The State of IP Addresses
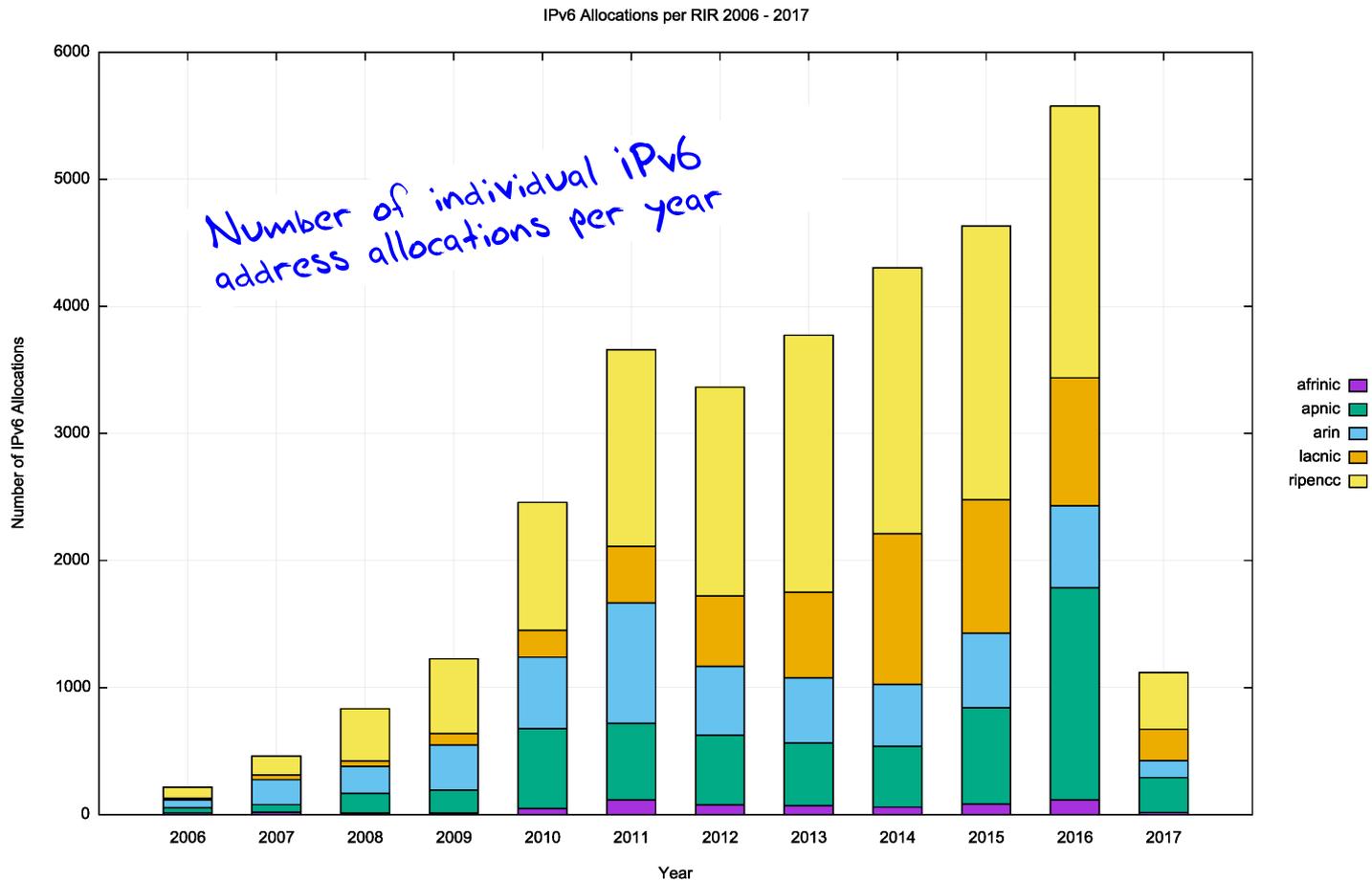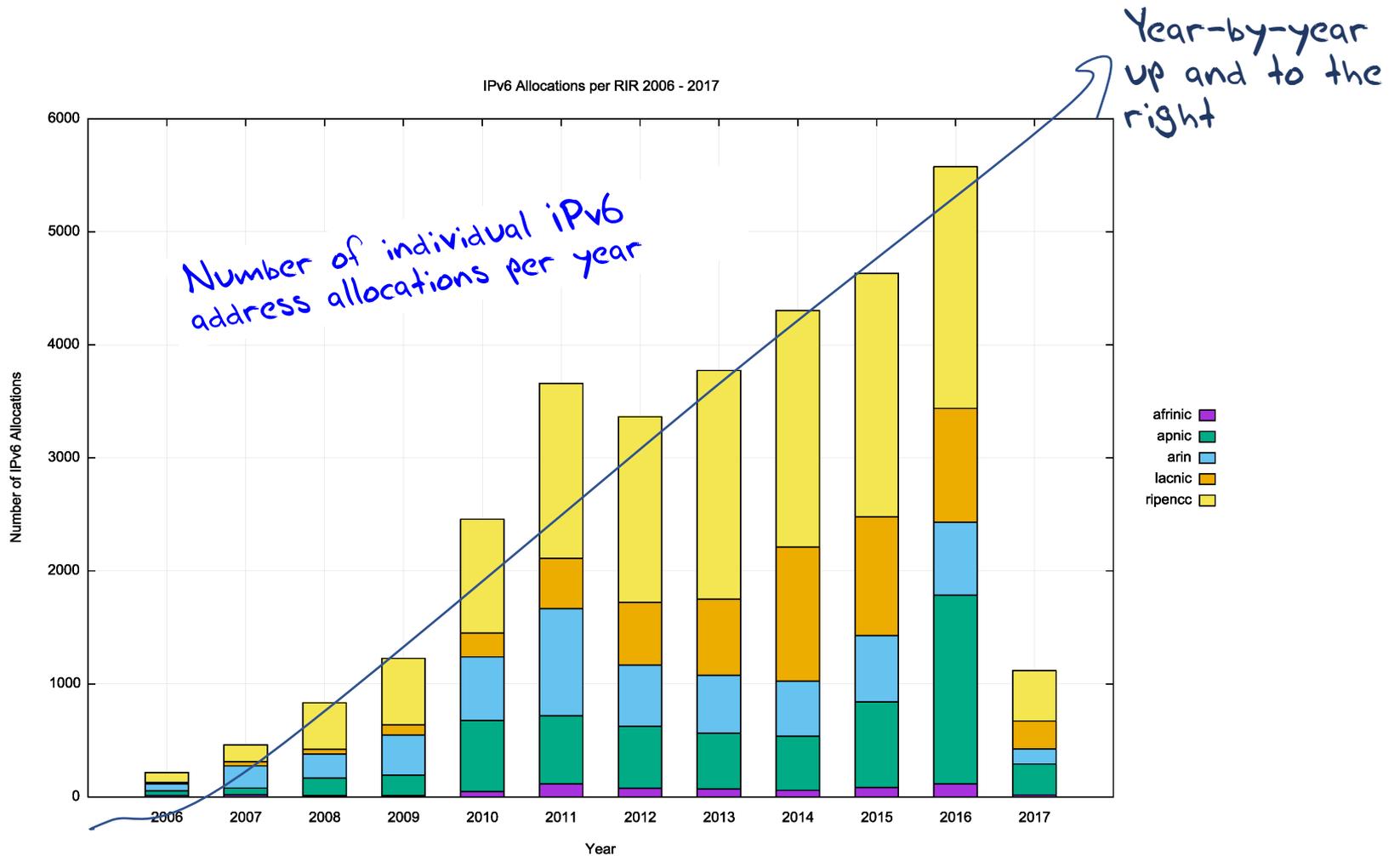
Geoff Huston
APNIC

IPv6

IPv6 Allocations by RIRs
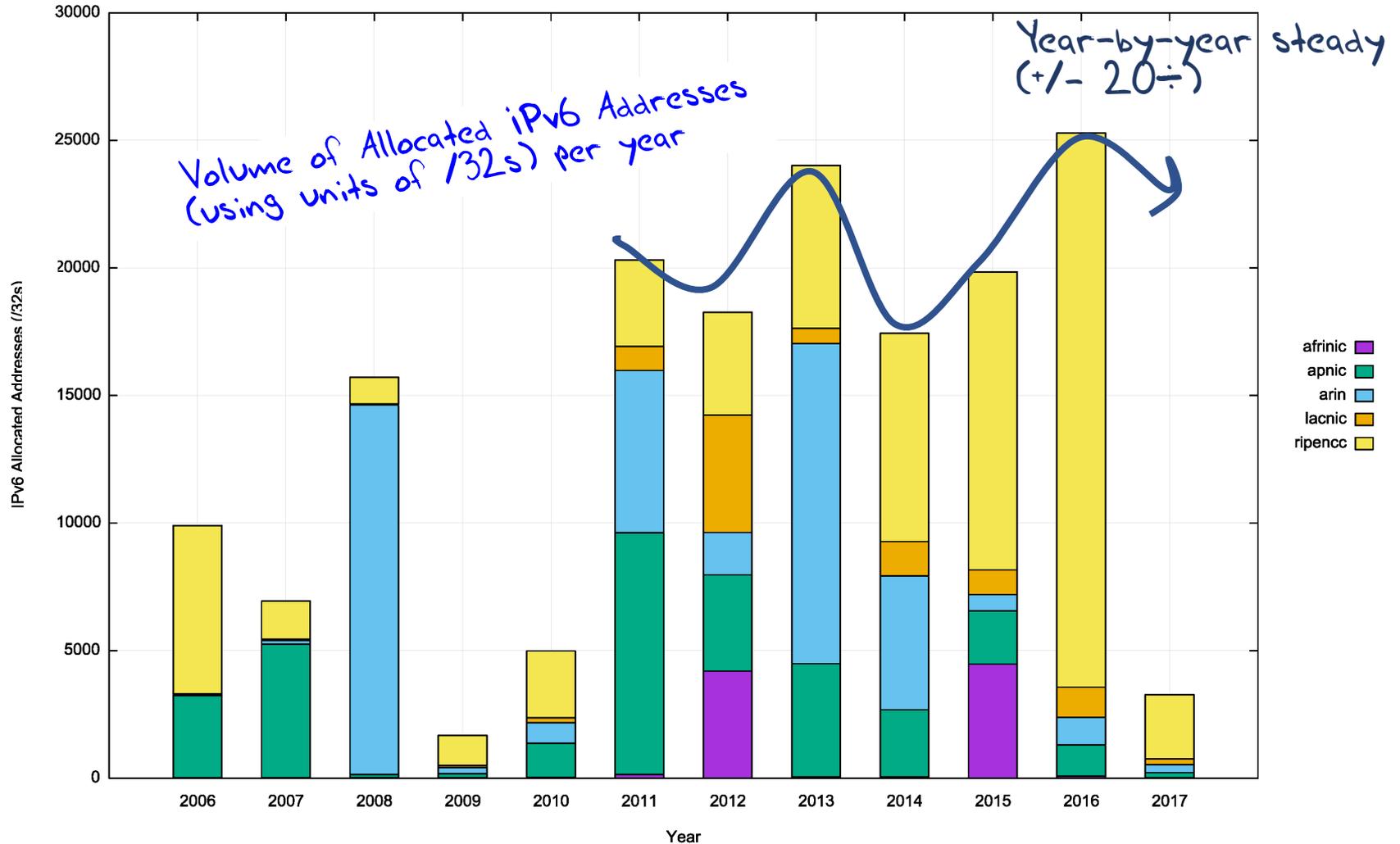

IPv6 Allocations per RIR 2006 - 2017

Number of individual iPv6 address allocations per year

IPv6 Allocations by RIRs

IPv6 Allocations per RIR 2006 - 2017

Year-by-year up and to the right

Number of individual iPv6 address allocations per year

IPv6 Allocated Addresses

IPv6 Address Allocation Volumes per RIR 2006 - 2017

Volume of Allocated iPv6 Addresses (using units of /32s) per year

Year-by-year steady (+/- 20÷)

ARIN: IPv6 Allocated Addresses

Volume of Allocated iPv6 Addresses
(using units of /32s) per year

IPv6 Address Allocation Volumes for ARIN 2006 - 2017
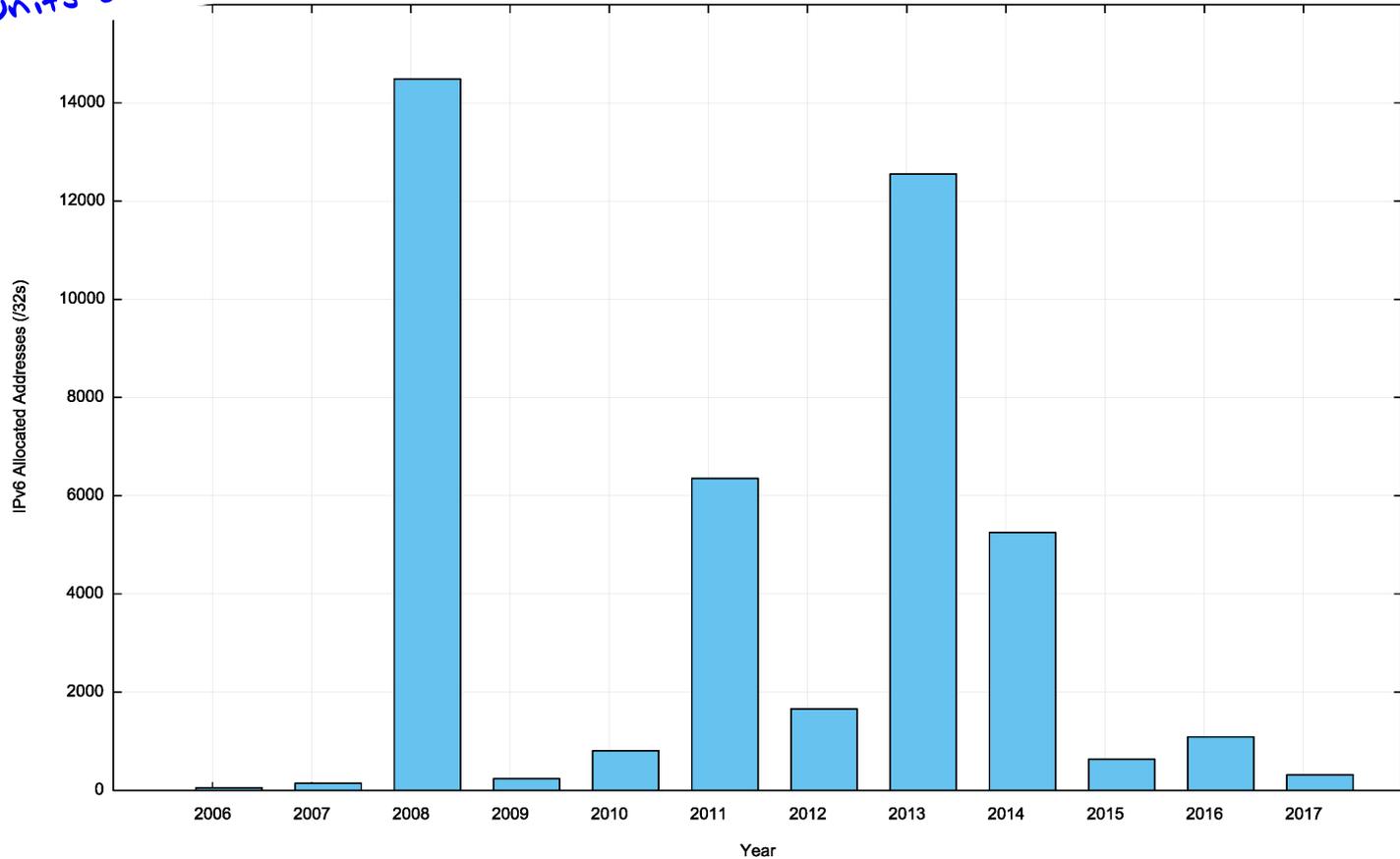
Where did these IPv6 addresses go?

Volume of Allocated iPv6 Addresses (using units of /32s) per country, per year

Rank	2012		2013		2014		2015		2016	
1	Argentina	4,178	United States	12,520	United States	5,213	South Africa	4,440	United Kingdom	9,571
2	Egypt	4,098	China	4,135	China	2,126	China	1,797	Germany	1,525
3	China	3,136	United Kingdom	784	United Kingdom	1,032	Germany	1,245	Netherlands	1,312
4	United States	1,337	Germany	663	Brazil	856	United Kingdom	1,204	United States	1,137
5	Italy	641	Russian	518	Germany	713	Netherlands	1,009	Russian Federation	1,005
6	Germany	452	Netherlands	480	Netherlands	694	Russian Federation	832	France	926
7	Russian Federation	413	Brazil	444	Russian Federation	636	Brazil	746	Brazil	727
8	United Kingdom	373	France	406	France	409	Italy	699	Spain	702
9	Canada	321	Italy	344	Italy	399	United States	640	Italy	679
10	Brazil	283	Switzerland	272	Switzerland	352	France	629	China	596

Where did these IPv6 addresses go?

2016

United Kingdom	9,571
Germany	1,525
Netherlands	1,312
United States	1,137
Russian Federation	1,005
France	926
Brazil	727
Spain	702
Italy	679
China	596

0.1% 10% 1.5% 1% 0.5%

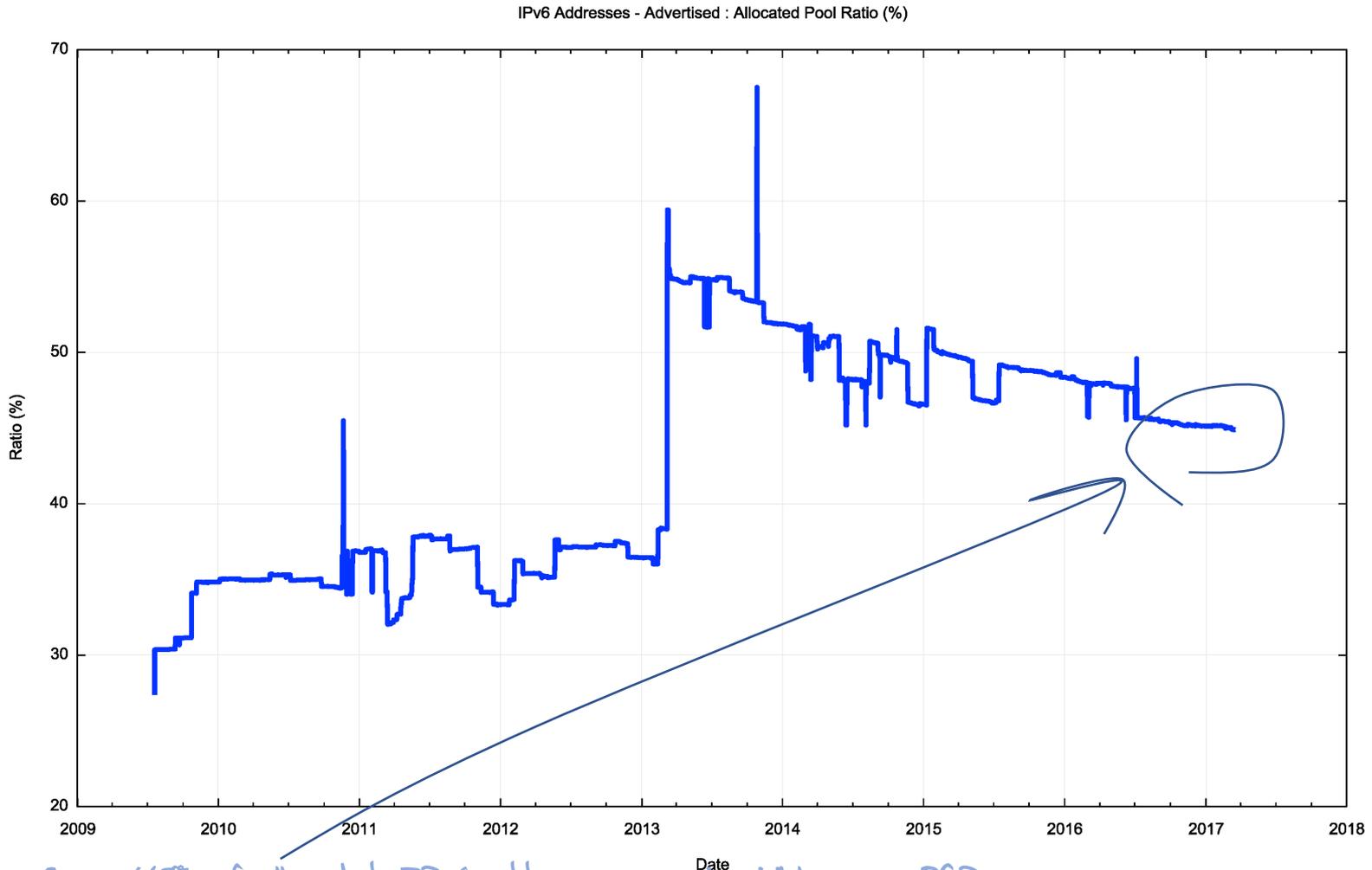IPv6 Adoption rate per country (%)

0 — 56
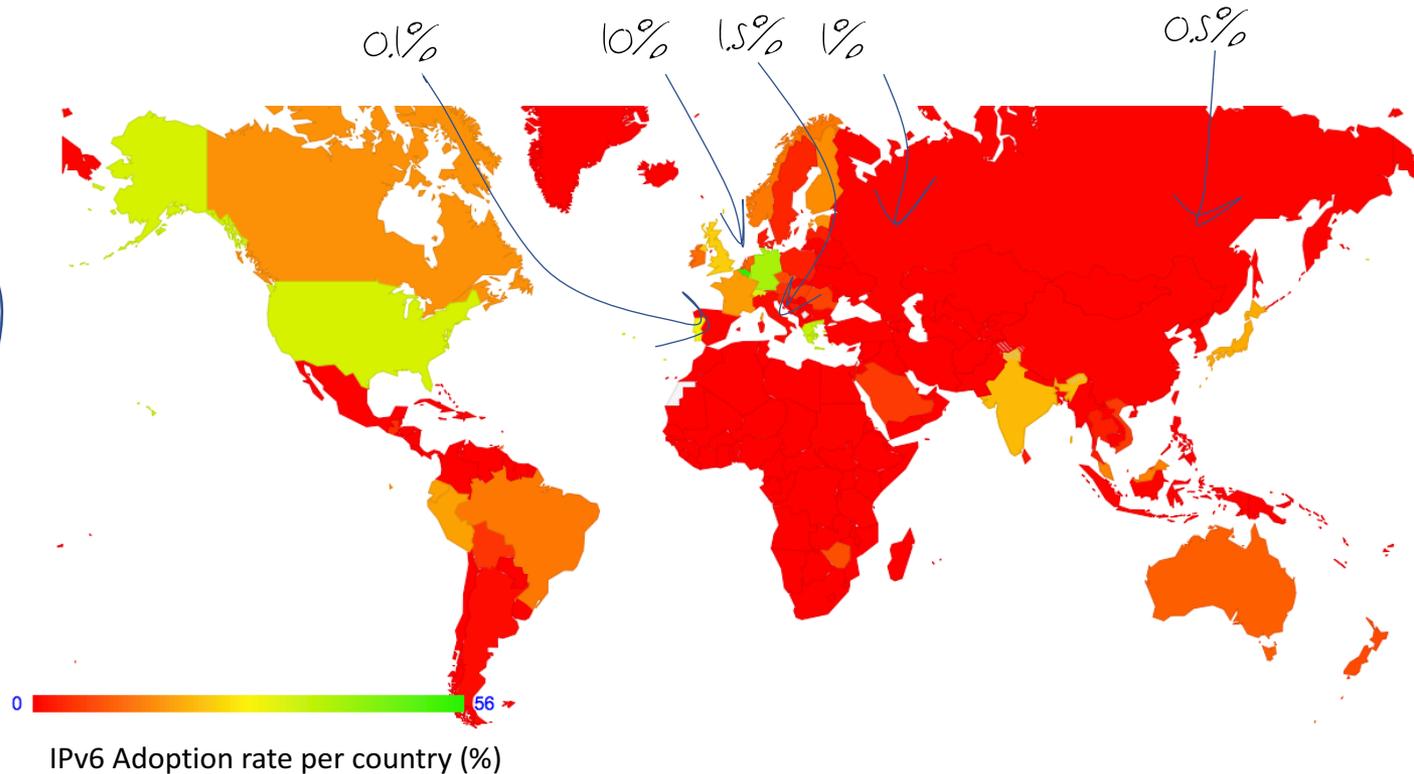
5 of the 10 largest iPv6 allocations have been made into countries with little in the way of visible current deployment in the public internet

Advertised vs Unadvertised

IPv6 Addresses - Allocated, Adverties and Unadvertised
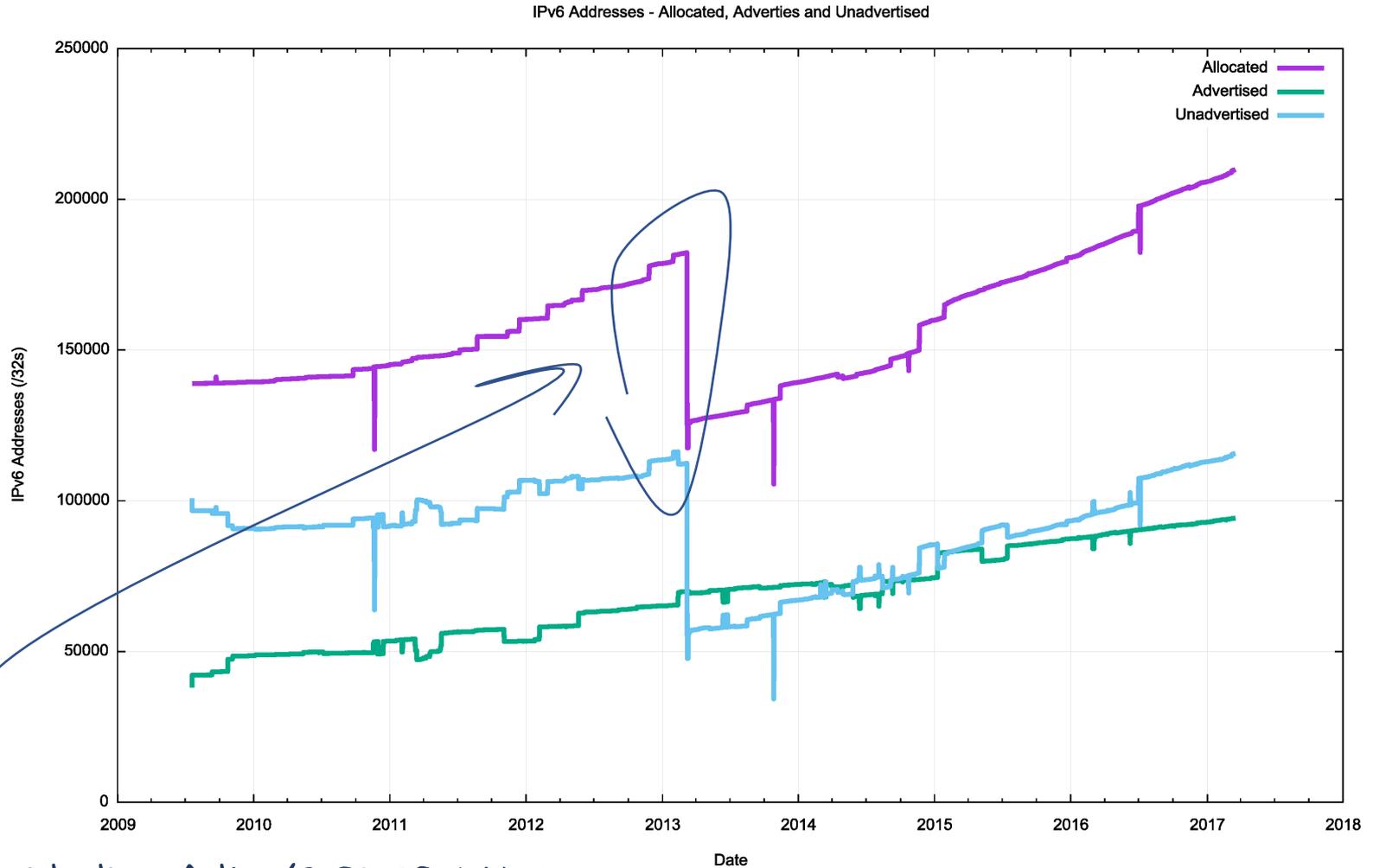
Re-registration of the /18 BR IPv6 block
in March 2013 in LACNIC

Advertised : Allocated (%)

IPv6 Addresses - Advertised : Allocated Pool Ratio (%)

Some 45% of allocated IPv6 address space is visible as a BGP advertisement

Total IPv6 Holdings by Country

CC	Users (M)	Allocated /48s (M)	Allocated /48s per User	IPv6 Adoption	IPv6 Users (M)	Advertised /48s (M)	Advertised /48s per IPv6 User	Country
US	283	2,845	10	32.91%	93	1,062	11	USA
CN	694	1,391	2	0.24%	2	39	23	China
GB	59	1,135	19	25.51%	15	308	21	UK
DE	70	1,068	15	42.85%	30	836	28	Germany
FR	54	758	14	18.66%	10	608	60	France
JP	114	617	5	19.66%	22	467	21	Japan
AU	21	582	27	14.82%	3	284	90	Australia
IT	35	474	14	1.93%	1	343	506	Italy
SE	9	380	40	3.50%	0	333	1,013	Sweden
KR	47	344	7	1.00%	0	4	9	Republic of Korea
NL	16	343	21	9.77%	2	158	101	Netherlands
AR	35	315	9	1.13%	0	274	691	Argentina
ZA	29	304	10	0.12%	0	14	421	South Africa
RU	88	272	3	1.49%	1	72	55	Russian Federation
EG	36	269	7	0.44%	0	269	1,684	Egypt
PL	25	250	10	3.53%	1	168	189	Poland
BR	114	246	2	13.22%	15	100	7	Brazil
ES	34	197	6	0.65%	0	60	271	Spain
TW	20	155	8	0.25%	0	152	3,156	Taiwan
CH	7	141	19	35.74%	3	68	26	Switzerland
NO	5	107	21	15.12%	1	67	87	Norway
IR	46	102	2	0.04%	0	4	202	Iran
CZ	8	93	12	11.49%	1	47	52	Czech Republic
TR	37	91	2	0.46%	0	13	77	Turkey
UA	19	75	4	0.06%	0	17	1,579	Ukraine

IPv6 Allocations

Many IPv6 address holders appear to want to avoid being "caught short" with IPv6, and have received IPv6 address allocations that are far larger than their current needs for public IPv6 addresses

This is consistent with an overall address management framework that is not primarily driven by address conservation objectives

This, in turn, is consistent with the IPv6 design choice to use a very large address field, so that such liberal address allocation practices can be sustained for many decades
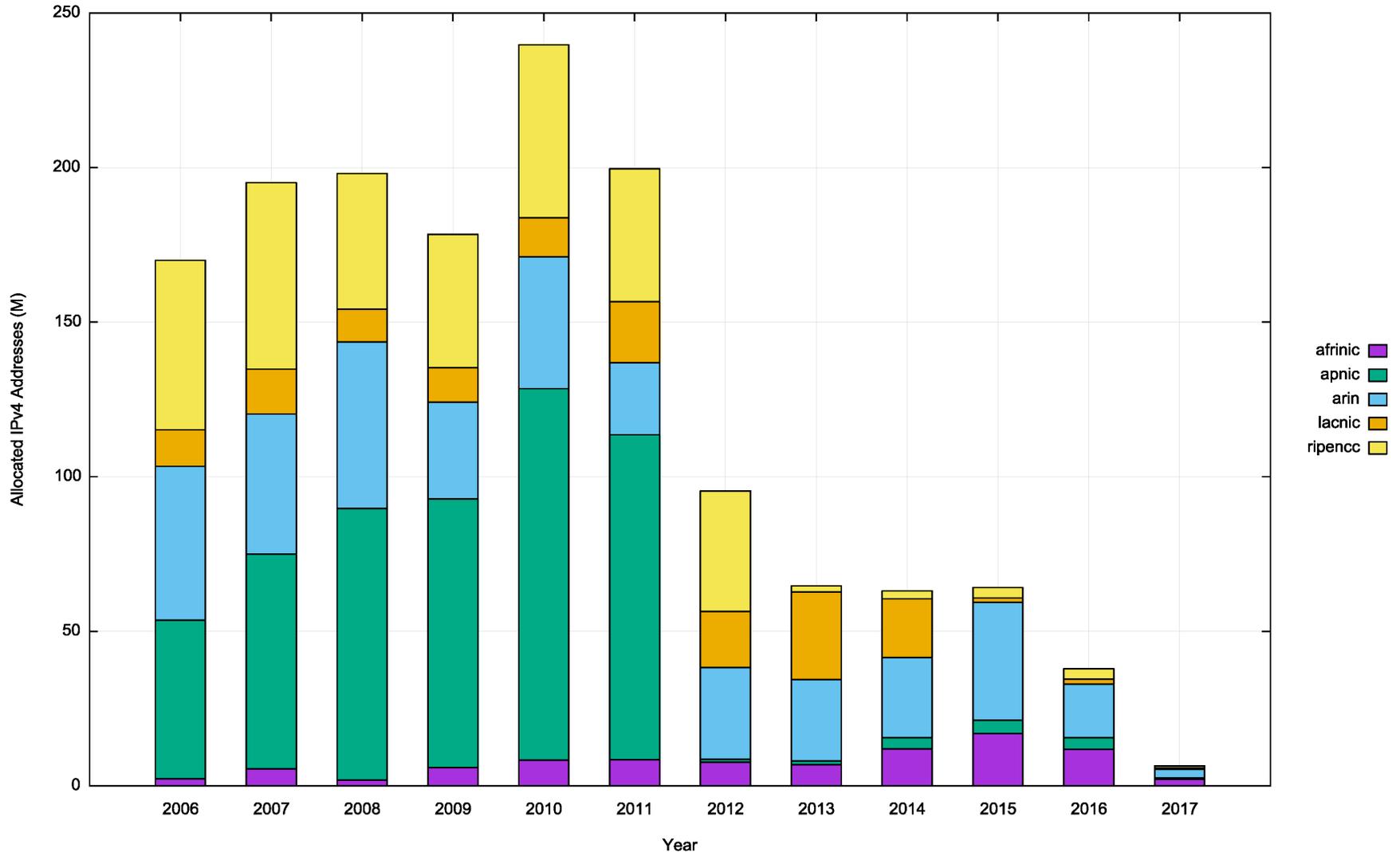
IPv4

Addressing V4 Exhaustion

RIR IPv4 Address Run-Down Model
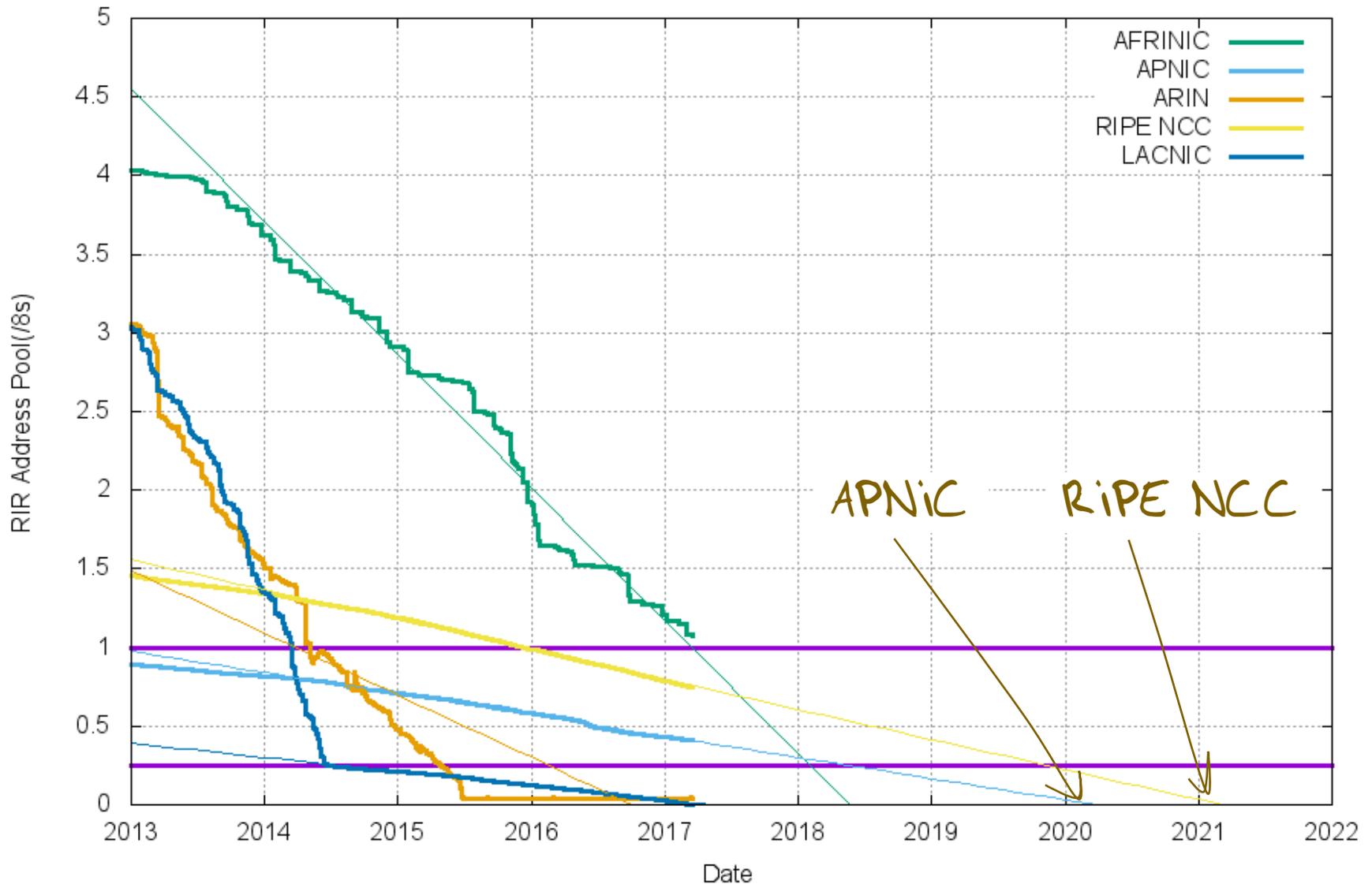
A Decade of IPv4 Allocations

IPv4 Allocations per RIR 2006 - 2017

A Decade of IPv4 Allocations

IPv4 Allocations per RIR 2006 - 2017

Pre Exhaustion

Global Financial Crisis

Exhaustion Profile

Allocated IPv4 Addresses (M)

Year

afrinic
apnic
arin
lacnic
ripencc
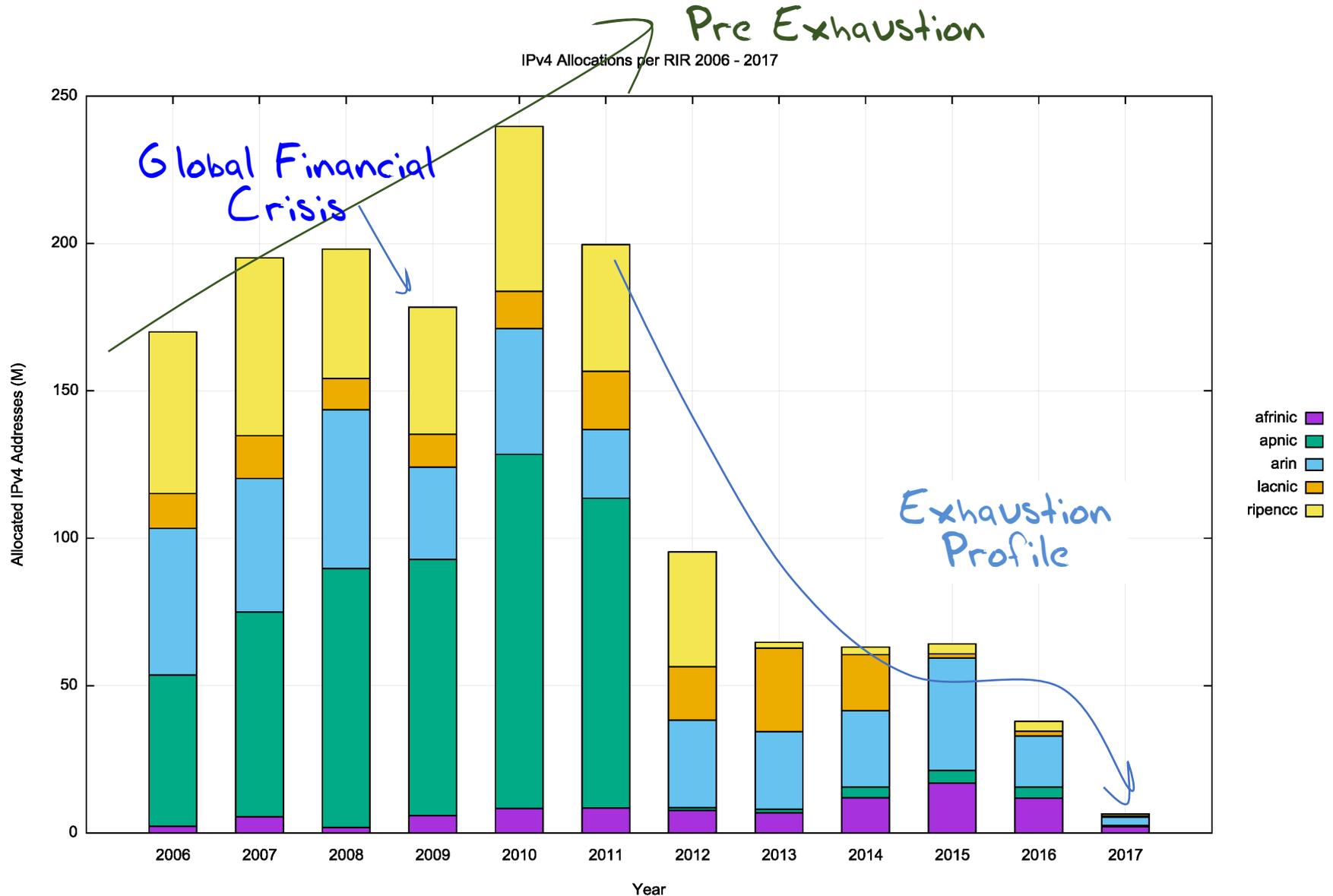
Where did the Addresses Go?

Volume of Allocated IPv4 Addresses
(using units of millions of /32s)
per year

| Rank		2012		2013		2014		2015		2016
1	China	28.2	USA	25.0	USA	24.5	USA	7.6	Morocco	3.1
2	Canada	16.7	Brazil	17.4	Brazil	10.9	Egypt	7.4	Seychelles	2.1
3	Brazil	8.4	Colombia	3.8	Morocco	2.6	Seychelles	2.1	USA	1.7
4	Russia	5.3	Argentina	1.6	Colombia	2.1	Sth Africa	2.0	China	1.3
5	Iran	4.5	Egypt	1.6	Sth Africa	1.7	Tunisia	1.8	Brazil	1.3
6	Germany	3.4	Canada	1.4	Egypt	1.6	Brazil	1.4	Sth Africa	1.2
7	Sth Africa	3.4	Nogeria	1.2	China	1.5	China	1.3	India	1.1
8	Italy	3.3	Chile	1.1	Canada	1.4	India	1.3	Egypt	1.1
9	Colombia	2.6	Mexico	1.1	Kenya	1.4	Canada	1.1	Kenya	1.1
10	Romania	2.6	Seychelles	1	Mexico	1.1	Ghana	0.6	Algeria	1.1

APNiC ran out in 2011

RiPE NCC ran out in 2012

LACNiC ran out in 2014

ARiN ran out in 2015

What's Left? (20 March 2017)

	Available /32s	Reserved /32s	Current Run Out
APNIC	6,840,832	4,071,680	Last /8: early 2020
RIPE NCC	12,497,304	1,050,176	Last /8: early 2021
ARIN	0	6,163,968	
LACNIC	16,128	4,930,560	
AFRINIC	18,076,672	1,840,384	Pool: May2018
	37,412,936	**18,056,768**	

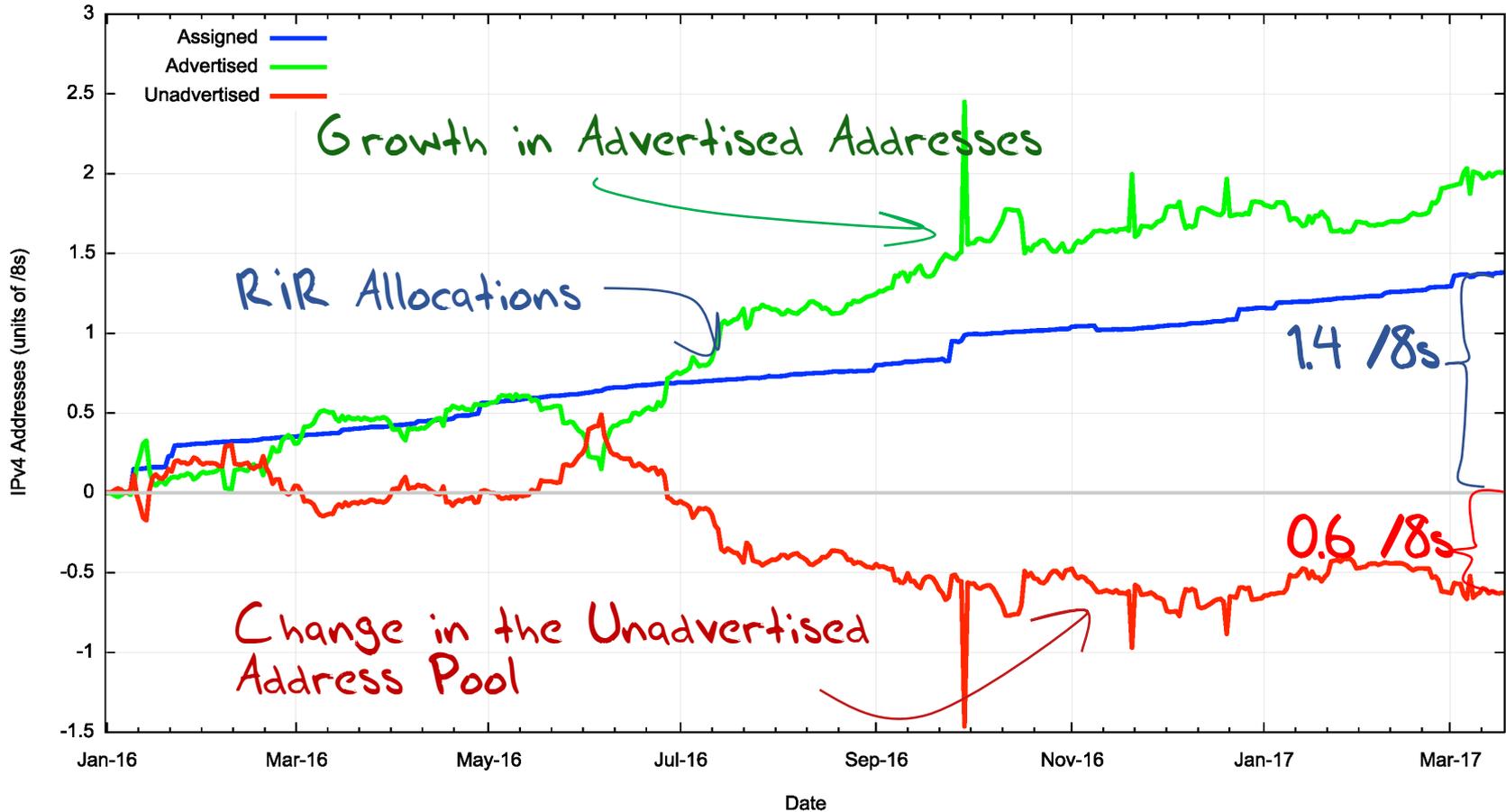# IPv4: Advertised vs Unadvertised
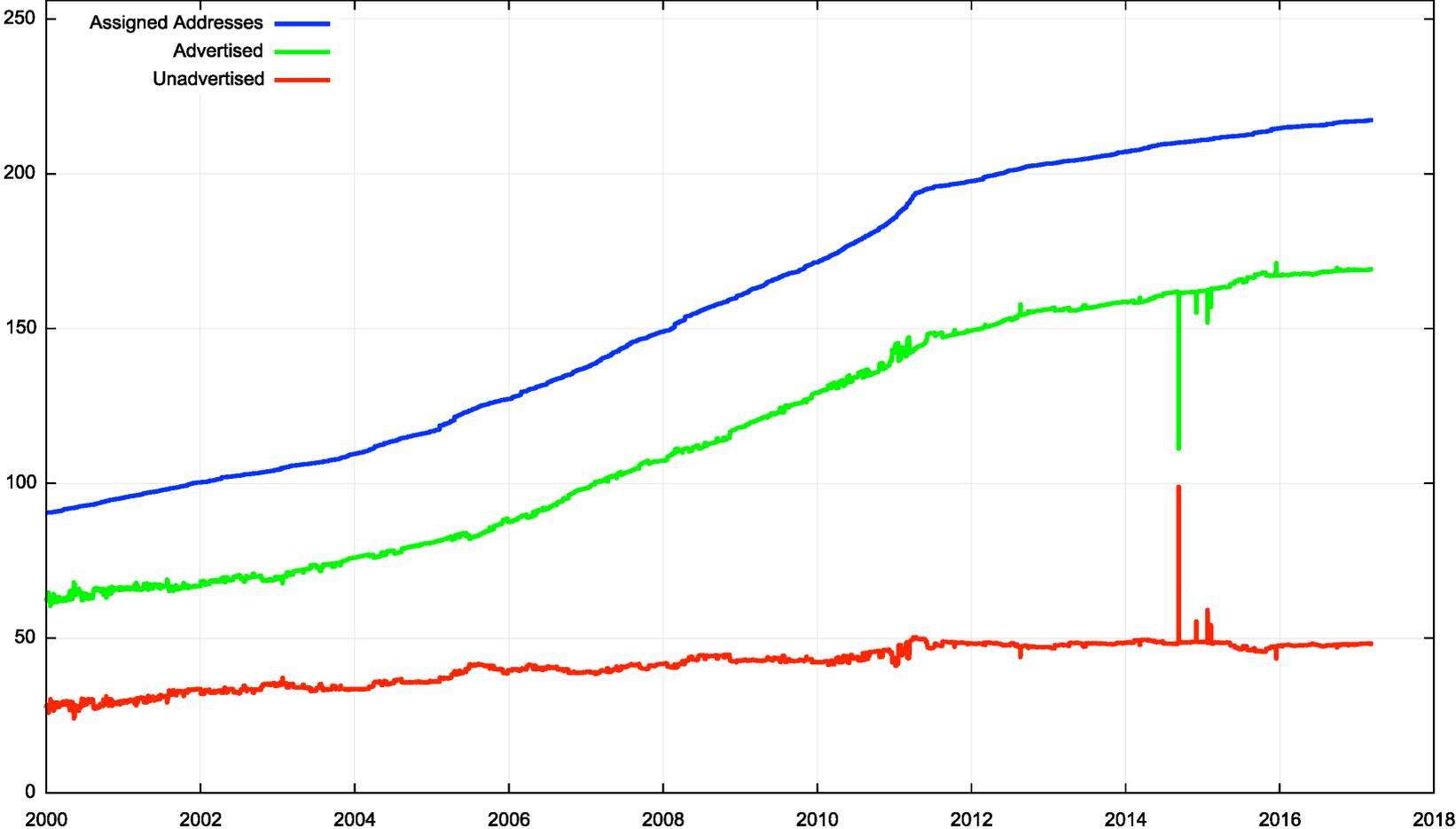
IPv4 Unadvertised Address Pool: 2016 - 2017

Unadvertised Address Pool: 2016 - 2017

IPv4:Allocated vs Recovered in 2016

IPv4 Address Pools: 2016 - 2017

The IPv4 After-Market: Address Transfers

- There is a considerable residual demand for IPv4 addresses following exhaustion

  - IPv6 is not a direct substitute for the lack of IPv4

- Some of this demand is pushed into using middleware that imposes address sharing (Carrier Grade NATS, Virtual Hosting, etc)

- Where there is no substitute then we turn to the aftermarket

- Some address transfers are "sale" transactions, and they are entered into the address registries

- Some transfers take the form of "leases" where the lease holder's details are not necessarily entered into the address registry

Registered Address Transfers

Number of registered Address transfers per year

Receiving RIR	2012	2013	2014	2015	2016	2017
ARIN	26	29	57	263	819	128
APNIC	126	128	312	325	488	70
RIPE NCC	10	164	1,024	2,828	2,409	388
TOTAL	162	321	1,393	3,416	3,716	586

Volume of addresses transferred per year (/32s)

Receiving RIR	2012	2013	2014	2015	2016	2017
ARIN	4,788,480	5,062,912	4,740,864	29,335,552	16,278,016	2,327,552
APNIC	1,808,128	1,887,488	3,683,072	6,023,936	7,855,872	788,992
RIPE NCC	65,536	1,946,624	9,596,672	12,379,648	9,374,208	1,856,256
TOTAL	6,662,144	8,897,024	18,020,608	47,739,136	33,508,096	4,972,800

Where From and Where To?

From	Addresses	To
USA	58,160,128	USA
Canada	8,846,848	USA
USA	4,683,008	India
Russia	2,849,792	Russia
Japan	2,773,248	Japan
Ukraine	2,527,488	Ukraine
Canada	2,359,296	China
China	1,847,040	China
Germany	1,545,984	Germany
Romania	1,390,592	Saudi Arabia
Romania	1,066,496	Iran
Canada	1,049,600	India
USA	958,976	Japan
Romania	941,568	Romania
Hong Kong	886,272	China
Ukraine	771,840	Ukraine
USA	672,768	China
Turkey	666,880	Turkey
USA	652,288	Canada

US & Canada: Exports and Imports

EXPORTS		To		IMPORTS		From
US	4,683,008	India		US	276,480	UK
CA	2,359,296	China		US	21,504	New Zealand
CA	1,049,600	India		US	16,384	Germany
US	958,976	Japan		US	16,384	Japan
US	672,768	China		US	9,216	Romania
US	652,288	Canada		US	8,704	Australia
US	540,416	Australia		US	6,656	Netherlands
US	451,328	Singapore		US	6,400	Belgium
US	417,792	Thailand		US	6,144	St Kitts and Nevis
CA	393,216	Japan		US	6,144	Philippines
CA	357,632	Canada		US	5,120	Russia
US	327,680	Portugal		CA	4,096	India
US	201,984	Netherlands		US	4,096	Italy
CA	196,608	France		US	3,072	Czech Rep.
US	169,728	Germany		US	1,792	Portugal
US	131,072	Saudi Arabia		US	1,024	Israel
US	131,072	UAE		CA	1,024	Australia

How old are transferred addresses?

Age Distribution of Transferred Addresses by Year

65÷ of transferred addresses are >20 years old in 2017
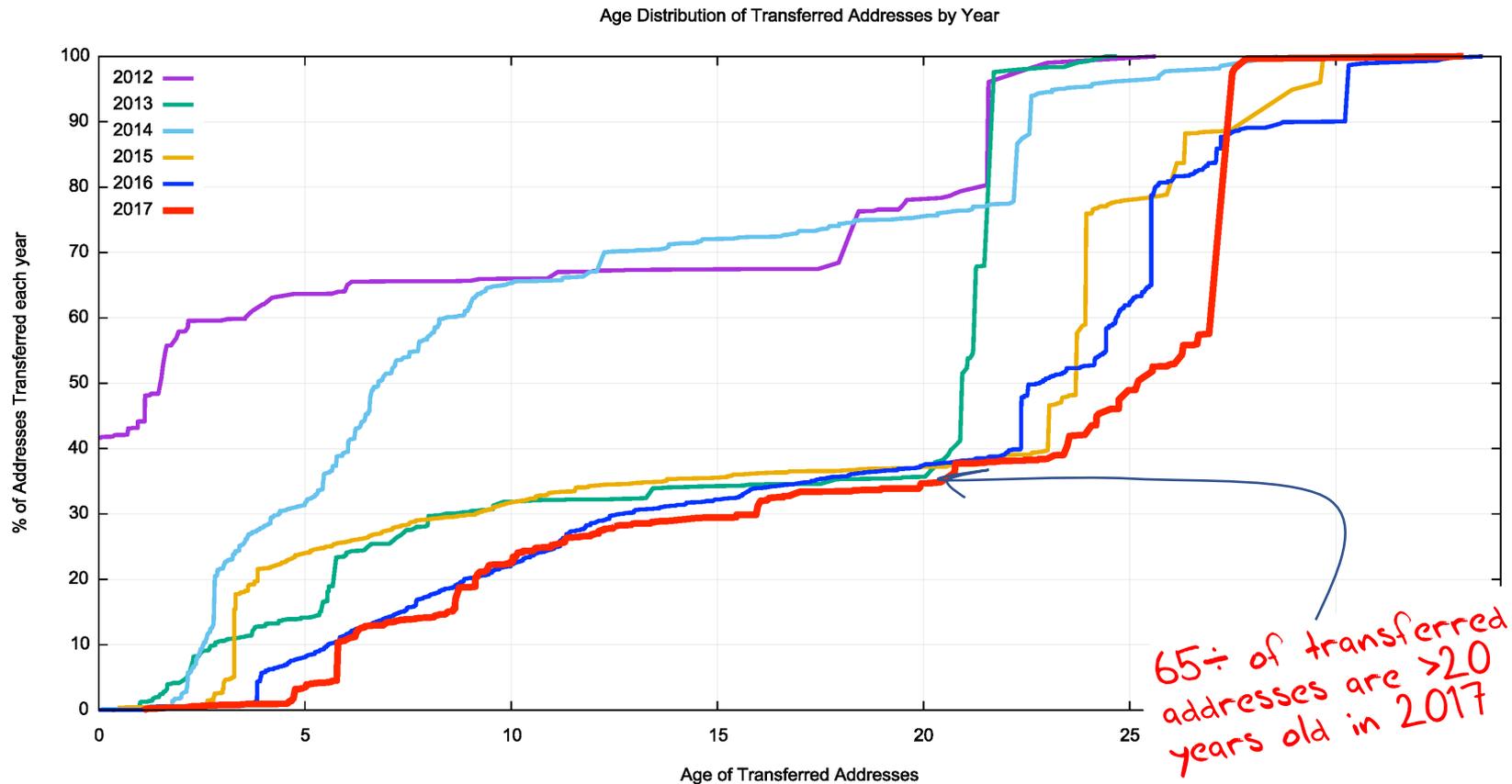
But

The RIR Transfer Logs are not the entire story:

- For example, the RIPE NCC's address transfer logs appear not to contain records of transfers of legacy space
- Address leases and similar "off market" address transactions are not necessarily recorded in the RIRs' transfer logs

Can BGP tell us anything about this missing data?

A BGP View of Addresses

Lets compare a snapshot of the routing table at the start of 2016 with a snapshot taken at the end of the year.
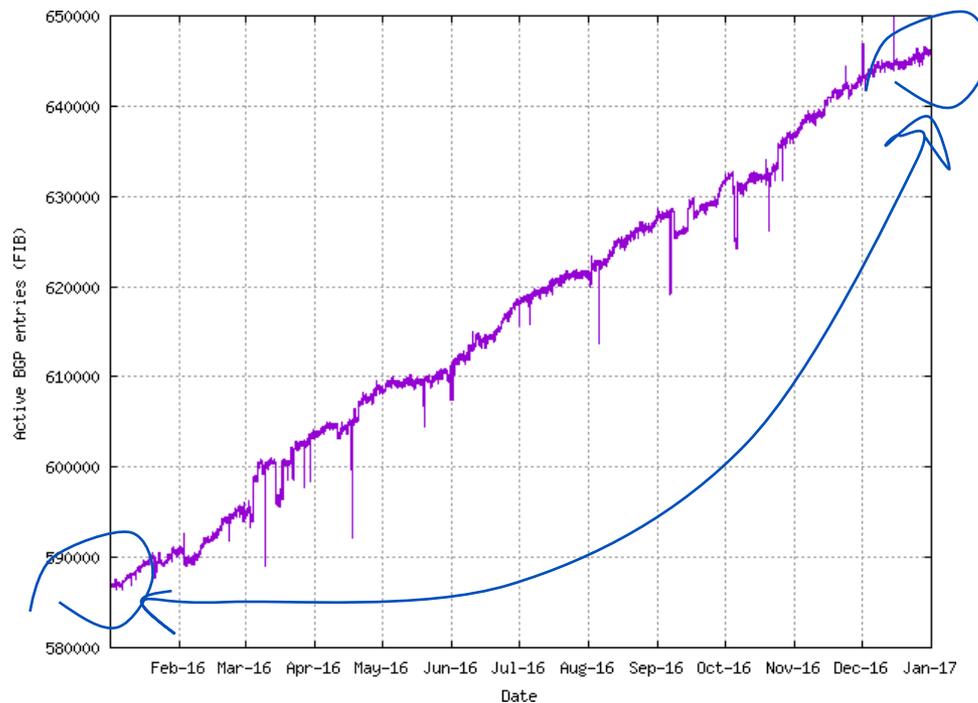
BGP Changes Across 2016

	Jan-16	Jan-17		Delta	Unchanged	Re-Home	Removed	Added
Announcements	586,918	646,059		59,141	502,846	16,928	67,504	126,645
Root Prefixes	286,249	309,092		22,843	252,411	10,803	22,080	46,238
Address Span (/8s)	156.35	158.40		2.04	147.31	2.52	5.58	8.57
More Specifics	300,669	336,967		36,298	250,435	6,125	45,424	80,407
Address Count (/8s)	51.86	56.04		4.18	47.06	0.81	4.94	8.17

What is the level of correlation between these addresses and the address ranges recorded in the transfer logs?

BGP Changes Across 2016

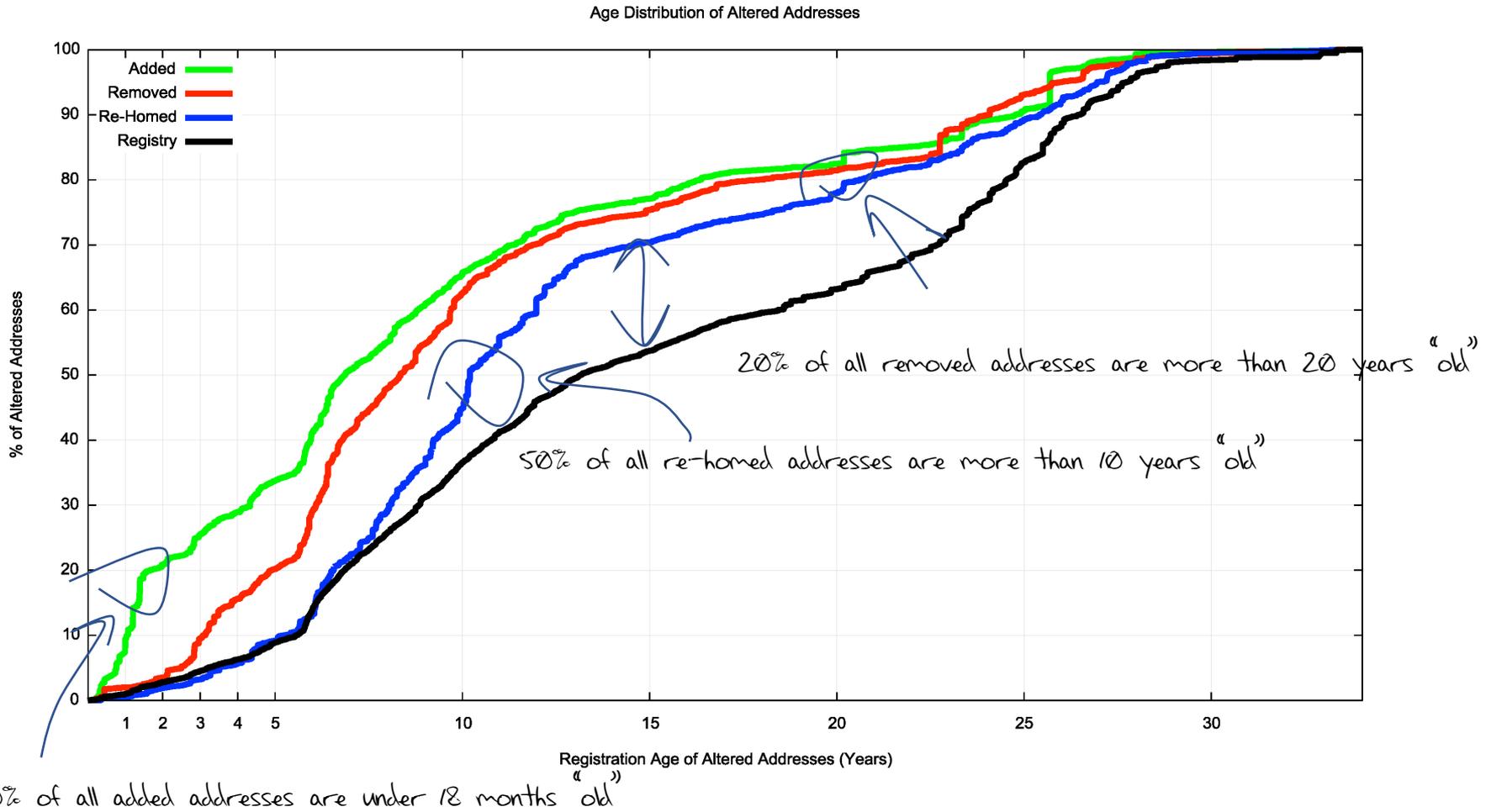|	Jan-16	Jan-17		Delta	Unchanged	Re-Home	Removed	Added
Announcements	586,918	646,059		59,141	502,846	16,928	67,504	126,645

8,663 announcements are listed in the transfer logs

117,982 announcements are NOT listed in the transfer logs

BGP Changes Across 2016

	Jan-16	Jan-17		Delta	Unchanged	Re-Home	Removed	Added
Announcements	586,918	646,059		59,141	502,846	16,928	67,504	126,645
Root Prefixes	286,249	309,092		22,843	252,411	10,803	22,080	46,238

	Listed as Transferred		UnListed
Rehomed			
All	1,539	15,389	9%
Root Prefixes	1,184	9,551	11%
Removed			
All	3,287	64,287	5%
Root Prefixes	1,877	20,203	9%
Added			
All	8,663	117,982	7%
Root Prefixes	4,617	41,621	10%

"Age" of Shifted Addresses

Age Distribution of Altered Addresses

20% of all removed addresses are more than 20 years "old"

50% of all re-homed addresses are more than 10 years "old"

20% of all added addresses are under 18 months "old"

"Age" of Shifted Addresses

- Some 20% of addresses that changed their routing state in 2016 are "legacy" allocated addresses that are more than 20 years "old"

- Addresses older than 20 years look to be more stable than the registry "norm"

- Addresses allocated in the past 18 months are more likely to have been announced (naturally!)

- Addresses that are 5 – 10 years old are more likely to have been removed from the routing system in 2016

BGP Data and Transfer Logs

- Some 5-10 % of address changes seen across 2016 (announced, withdrawn and re-homed) are listed in the RIR transfer logs

- That does **NOT** imply that the remaining 90-95% of address transfers are all unrecorded transfers

  - But it does point to a larger body of addresses that have changed their advertisement status in one way or another, some of which may have involved leasing or other forms of address movement, that are not recorded in the transfer logs

Address Movement and the Registries

- It is not clear from this analysis what has happened in the case of the other addresses. This could include:
  - "normal" movement of edge networks between upstream providers (customer 'churn')
  - Occluded multi-homing
  - Address movement within a distributed edge network
  - Address leasing
  - Address transfers not recorded in the transfer registries
- More analysis is required to understand what is happening here

Thank You!