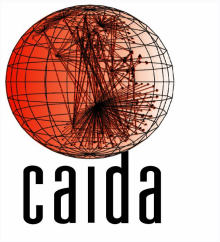
Measuring the IPv4 transfer markets

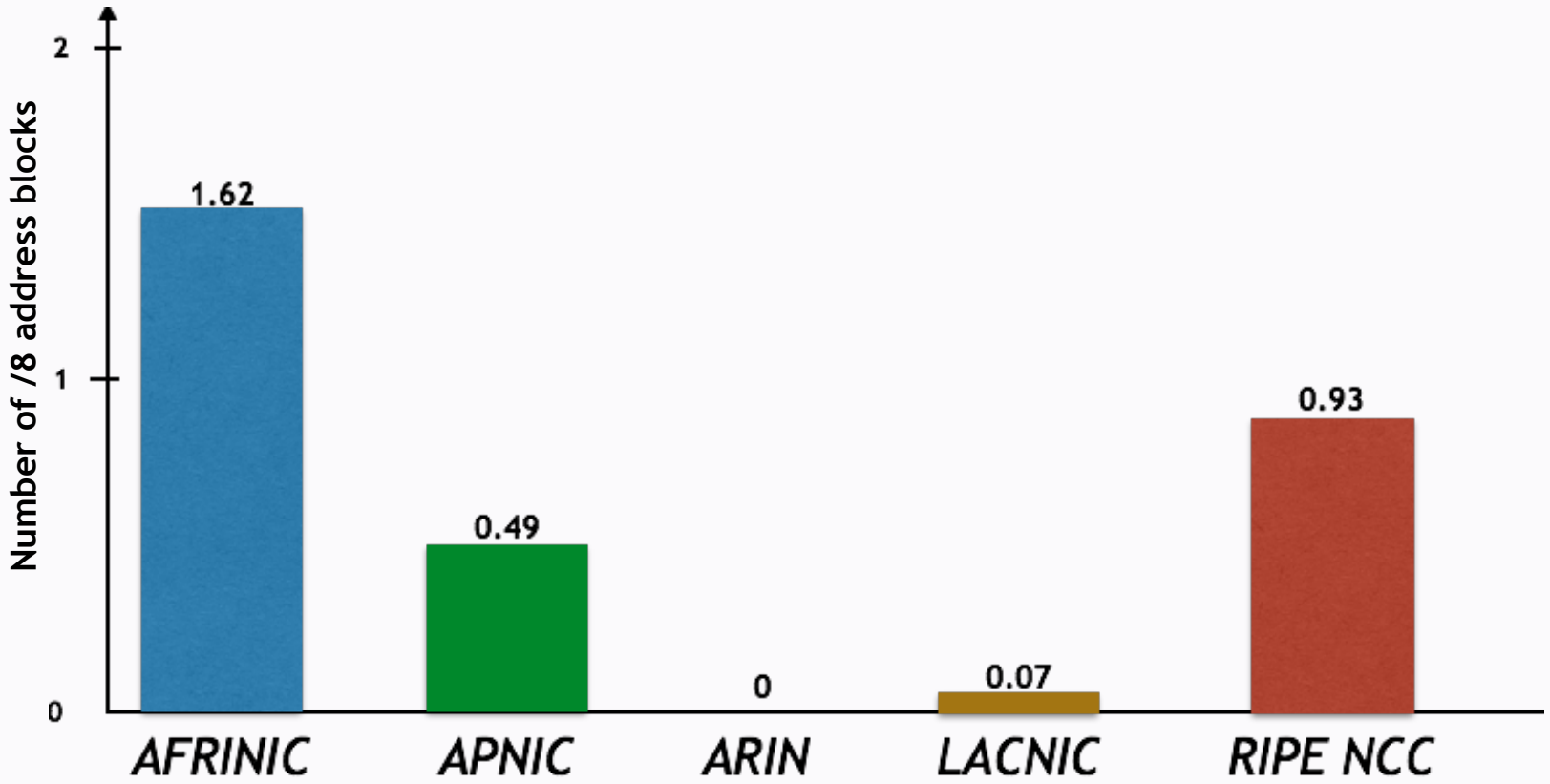
Ioana Livadariu, Ahmed Elmokashfi
(Simula Research Laboratory)

Amogh Dhamdhere
(CAIDA/UCSD)

[simula . research laboratory]



IPv4 address space: status

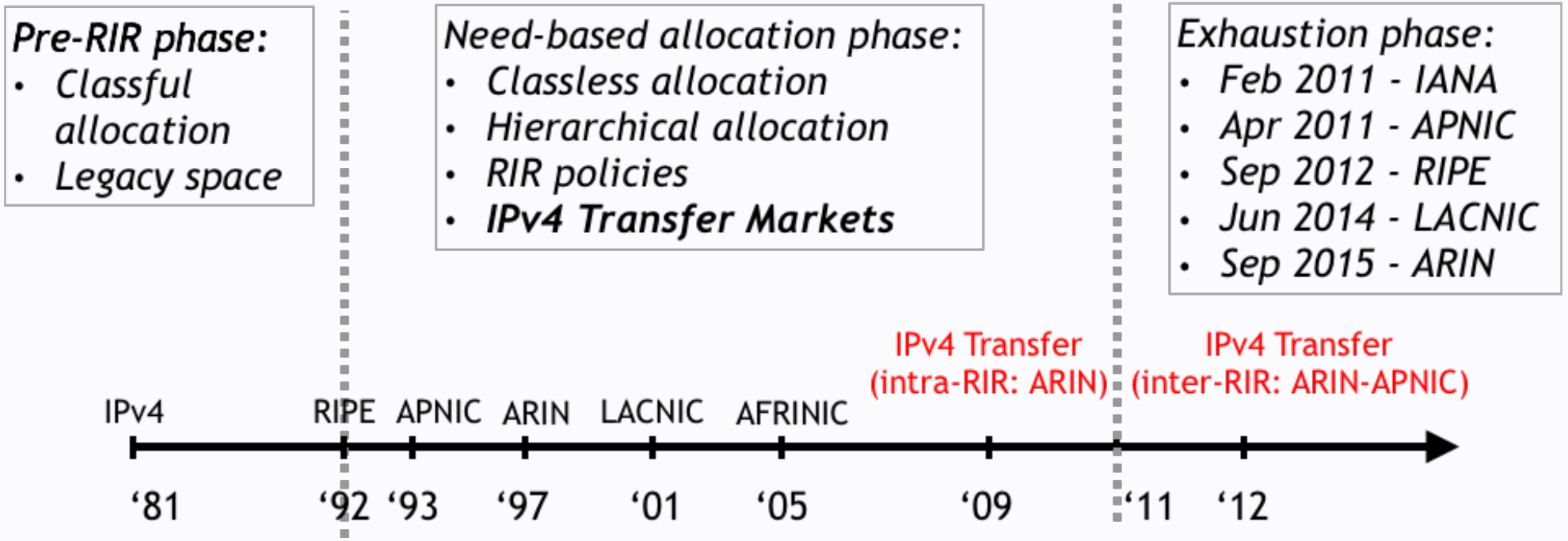


*Available IPv4 /8 address blocks per RIR**

- Limited address space assignment
- Organizations have to justify the required IPv4 address space

* Source: NRO Internet Number Resource Report June 2016

IPv4 address space: allocation



IPv4 Address space management

IPv4 Transfers

- *IPv4 address transactions that occur between organizations*
  - Can involve third-parties (**IPv4 brokers**)
  - Regulated by the **RIRs policies**

- Three RIRs have legitimized transfer markets

Internet Registry	Intra-RIR Policy	First Published Transfers
RIPE	December 2008	October 2012
ARIN	June 2009	October 2009
APNIC	February 2010	January 2011

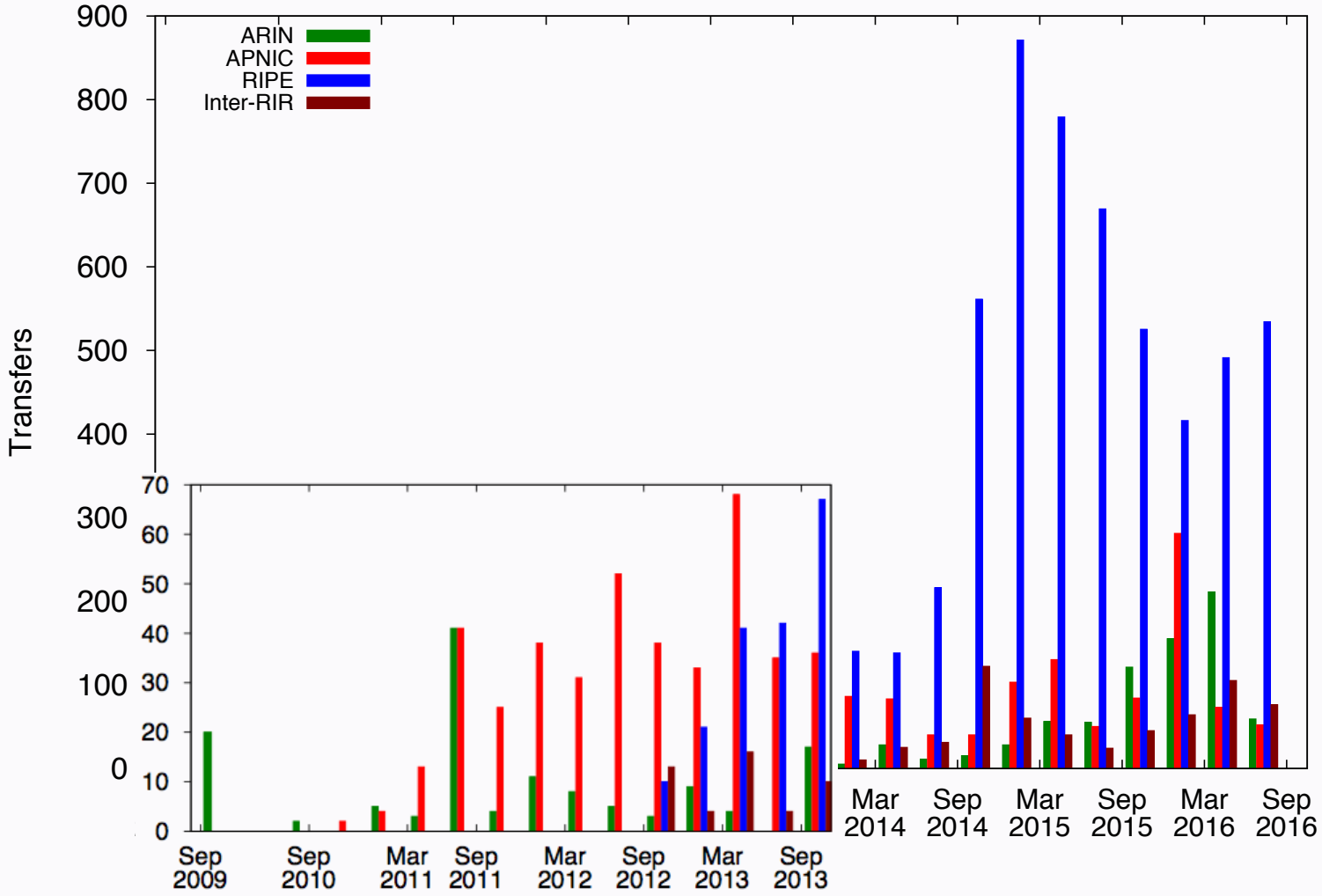
Internet Registry	Inter-RIR Policy	First Published Transfers
ARIN <—> APNIC	July 2012	October 2012
APNIC <—> RIPE <—> ARIN	September 2015	December 2015

Outline

- Analysis of published transfers:
  - How are transfers evolving over time ?
  - What type of addresses are being transferred ?
  - Are buyers using the acquired space ?
  - Is there a correlation between markets and IPv6 adoption ?
  - What is the market value ?

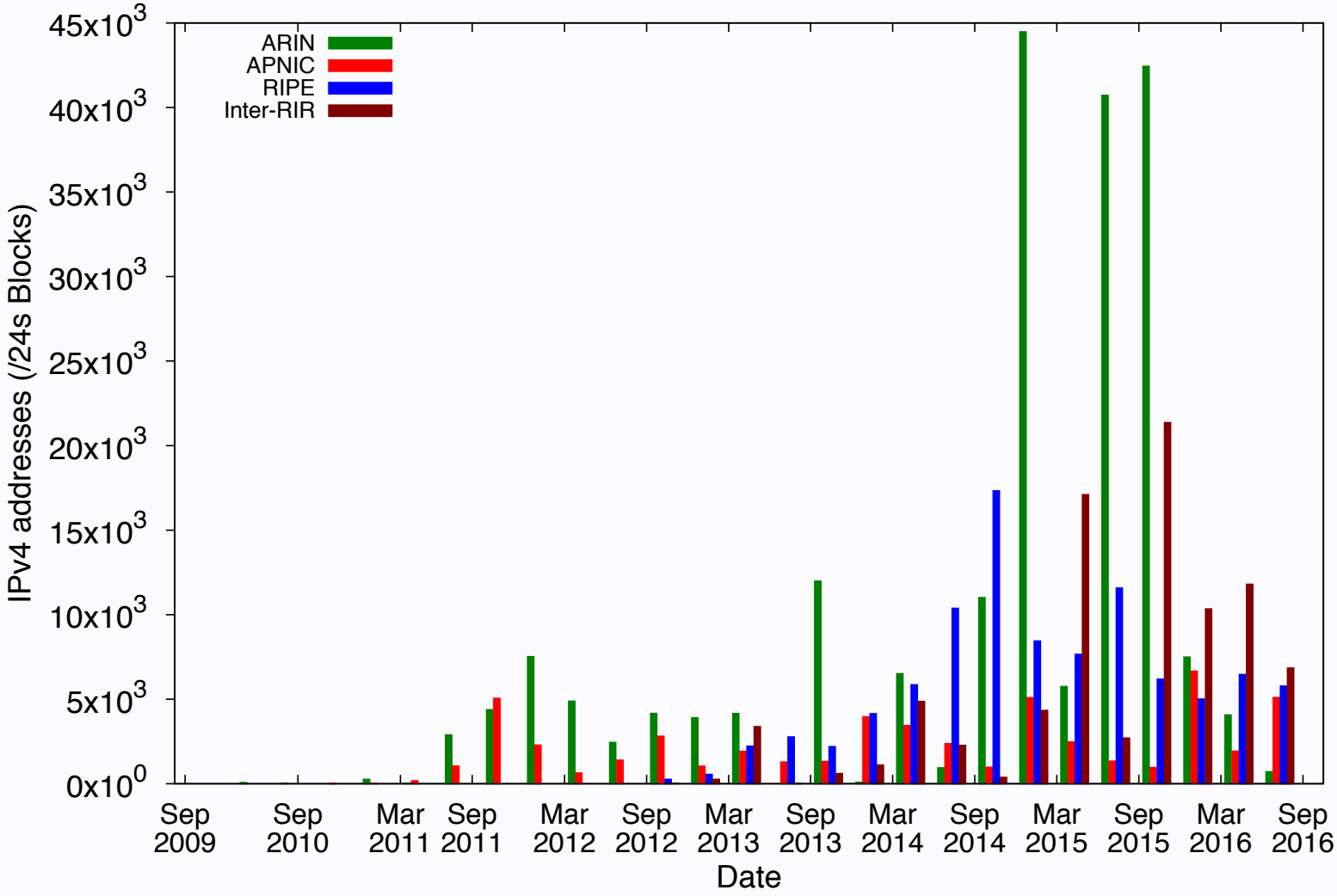
- Detecting transfers:
  - Can we detect transfers using publicly available data ?

Increasing number of transfers over time



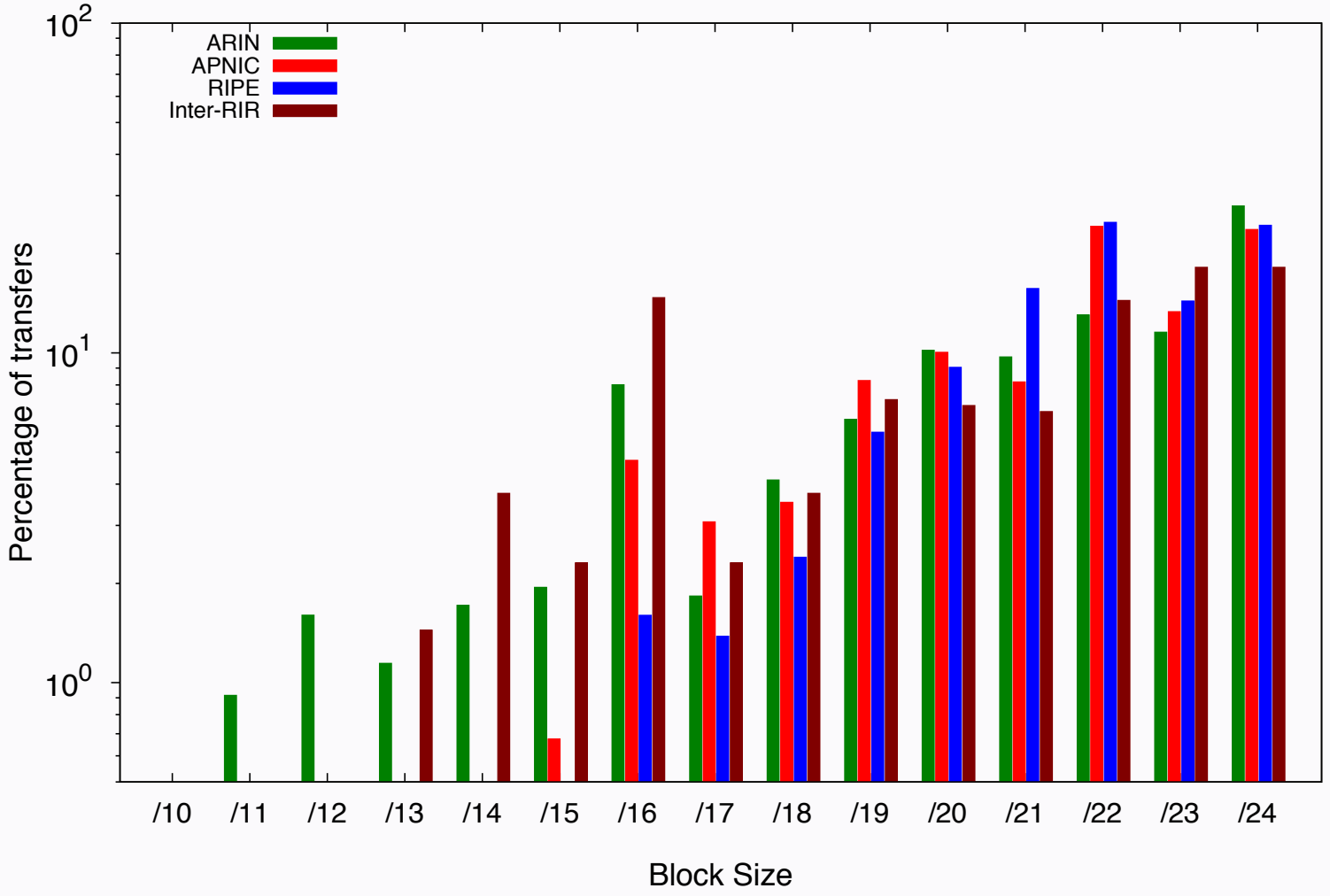
- 80% year on year increase (2013-2015); not much change in 2016
- Approx. 65% of the reported transfers occur within RIPE

How much space is transferred?



- Transferred address blocks account for ~2.67% of the IPv4 space
- 47% of the transferred space comes from ARIN

Which space is being transferred?



- 71% of the transferred space is legacy allocation (>90% ARIN)
- In ARIN, 37% of the blocks are larger than /20, whereas more than 80% transferred blocks are smaller than /20 for RIPE and APNIC

Transferred space = “Used” space ?

Class	*Before*	*After*	*% (Total space)*
A	Unrouted	Unrouted	4.04
B	Routed	Unrouted	1.49
C	Unrouted	Routed	85.17
D	Routed	Routed	9.27

Visibility of the transferred blocks in the routing table

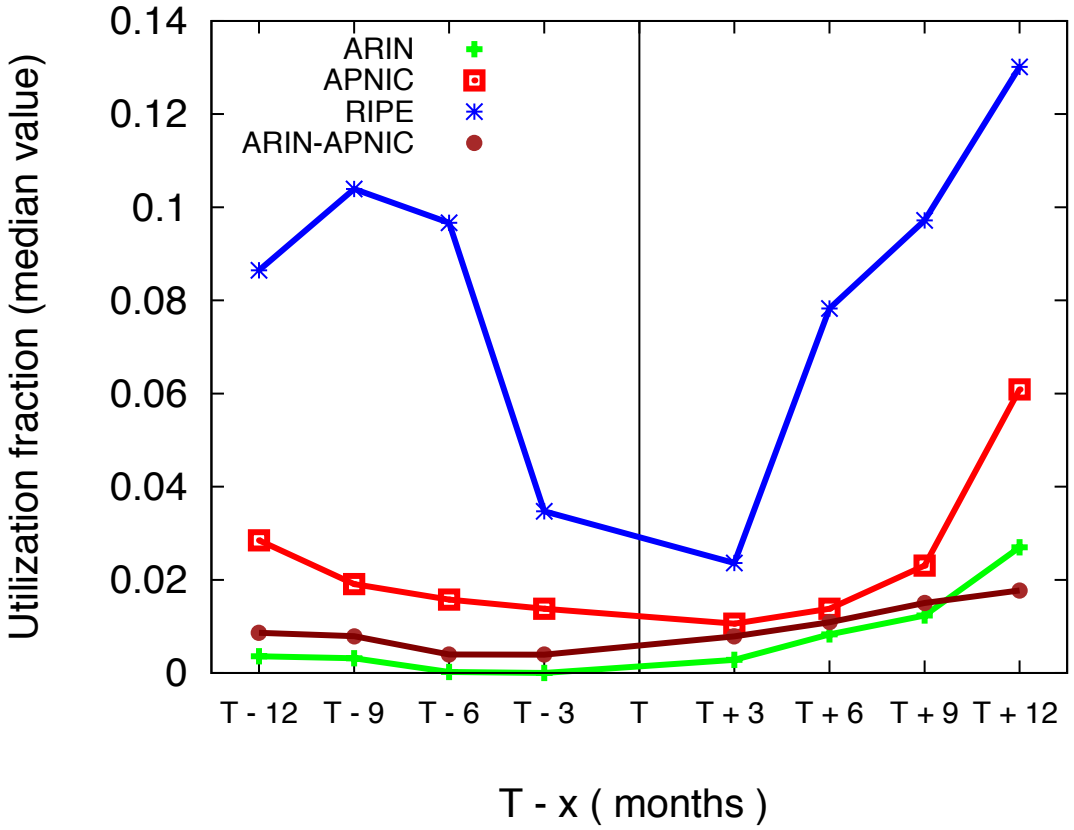
94% of the transferred space is routed after the transfer

RIR	*Time before re-announced (months)*
RIPE	1.91
APNIC	6.2
ARIN	6.48

Buyers acquire addresses to meet immediate needs

Buyers need addresses more than sellers

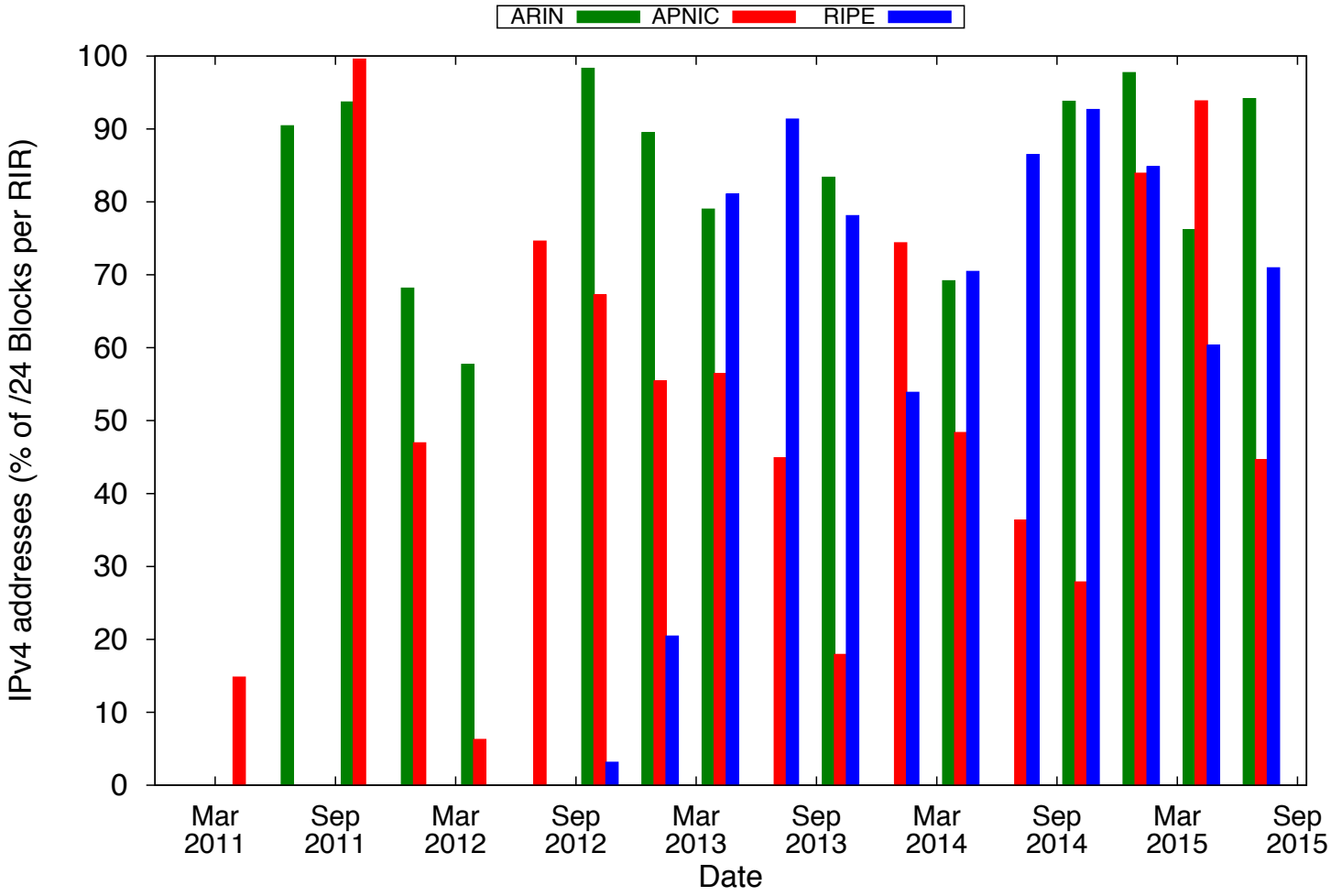
- Utilization fraction* = fraction of IP addresses that responds to ICMP requests in a transferred prefix



- Utilization fraction of the transferred space has increased with at least 50% after the transfer date

* Source: ISI Census data

High percentage of the address space is exchanged among the top participants in the market

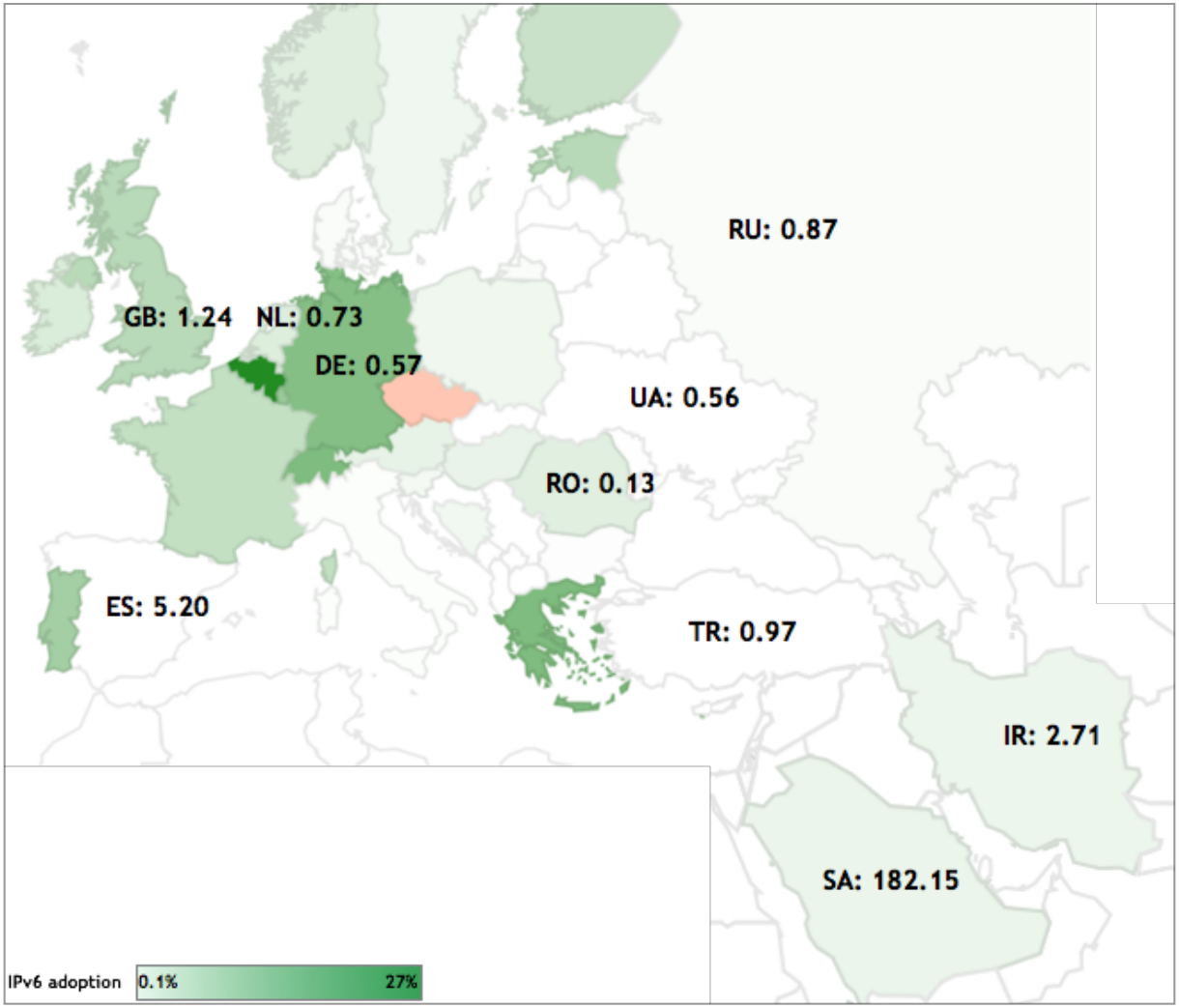


Percentage of IPv4 address space sold/bought by top 10% dominant players per RIR

RIPE: Four countries dominate the market

- Organizations involved in the IPv4 transfer market come from 64 countries
- Approx. 78% of the address space is exchanged between six countries

  - 50% of the sold IPv4 space comes from two countries (Germany and Romania)
  - 30% of the IPv4 space is bought by organizations in two countries (Saudi Arabia and Iran)

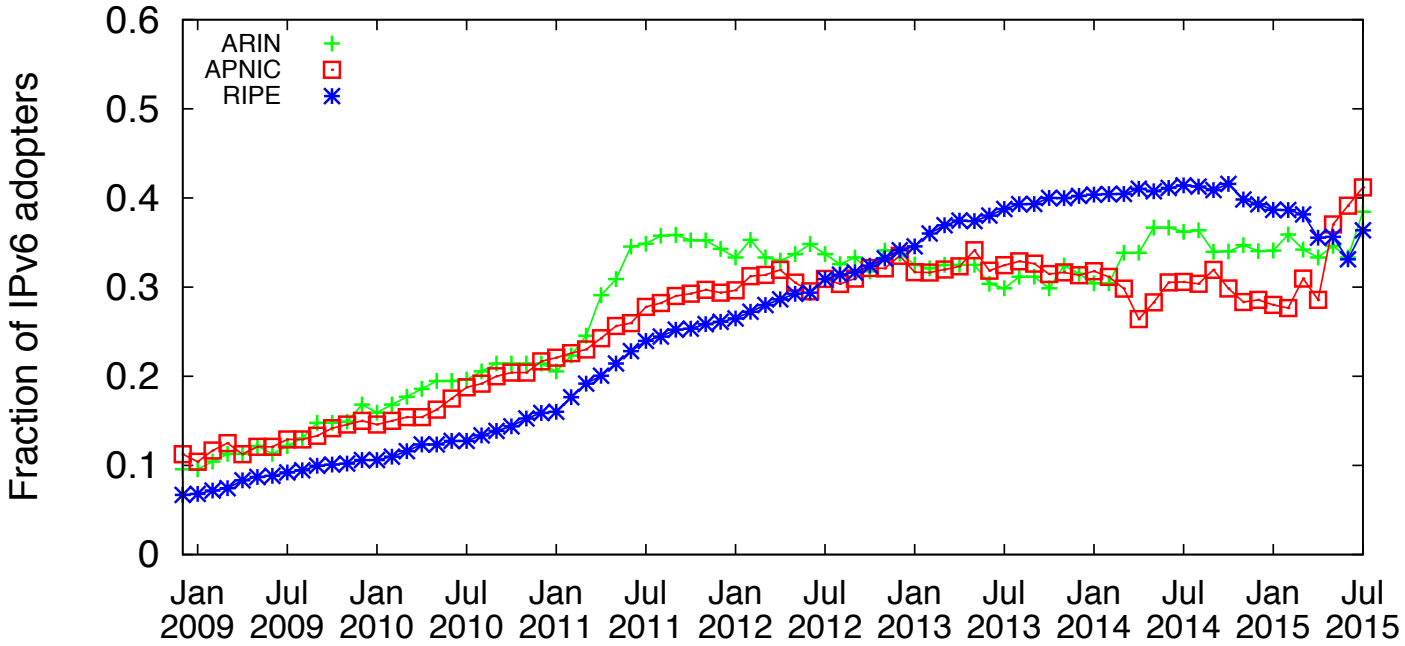


(IPv4 space bought/IPv4 space sold) and IPv6 adoption per country within RIPE*

* Source: Google IPv6 Statistics

Are markets slowing down IPv6 adoption?

- *Fraction of IPv6 adopters* = fraction of buyers that are originating IPv6 prefixes* after acquiring IPv4 addresses on the transfer market



- Increasing number of buyers that adopt IPv6 across all RIRs
- IPv4 transfers markets do not appear to inhibit the IPv6 adoption

* Source:BGP data (Routeviews and RIPE NCC)

What is the market monetary value?

- Widely known IP transactions:

  2011 Microsoft - Nortel*: $*11 per IPv4 address*
  2011 Cerner - Borders** : $*12 per IPv4 address*

- Prices published by IPv4 Brokers:

IPv4 Market Group *(retrieved in August 2015)*

RIR	/20	/19	/18	/17	/16
APNIC	12.50	10.00	8.00	7.25	6.50
ARIN	12.50	10.00	8.75	6.40	5.50
RIPE	12.55	12.00	10.50	8.50	8.20

IPv4Auctions.com *- (retrieved in September 2016)*

Block	Sold Date	Price per address
/22 Block Registered in ARIN	9/20/16	$12.00
/21 Block Registered in ARIN	9/20/16	$10.00
/23 Block Registered in ARIN	9/19/16	$12.00
/24 Block Registered in ARIN	9/19/16	$13.35
/23 Block Registered in ARIN	9/15/16	$11.75
/21 Block Registered in ARIN	9/13/16	$11.15
/23 Block Registered in ARIN	9/13/16	$12.74
/24 Block Registered in ARIN	9/13/16	$13.25
/19 Block Registered in ARIN	8/24/16	$8.75

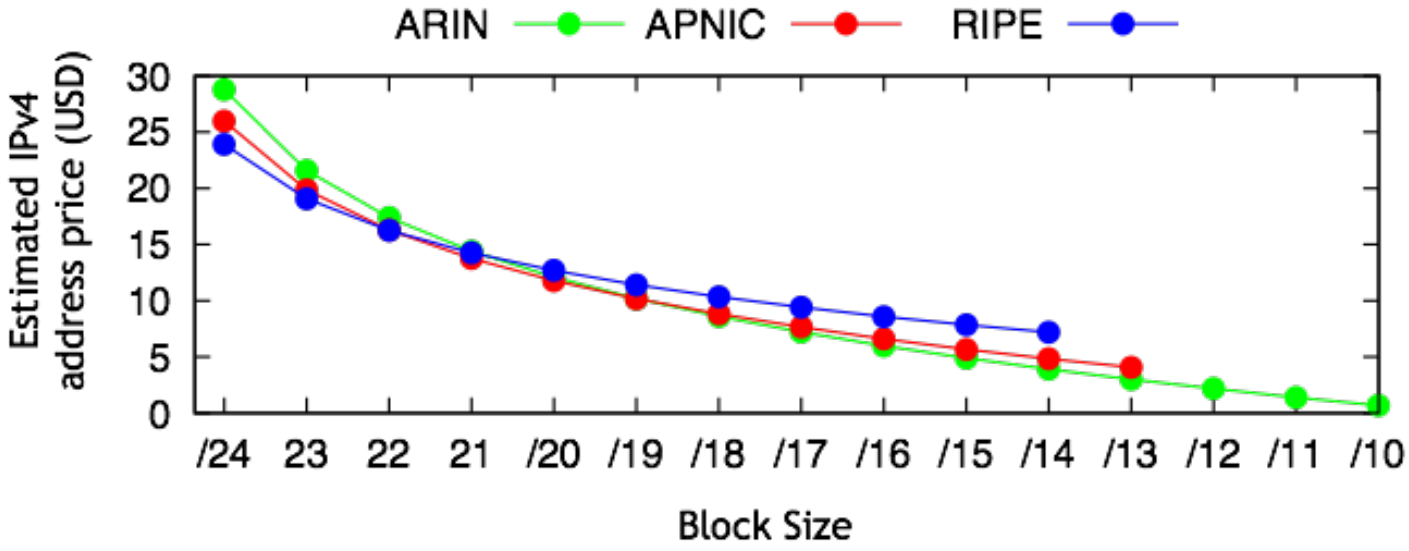
- Monetary aspects of the IPv4 transactions are confidential
- Prices published by IPv4 Brokers offer a partial view of the market value

* Source: http://www.networkworld.com/

**Source: http://www.ipaddressnews.com/

Estimating the market monetary value

- Approach:
  - We model the IPv4 address block prices using a *Hedonic Pricing Method*[*], which estimates the value of a good by taking into account both internal characteristics and external factors of the good
  - We use prices reported by IPv4 brokers to fit the hedonic prices model

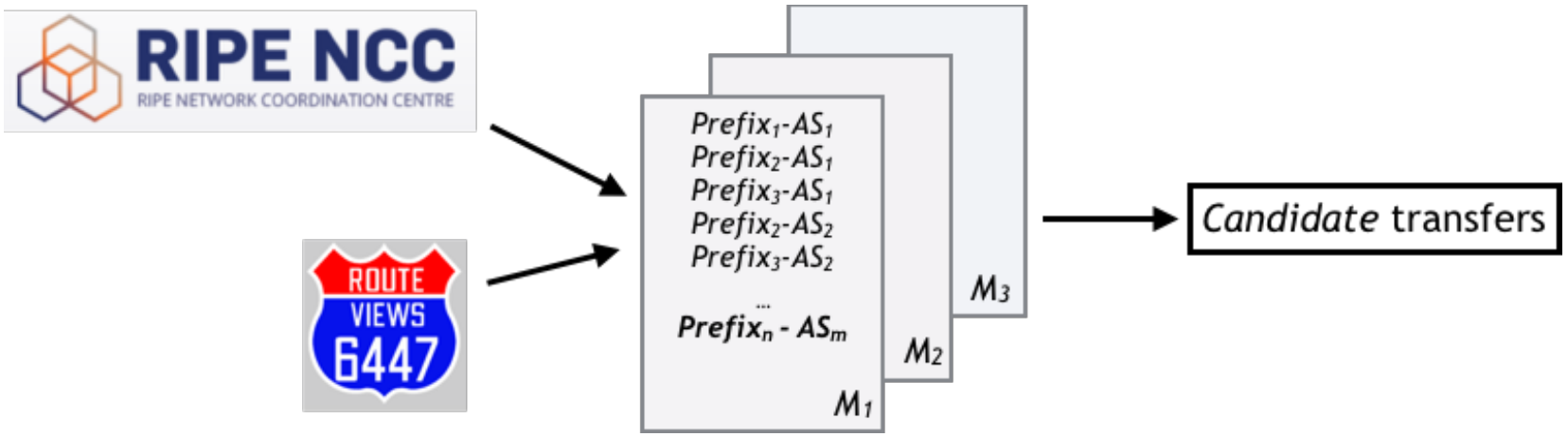


- Estimated value of the market: ~$386 M (USD)

*Source: S. Rosen, *Hedonic prices and implicit markets: Product differentiation in pure competition*

Can we detect transfers “in the wild” ?

- Transfers need to be approved by the RIRs, but there is no mechanism to ensure that organizations report to the RIRs
- Methodology: Use BGP data (routing table dumps) collected from January 2004 to September 2015 to construct prefix-AS mapping and identify prefixes that change origin AS

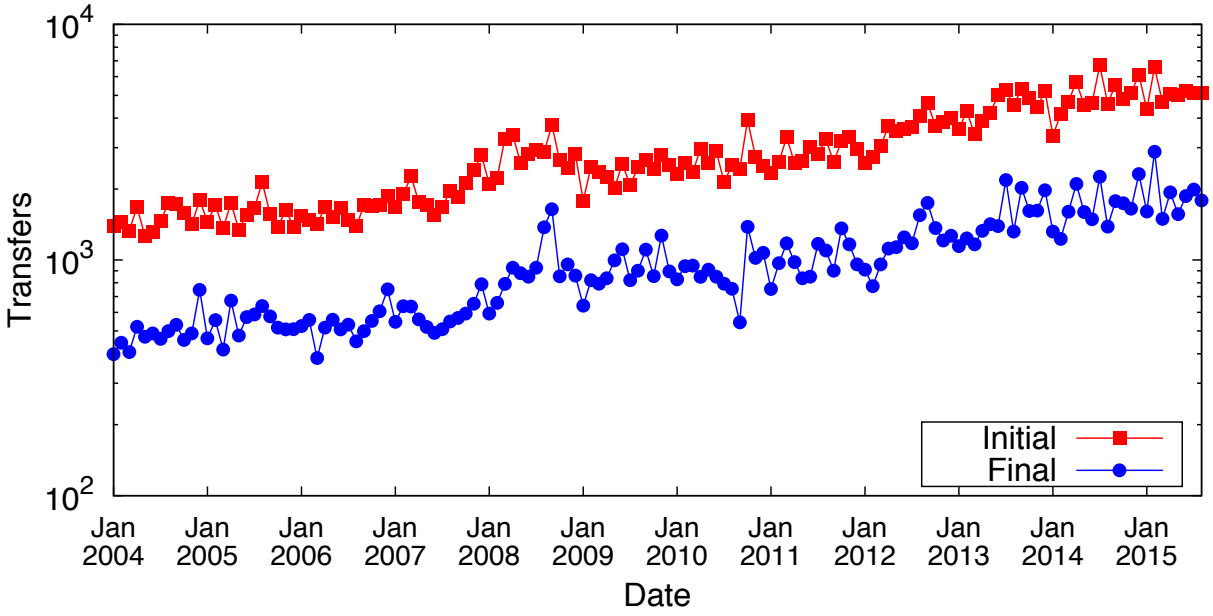


Detecting transfers: filtering approach

- Our approach is prone to false positives due to legitimate reasons
- Design four *filters* to reduce the number of candidate transfers

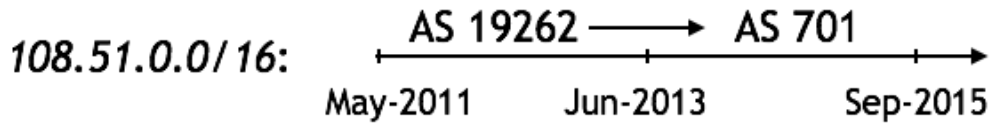
Filter	***Removed prefixes***
Map2Organization	IPv4 space movement within the same organization
Transient	Short-lived advertised IPv4 space (e.g. prefix hijacks)
RIR	IPv4 space advertised by RIRs
Delegation	Provider-aggregatable address space

Evaluating the results

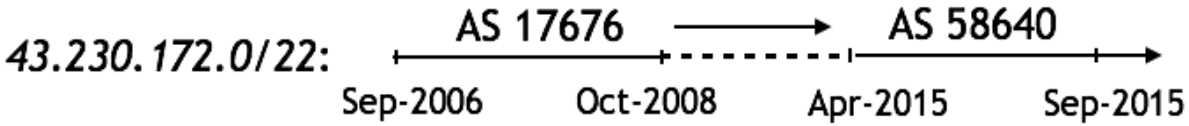


- Filters reduce 65% of the initial number of candidate transfers
- Our methodology infers more than 90% of the detectable published transfers

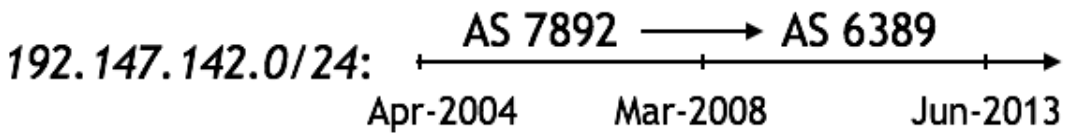
False positive: examples and causes



Incomplete AS2ORG mapping*



Reallocated address blocks



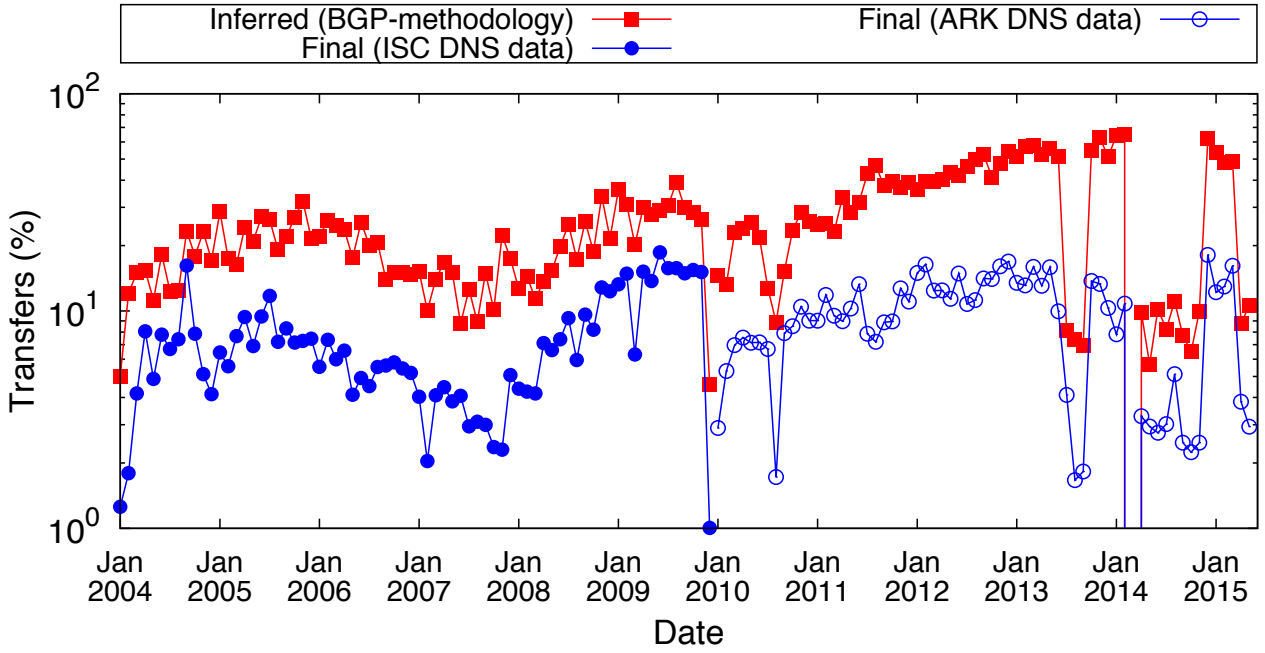
Non-BGP speaker organizations switching providers

*Source: CAIDA AS2ORG Mapping

Detecting transfers: expanding the methodology

- Possible solution: *Augmenting the data* (DNS names)
  - Changes in DNS resource record
  - Data: *IPv4 Routed /24 DNS Names Dataset*

- Preliminary analysis: Usage of DNS records removes two third of the analyzable candidate transfers



Conclusions

- Increase in the size of the IPv4 transfer markets
- The majority of the transferred blocks are legacy allocations
- Markets seem to serve their intended purpose (i.e buyers “use” the acquired address space)
- Markets appear not to slow down the IPv6 adoption
- Markets differ across regions in terms of size and type of the transferred blocks, participants

- Detecting transfers is difficult and requires using multiple data sources