Addressing 2016

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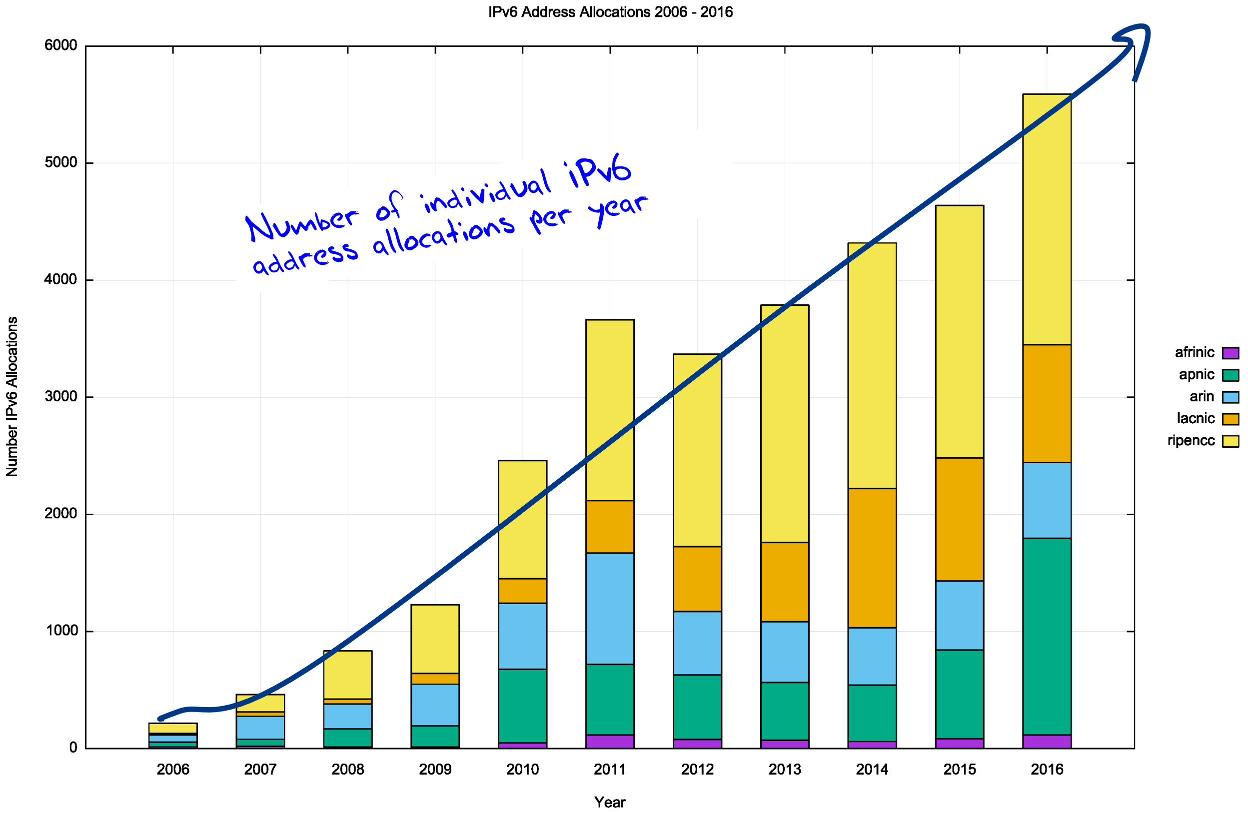
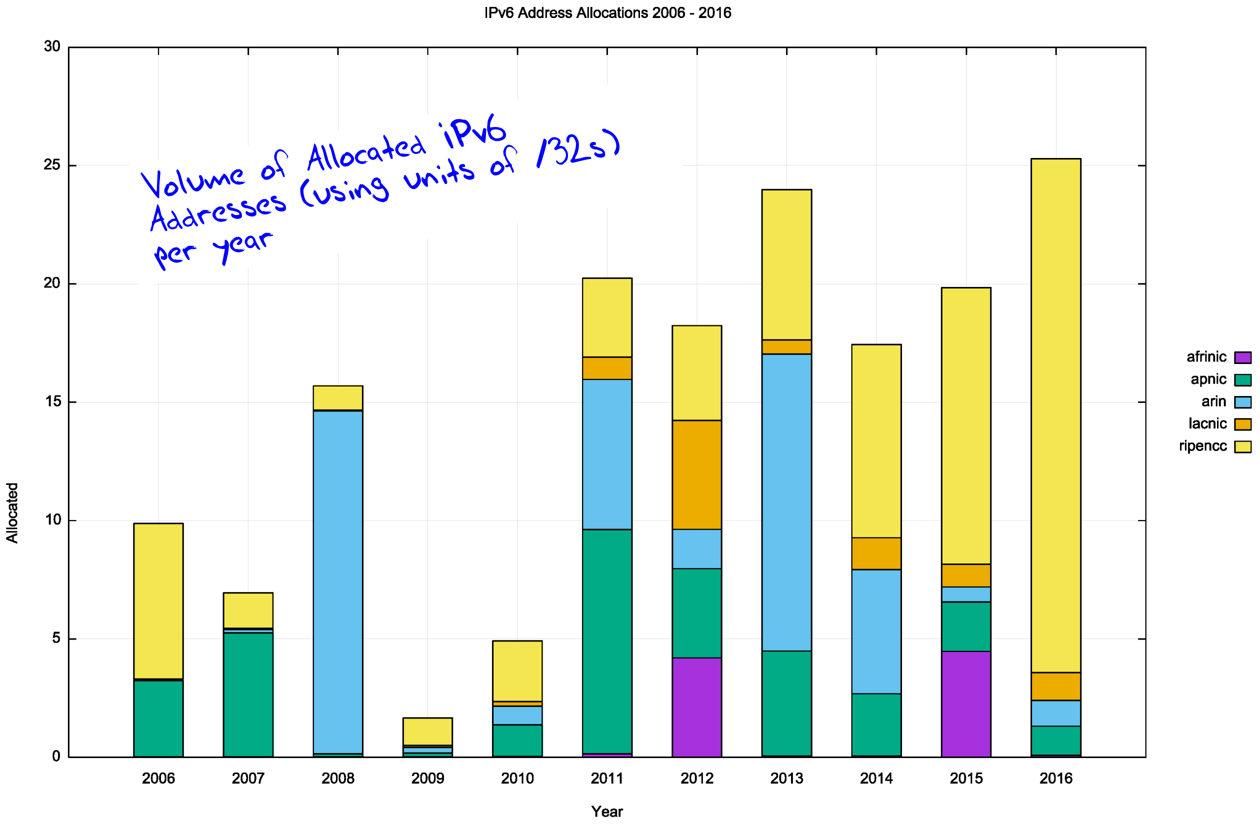
APNIC

IPv6

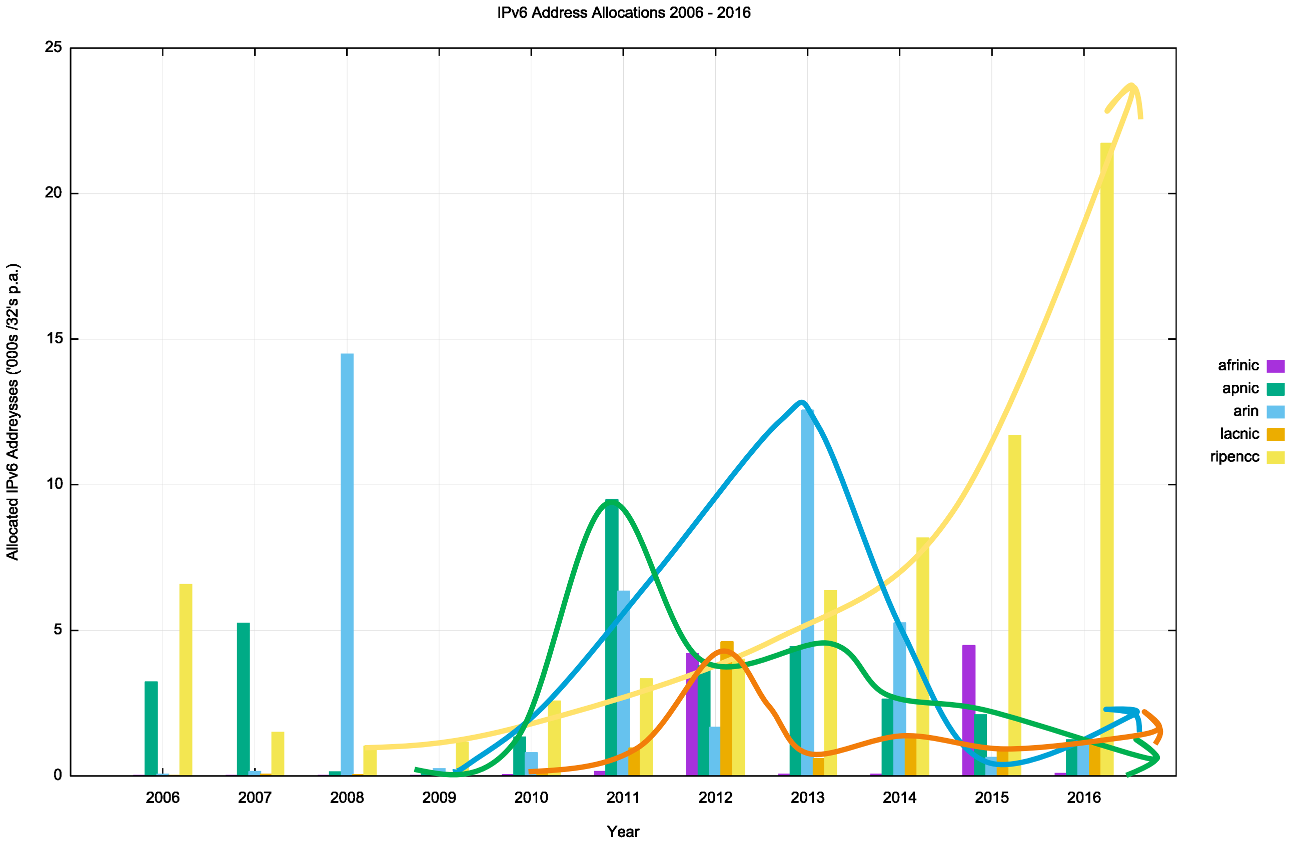
IPv6 Allocations by RIRs



IPv6 Allocated Addresses



IPv6 Allocated Addresses



Where did the IPv6 addresses go?

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

Volume of Allocated IPv6 Addresses (using units of /32s) per country, per year

Where did the IPv6 addresses go?

2015		2016	
South Africa	4,440	United Kingdom	9,571
China	1,797	Germany	1,525
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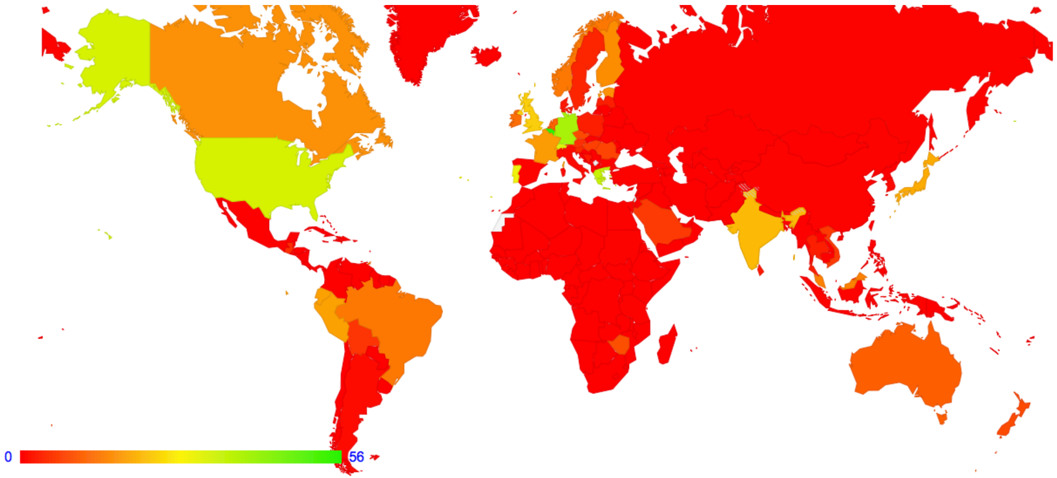
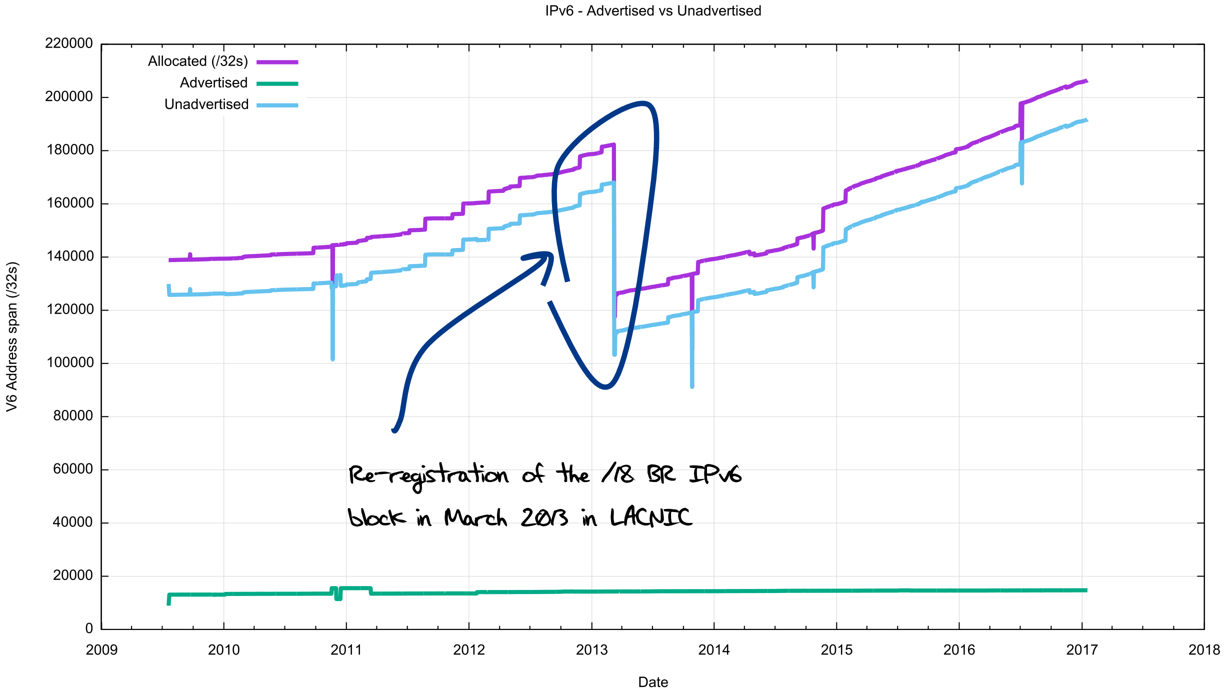


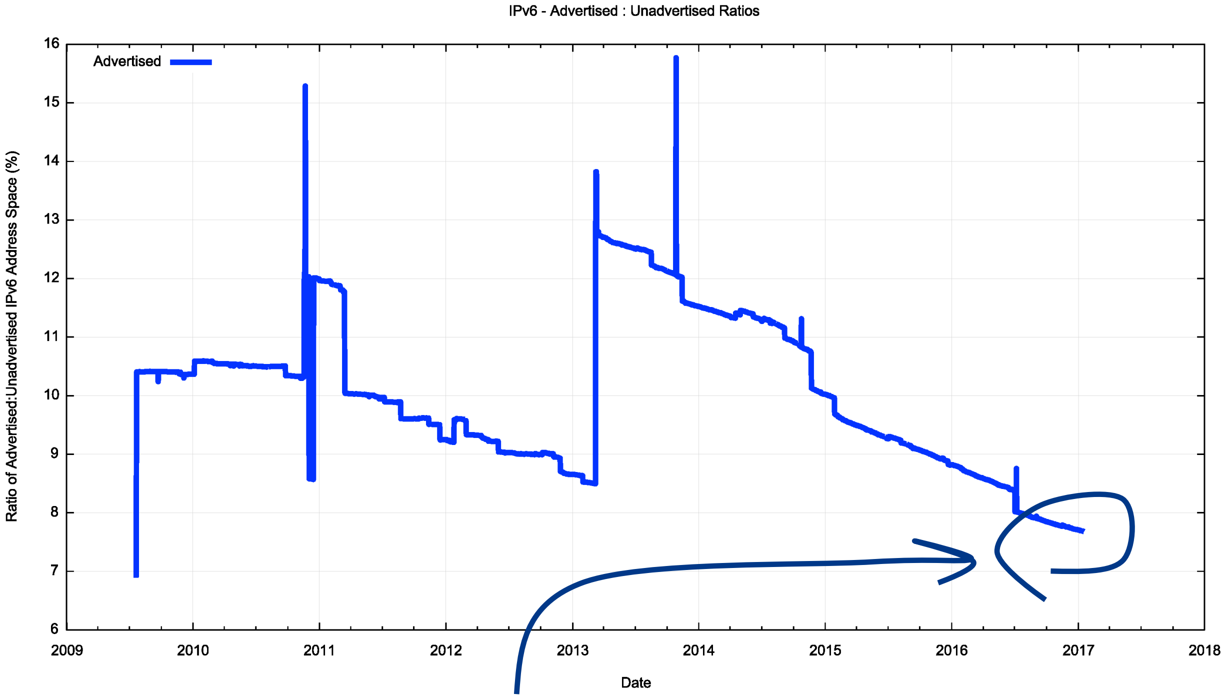
IPv6 Adoption rate per country (%)

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



Advertised : Unadvertised (%)



Less than 8% of allocated IPv6 address space is visible as a BGP advertisement

Total IPv6 Holdings by country

Rank	CC	Allocated /32s	Advertised /32s	Ratio	Country
1	US	43,030	138	0.3%	USA
2	CN	21,196	29	0.1%	China
3	GB	17,139	2,148	12.5%	UK
4	DE	16,107	226	1.4%	Germany
5	FR	11,432	38	0.3%	France
6	JP	9,415	93	1.0%	Japan
7	AU	8,864	4,109	46.4%	Australia
8	IT	7,143	50	0.7%	Italy
9	SE	5,736	4,148	72.3%	Sweden
10	KR	5,251	29	0.6%	Rep. Korea
11	NL	4,939	600	12.2%	Netherlands
12	AR	4,793	4	0.1%	Argentina
13	ZA	4,640	9	0.2%	South Africa
14	EG	4,105	4	0.1%	Egypt
15	RU	3,954	6	0.2%	Russia
16	PL	3,740	31	0.8%	Poland
17	BR	3,651	19	0.5%	Brazil
18	ES	2,800	9	0.3%	Spain
19	TW	2,359	2,159	91.5%	Taiwan
20	CH	2,090	111	5.3%	Switzerland
21	NO	1,618	286	17.7%	Norway
22	IR	1,491	3	0.2%	Iran
23	TR	1,326	1	0.1%	Turkey
24	CZ	1,319	41	3.1%	Czech Rep.
25	UA	1,082	1	0.1%	Ukraine

There is currently considerable disparity between countries as to the ratio between allocated and advertised IPv6 blocks.

Taiwan, Sweden, Australia, Norway, UK and Netherlands appear to advertise a visible part of their allocated IPv6 address holdings

Other countries have a far lower ratio of advertised to allocated address blocks

Why?

IPv4

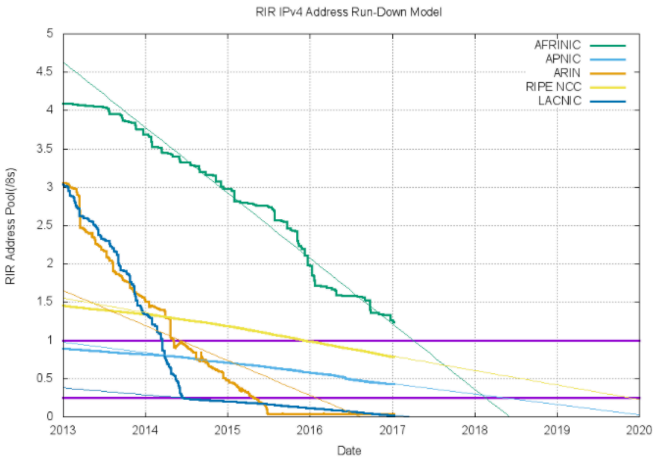
Addressing V4 Exhaustion

- We have been predicting that the exhaustion of the free pool of IPv4 addresses would eventually happen for the past 25 years!
- And, finally, we've now hit the bottom of the address pool!
  - APNIC, RIPE NCC, LACNIC and ARIN are now empty of general use IPv4 addresses
  - RIPE and APNIC are operating a Last /8
  - We now have just AFRINIC left with more than a /8 remaining

IANA Unallocated Address Pool Exhaustion:
03-Feb-2011

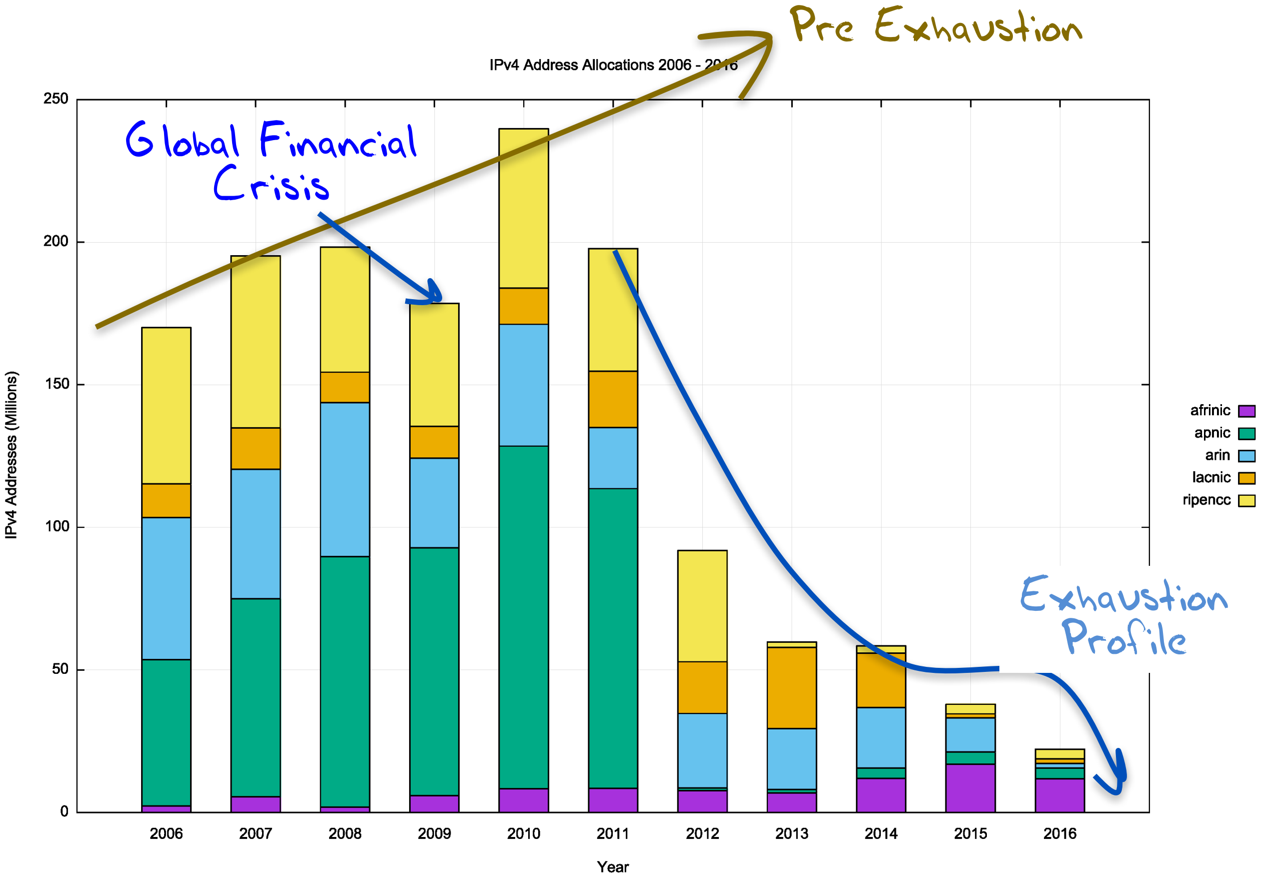
Projected RIR Address Pool Exhaustion Dates:

RIR	Projected Exhaustion Date	Remaining Addresses in RIR Pool (/8s)
APNIC:	**19-Apr-2011** (actual)	0.4271
RIPE NCC:	**14-Sep-2012** (actual)	0.7817
LACNIC:	**10-Jun-2014** (actual)	0.0158
ARIN:	**24 Sep-2015** (actual)	
AFRINIC:	**26-Jun-2018**	1.2368



Projection of consumption of Remaining RIR Address Pools

Allocations in the Last Years of IPv4



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

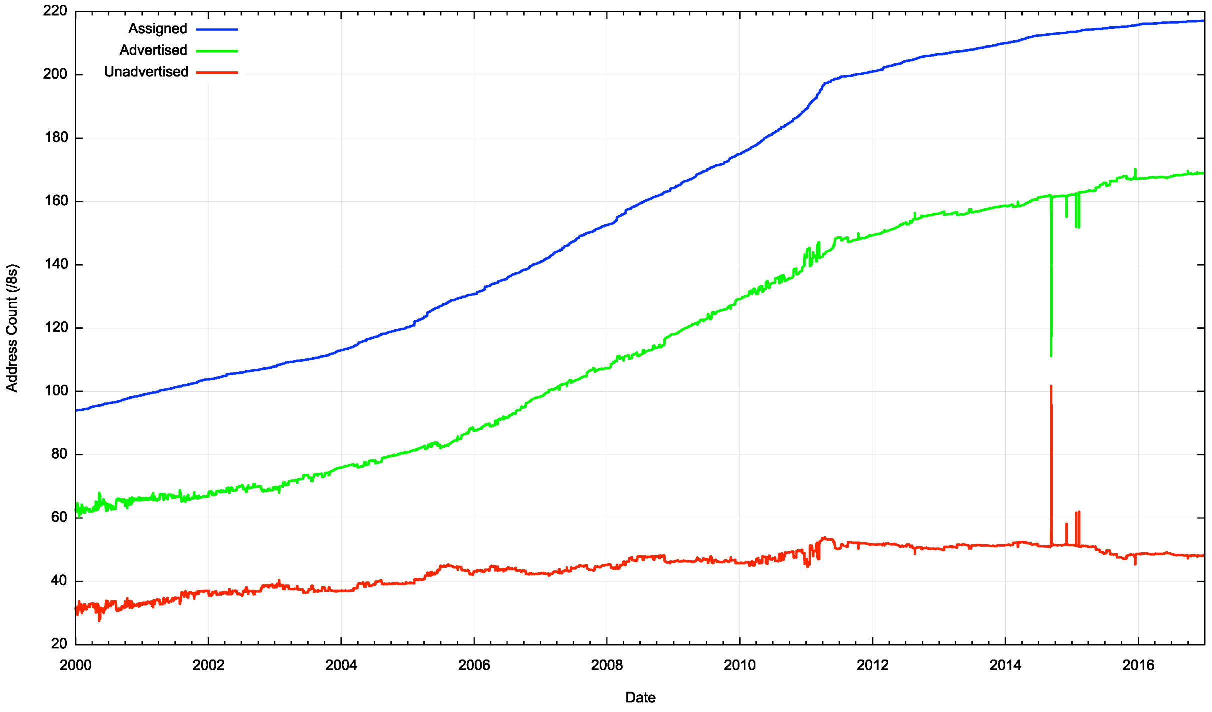
APNIC ran out in 2011

RIPE NCC ran out in 2012

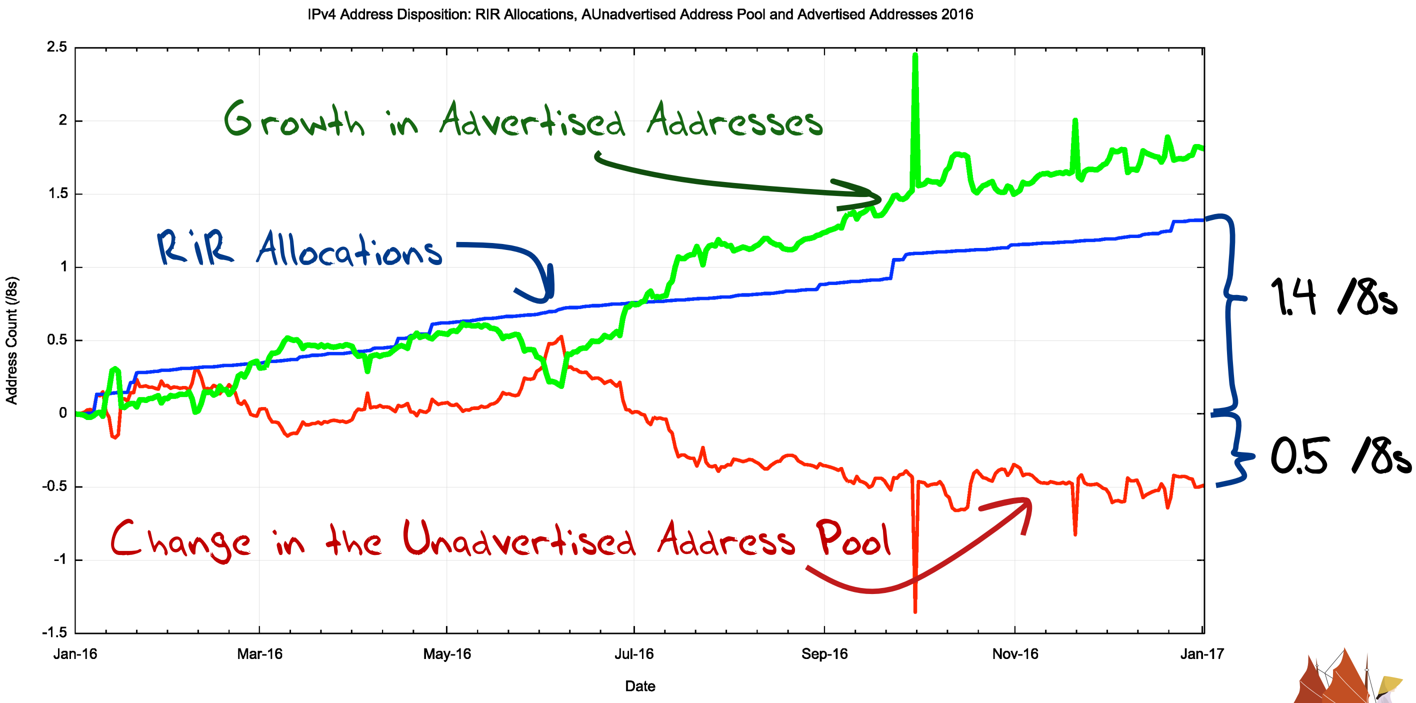
LACNIC ran out in 2014

ARIN ran out in 2015

IPv4: Advertised vs Unadvertised



IPv4: Assigned vs Recovered



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

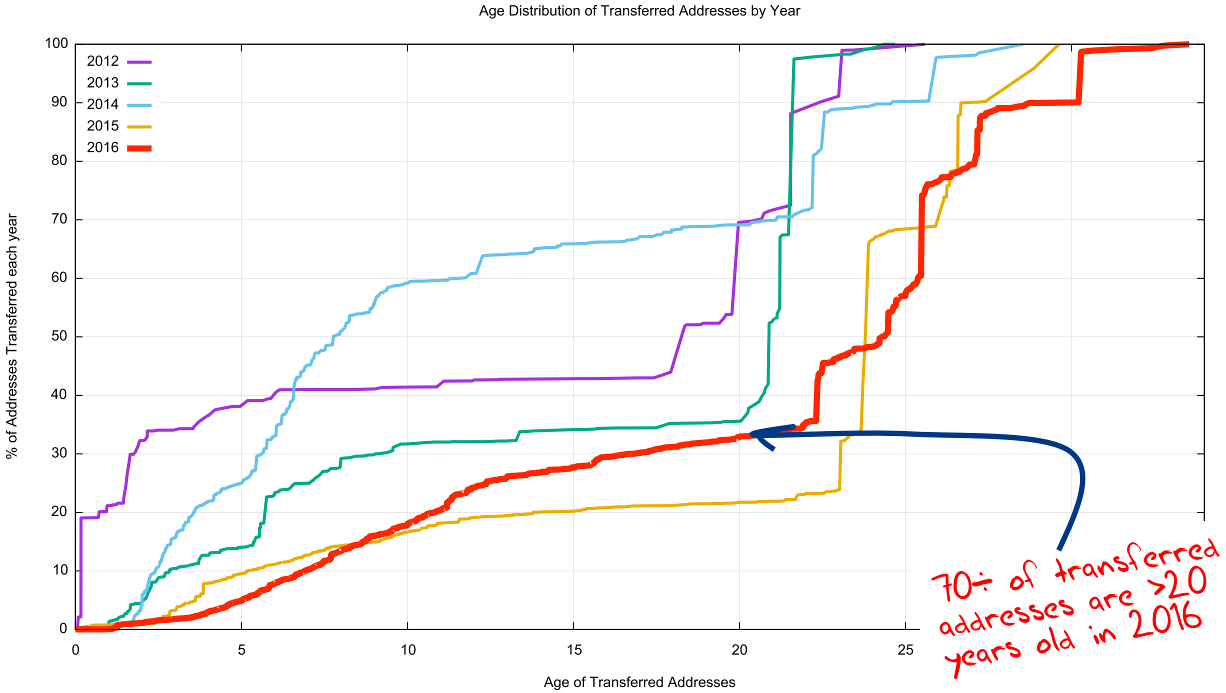
Number of registered Address transfers per year

Receiving RIR	2012	2013	2014	2015	2016
ARIN	79	31	58	277	727
APNIC	255	206	437	514	581
RIPE NCC	10	171	1,050	2,852	2,411

Volume of addresses transferred per year (/32s)

Receiving RIR	2012	2013	2014	2015	2016
ARIN	6,728,448	5,136,640	4,737,280	37,637,888	15,613,952
APNIC	3,434,496	2,504,960	4,953,088	9,836,288	7,842,816
RIPE NCC	65,536	1,977,344	9,635,328	10,835,712	9,220,864

How old are transferred addresses?



But

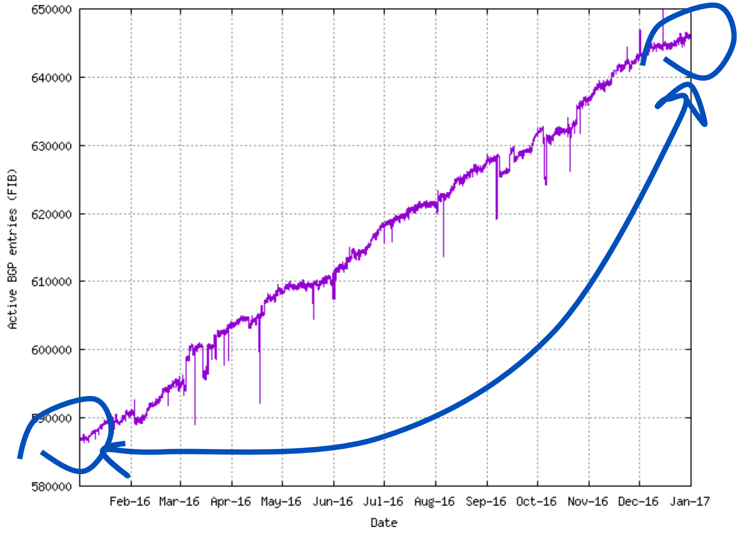
The RIR Transfer Logs are not the entire story:

- 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?

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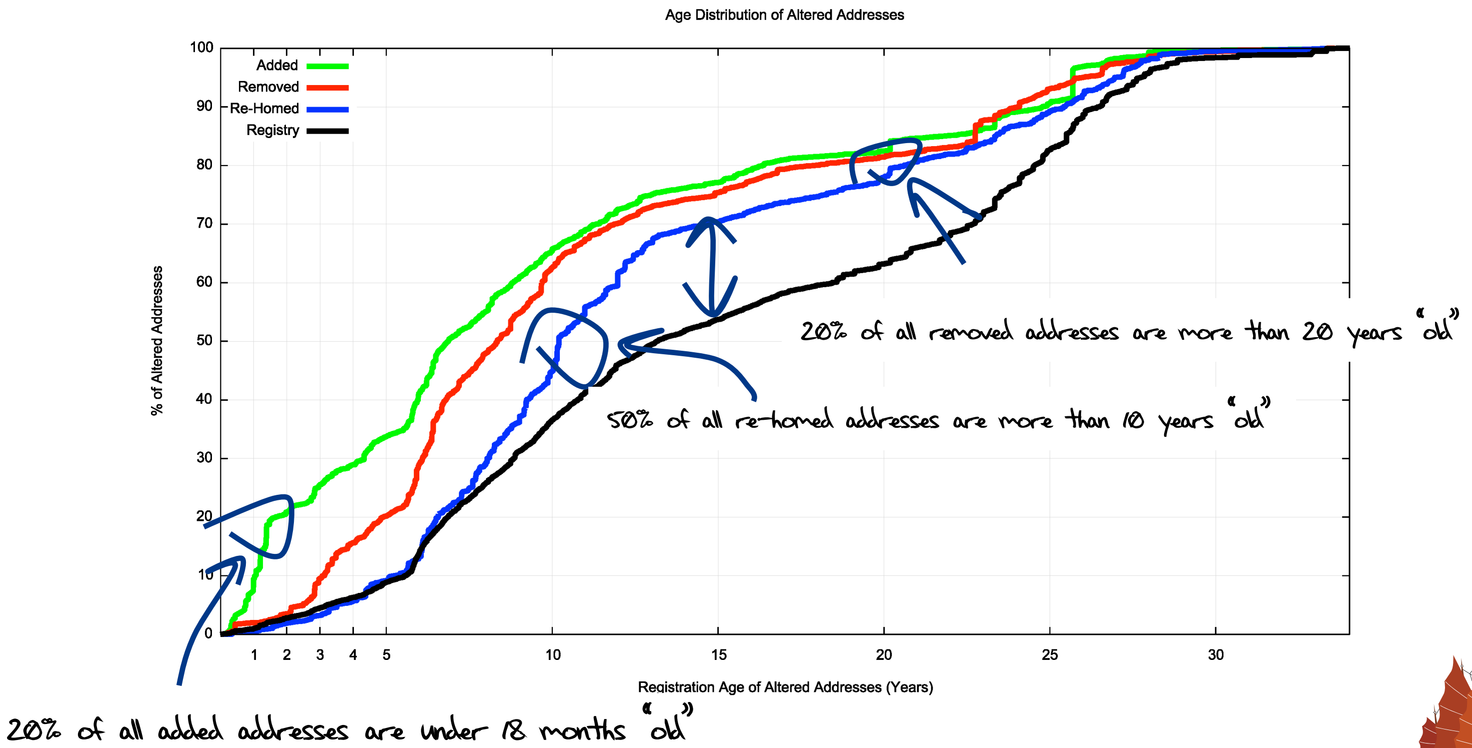
	Listed as Transferred	UnListed	
Rehomed			
All	1,539	15,389	9%
Root Prefixes	1,184	9,551	11%
Removed			
All	3,287	64,287	5%
Root Prefixes	1,877	20,203	9%
Added			
All	8,663	117,982	7%
Root Prefixes	4,617	41,621	10%

"Age" of Shifted Addresses



"Age" 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

Address Movement and Registry Data

- Some 10% of the announced address span changed its advertised behaviour in 2016 (advertised, withdrawn or re-homed)
- Of these changed addresses:
  - Some 5% of this set of changed addresses are listed in the transfer logs, and have updated registry records
  - The disposition of the remaining changed addresses (95%) is not clearly understood with respect to the relevance of the current registry records for these addresses.

Address Movement and Registry Data

- 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

We have no clear way of recording these transactions in the registry

Leasing and the Registry

Should we make address leasing arrangements explicit in the address registry?

- *For example*, we could mark the distinction between the holder of the address (admin-c) and the current operator (tech-c)
  - Allow the admin-c and tech-c point to organization objects rather than person objects
  - The admin-c field would indicate to the organization object that is the holder of the address block
  - The tech-c field would point to the organization object that is the current operator (lessee) of the address block
- *Or* we could add a *leasee:* field to indicate that
  - the object has been leased
  - The leasee: field would point to an organisation object that is the current operator (lessee) of the address block

RPKI and Leasing

– When an address is leased then whose RPKI keys control the ROA?
  - The Lessee?
  - The Leasor?

– And why not implement RFC7909 while we are at it?
  - What registry objects/fields could or should be signed by the admin org (leasor) and what could be signed by the tech org (the lessee)

Registry Changes and APNIC Policies

- Do we need an Address Policy SIG decision to proceed with making address lease arrangements explicit in the registry in some manner?
  - If so, what does the SIG require?

- If not, then what process should we use to bring leasing arrangements out into the clear, in order to remove the current uncertainty over the distinction between the organisation who has administrative control of a resource and the organisation that currently has operational control?

Discuss!