

19. What is the approximate annualized cost of the entire CGN system in your network (if possible, please integrate the initial capital expenditure into the annualized cost estimate over its expected lifetime)?

20. Please estimate your per-device renumbering cost, for example, renumbering a devices with a NAT IPv4 address to an IPv6 address, or adding an IPv6 address to an existing IPv4 device.

21. If you have deployed IPv6 in production, please estimate the cost of deploying this address space, accounting for the costs of acquiring the address space, training personnel, customer support, etc.

Section 7: Policy mandates

22. To the best of your knowledge, are you subject to any policies or regulations as regards to IPv6, such as prohibiting the use of IPv4 NATs, or mandating IPv6 deployment, or conditions from customers, government or otherwise? If so, please briefly describe.

Section 8: Legal Intercept, Record Keeping

23. Please describe (to the best of your knowledge) your obligations regarding record keeping and legal intercept if you are deploying CGNs in your network.