

A Primer on IPv4 Scarcity

Best of CCR
SIGCOMM 2015
London

Philipp Richter
TU Berlin

Mark Allman
ICSI

Randy Bush
IIJ

Vern Paxson
ICSI / UC Berkeley

IPv4 Scarcity



As of today only ~2% of the IPv4 address space “free”

routing data

allocation files

transfer logs

RFCs

routing registries

broker statistics

Many institutions involved, 35 years of evolution

Patchwork of different sources of information

policy documents

WHOIS

policy mailing lists

What is IPv4 scarcity? What factors affect it? What challenges does it pose? How are we dealing with it?

Agenda

- The History of IPv4 Address Space
 - ➡ Management
 - ➡ Allocation
 - ➡ Routing
- IPv4 Addresses: A Virtual Resource
- The Emerging Address Market

A History of IPv4 Address Block Management

1981

Early Registration

- Informal Distribution
- Scarcity minor issue
- Non-commercial Internet

~1992

Needs-Based Provision

- Distribution process
- Justification of need
- ISPs don't pay for IPs

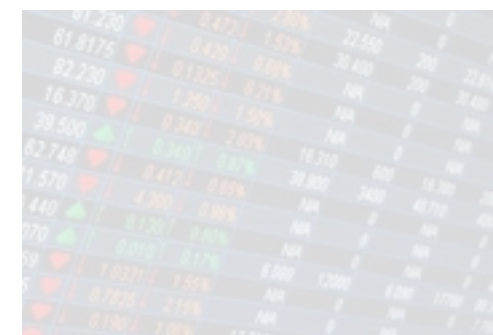
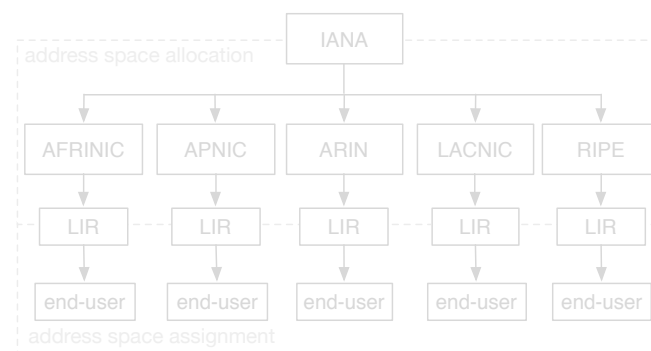
~2011

Depletion & Exhaustion

- Address Markets
- Money comes into play!



Jon Postel
† 1998



Early Registration Phase: Policies

RFC790

J. Postel

ISI

September 1981

current information can be obtained from Jon Postel. The assignment of numbers is also handled by Jon. If you are developing a protocol or application that will require the use of a link, socket, port, protocol, or network number please contact Jon to receive a number assignment.

Jon Postel

USC - Information Sciences Institute

4676 Admiralty Way

Marina del Rey, California 90291

phone: (213) 822-1511

ARPANET mail: POSTEL@ISIF

- Rather Informal address distribution
- First RFC: More than 700M IPv4 addresses registered
- Classful Addressing, heavy internal fragmentation

A History of IPv4 Address Block Management

1981

Early Registration

- Informal Distribution
- Scarcity minor issue
- Non-commercial Internet

~1992

Needs-Based Provision

- Distribution process
- Justification of need
- ISPs don't pay for IPs

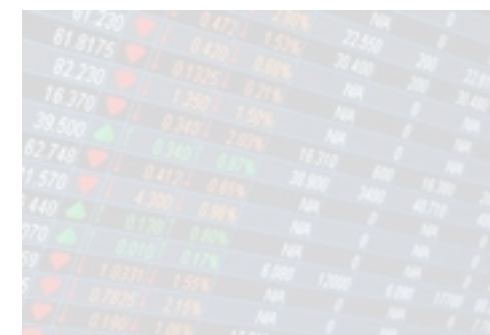
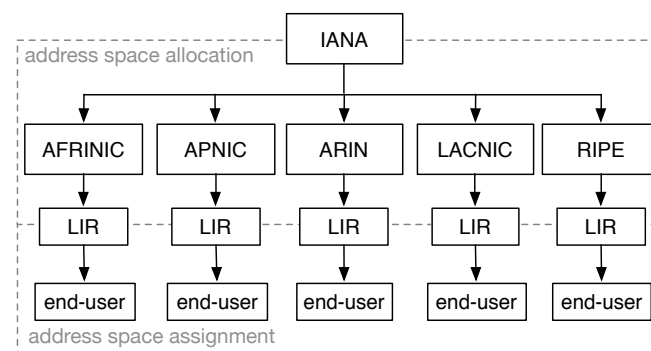
~2011

Depletion & Exhaustion

- Address Markets
- Money comes into play!

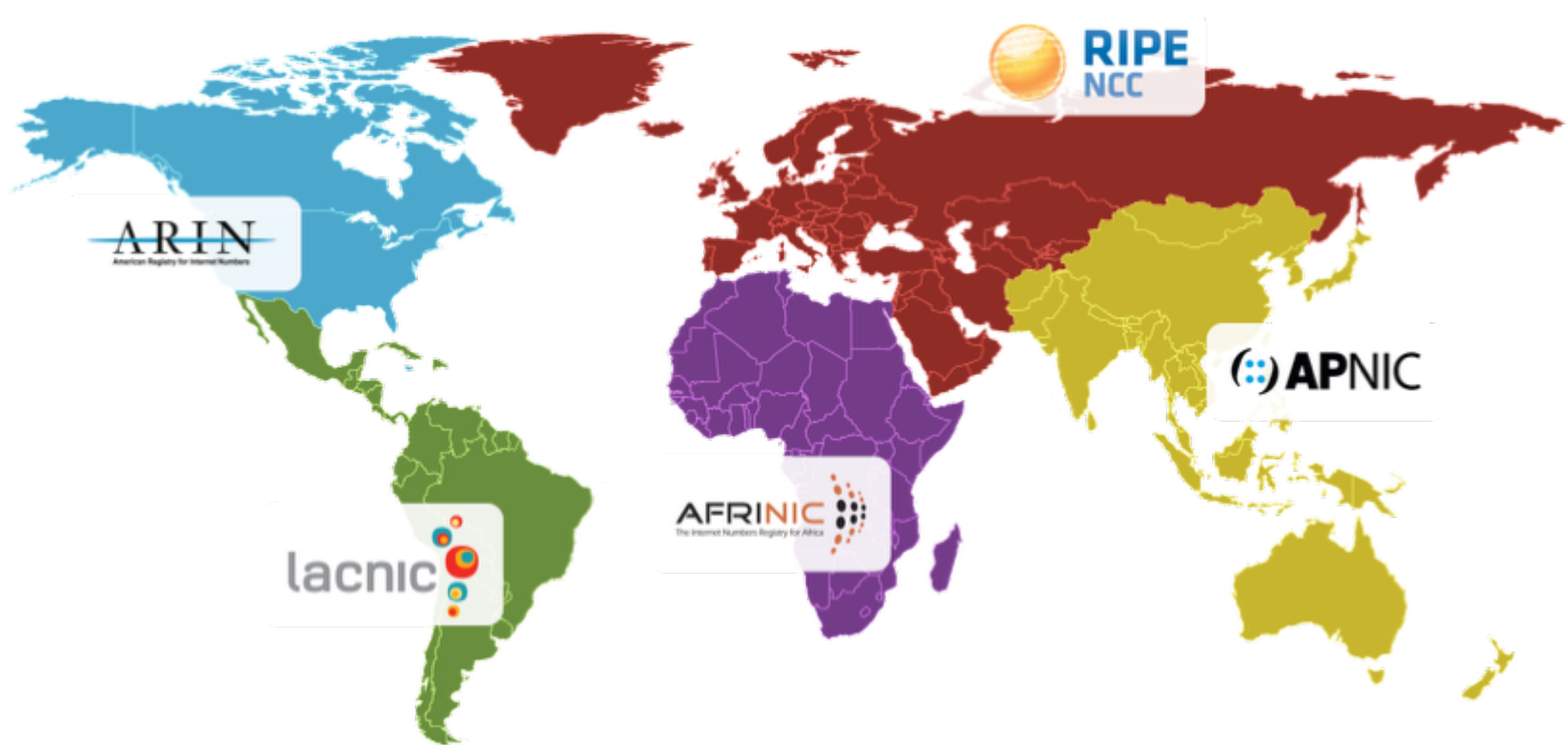


Jon Postel
† 1998



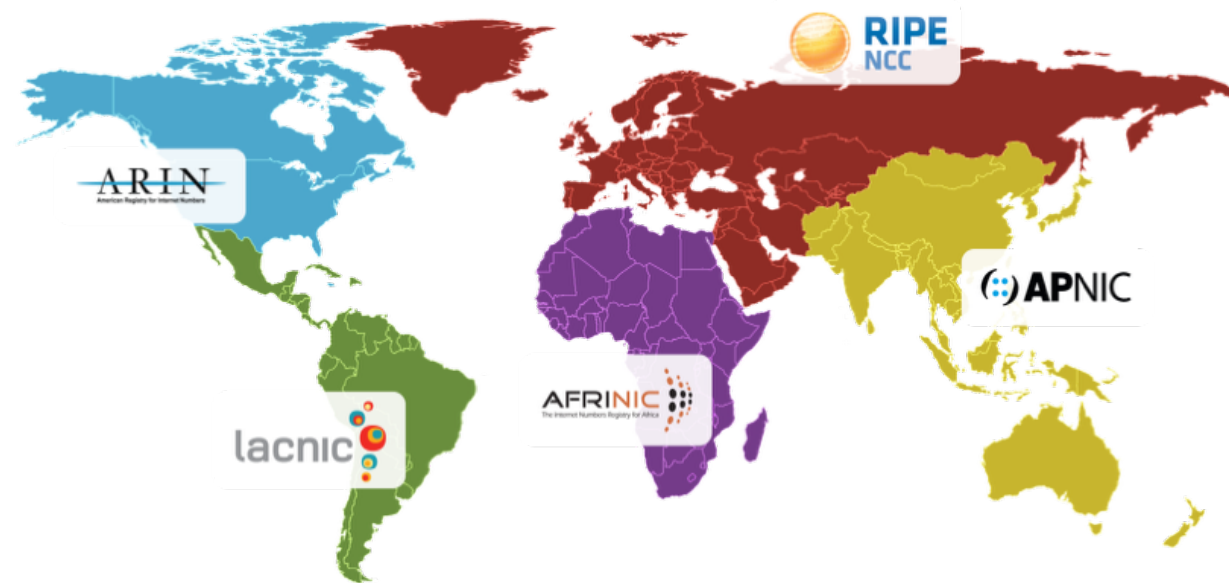
Needs-based Provision Phase

The Registry Framework



Needs-based Provision Phase

The Registry Framework



- One primary goal: address space conservation
- ISPs must justify “**need**”
 - Efficient utilization of previously allocated blocks
 - Intended use of blocks

A History of IPv4 Address Block Management

1981

Early Registration

- Informal Distribution
- Scarcity minor issue
- Non-commercial Internet

~1992

Needs-Based Provision

- Distribution process
- Justification of need
- ISPs don't pay for IPs

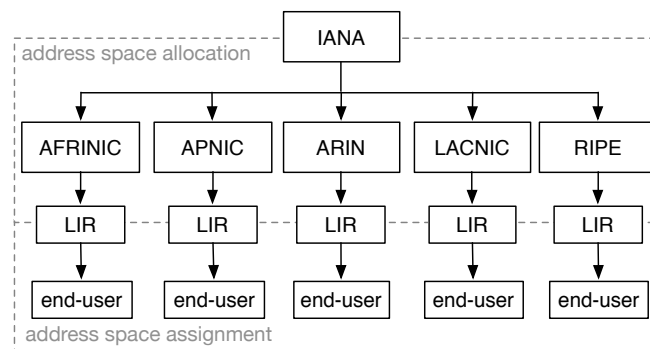
~2011

Depletion & Exhaustion

- Address Markets
- Money comes into play!



Jon Postel
† 1998



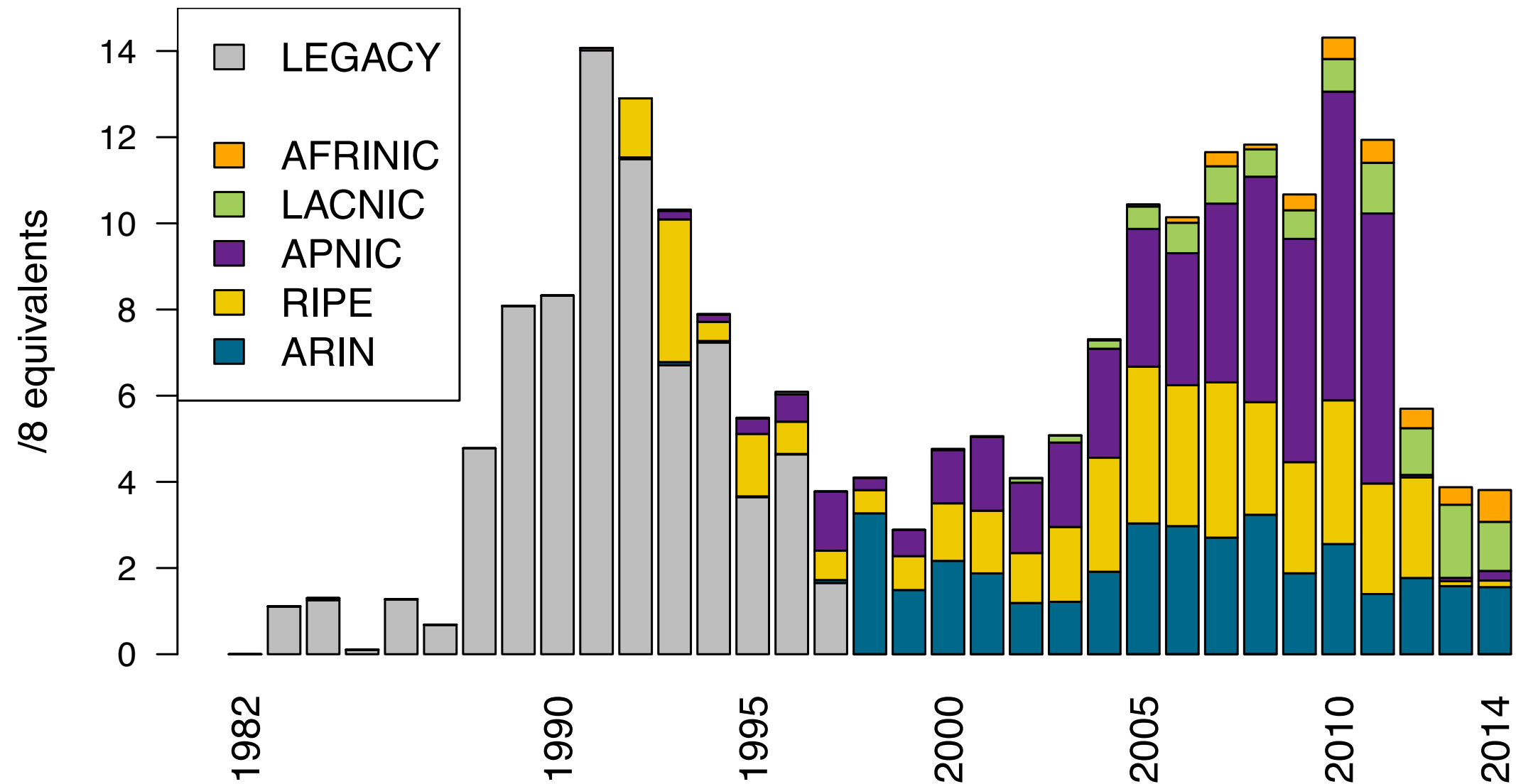
Depletion and Exhaustion Phase

- The IANA distributed its last 5 /8 blocks to the RIR (2011)
- Strict allocation policies for last remaining blocks
 - ➔ New market entrants can still receive a last small block
- Emergence of Address Transfer Markets
- Introduction of Transfer Policies

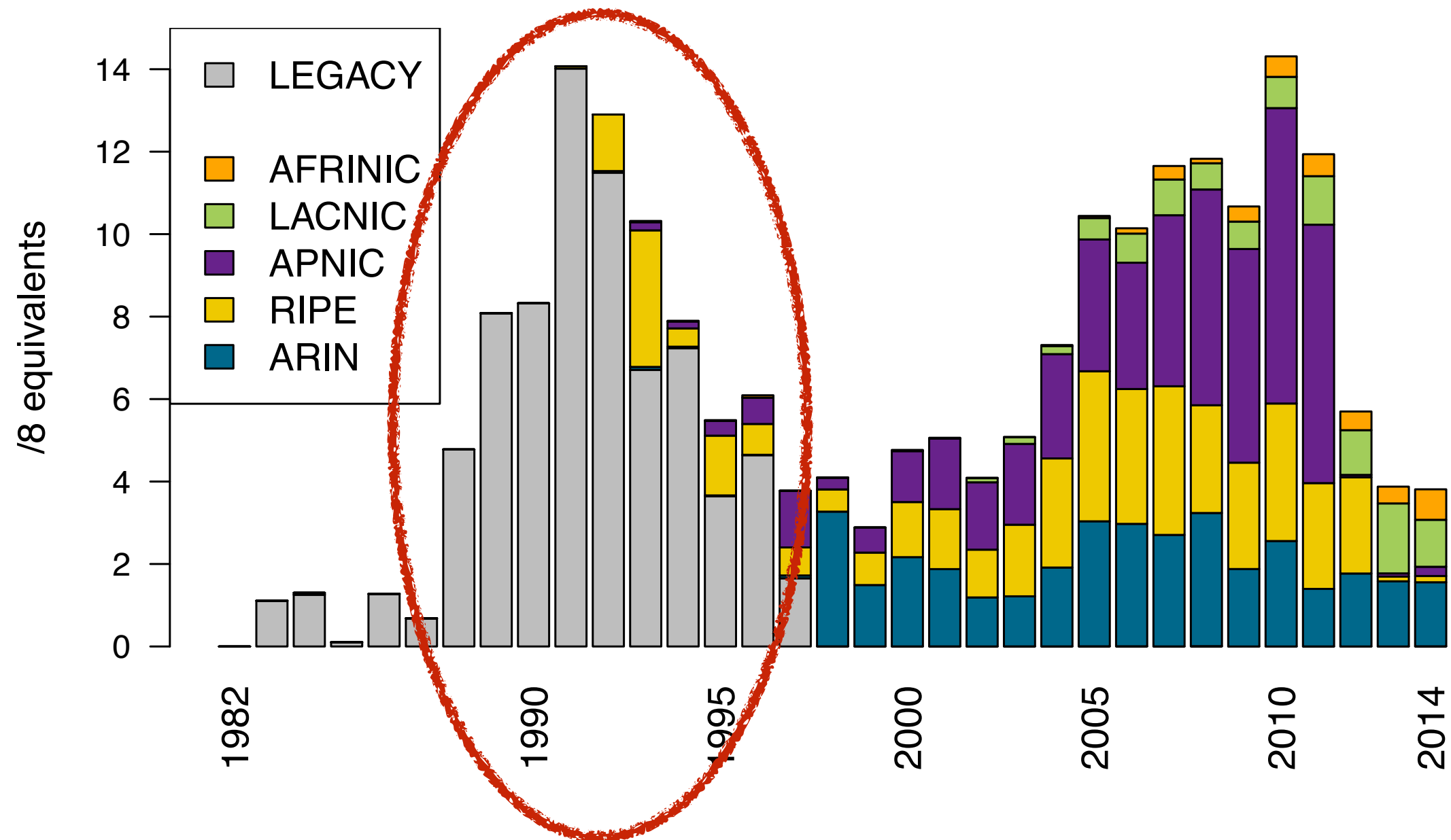
Agenda

- The History of IPv4 Address Space
 - ➔ Management
 - ➔ **Allocation**
 - ➔ Routing
- IPv4 Addresses: A Virtual Resource
- The Emerging Address Market

A History of Allocations

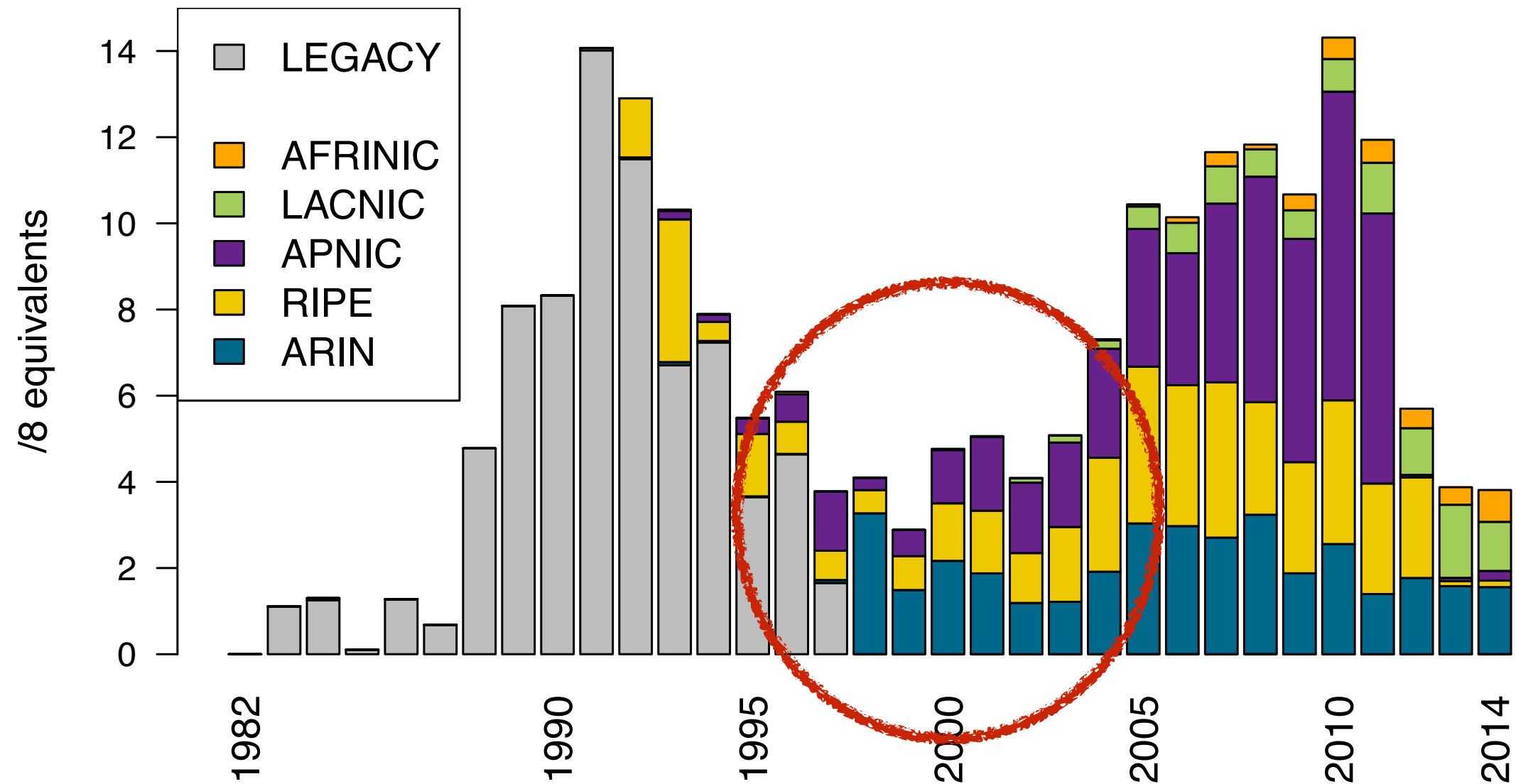


A History of Allocations



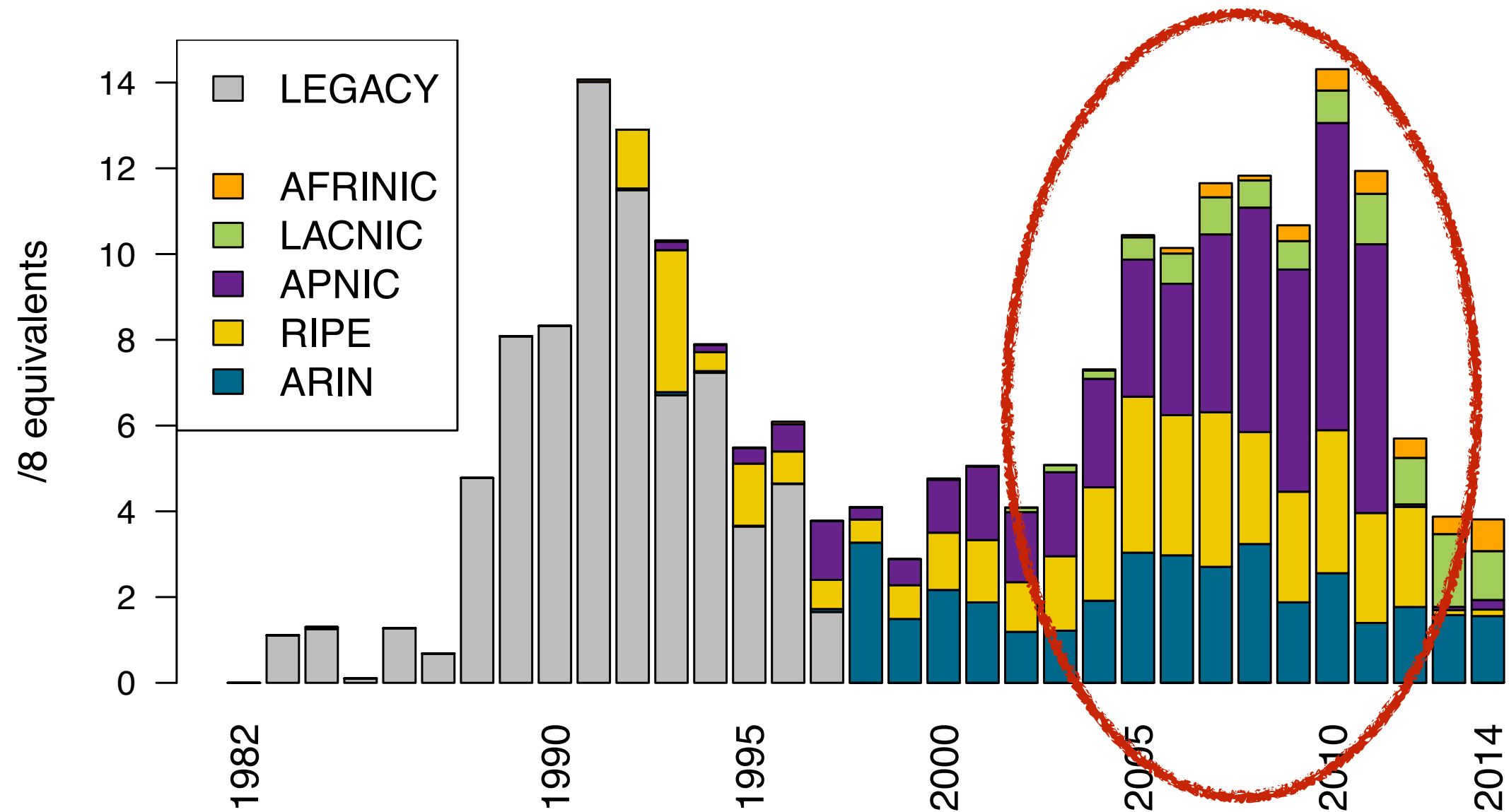
around 40% of the routable address space are LEGACY

A History of Allocations



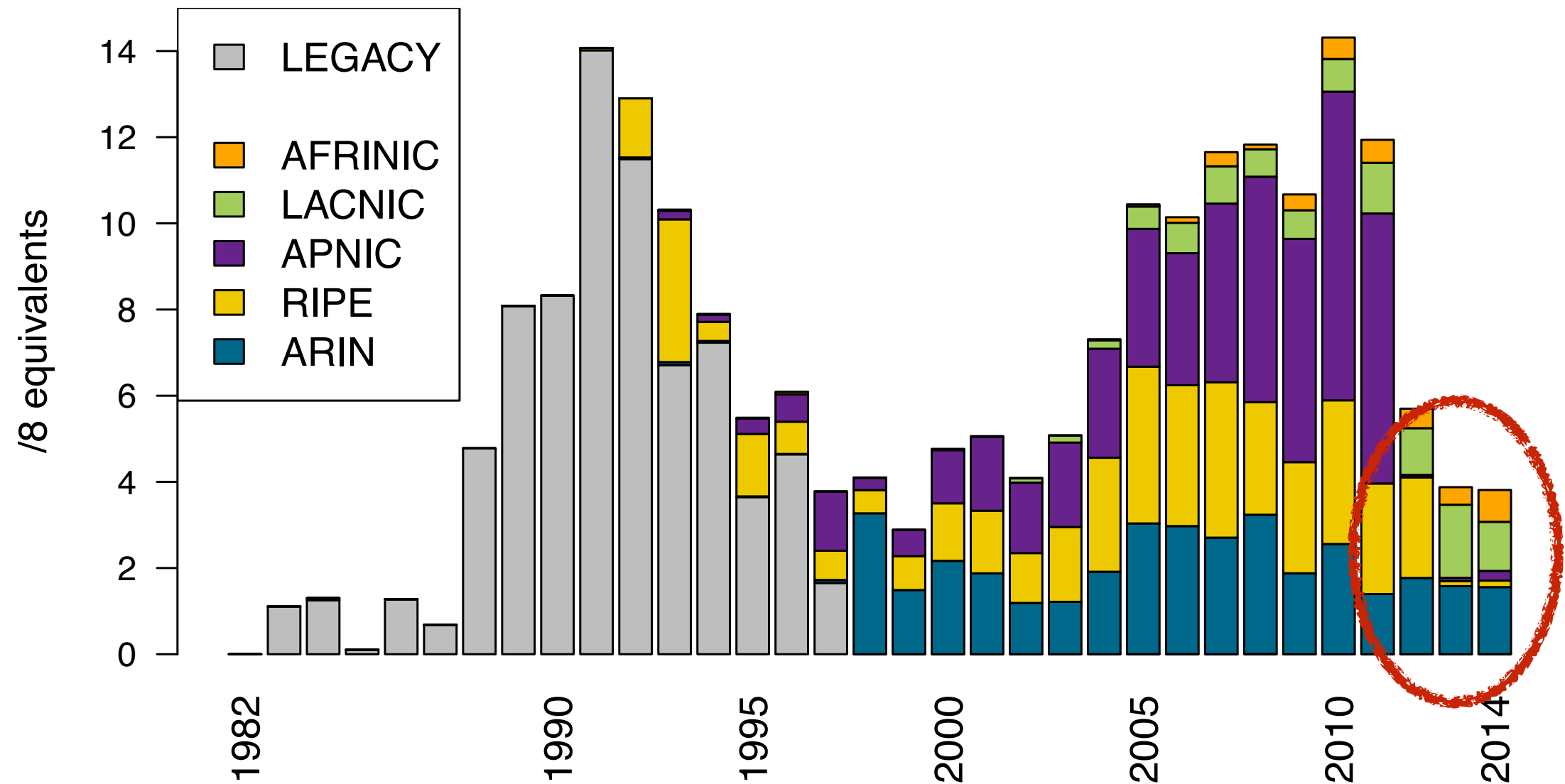
address space conservation shows effect

A History of Allocations



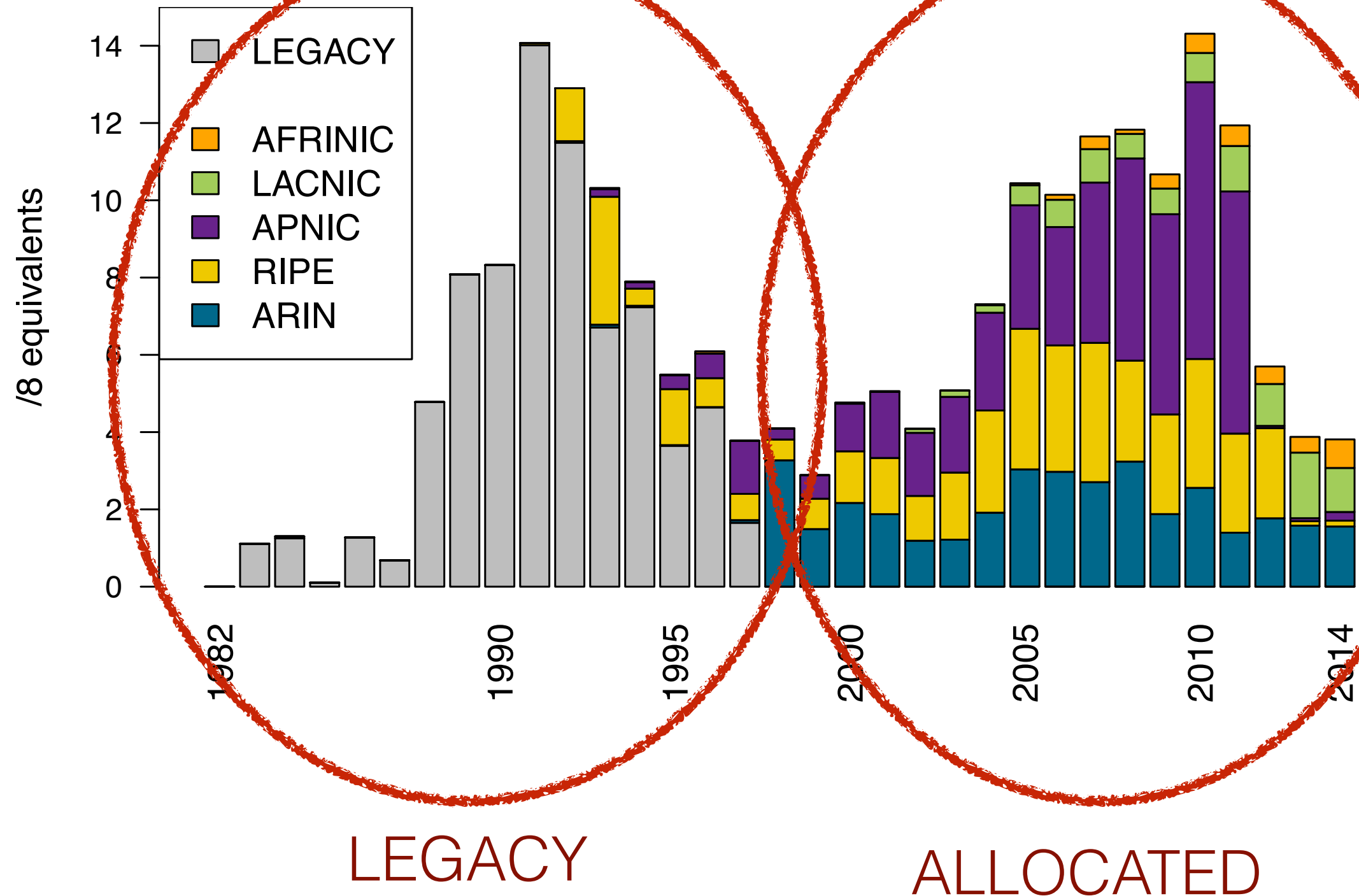
rapid consumption (primarily in Asia)

A History of Allocations



depletion (APNIC and RIPE exhausted)

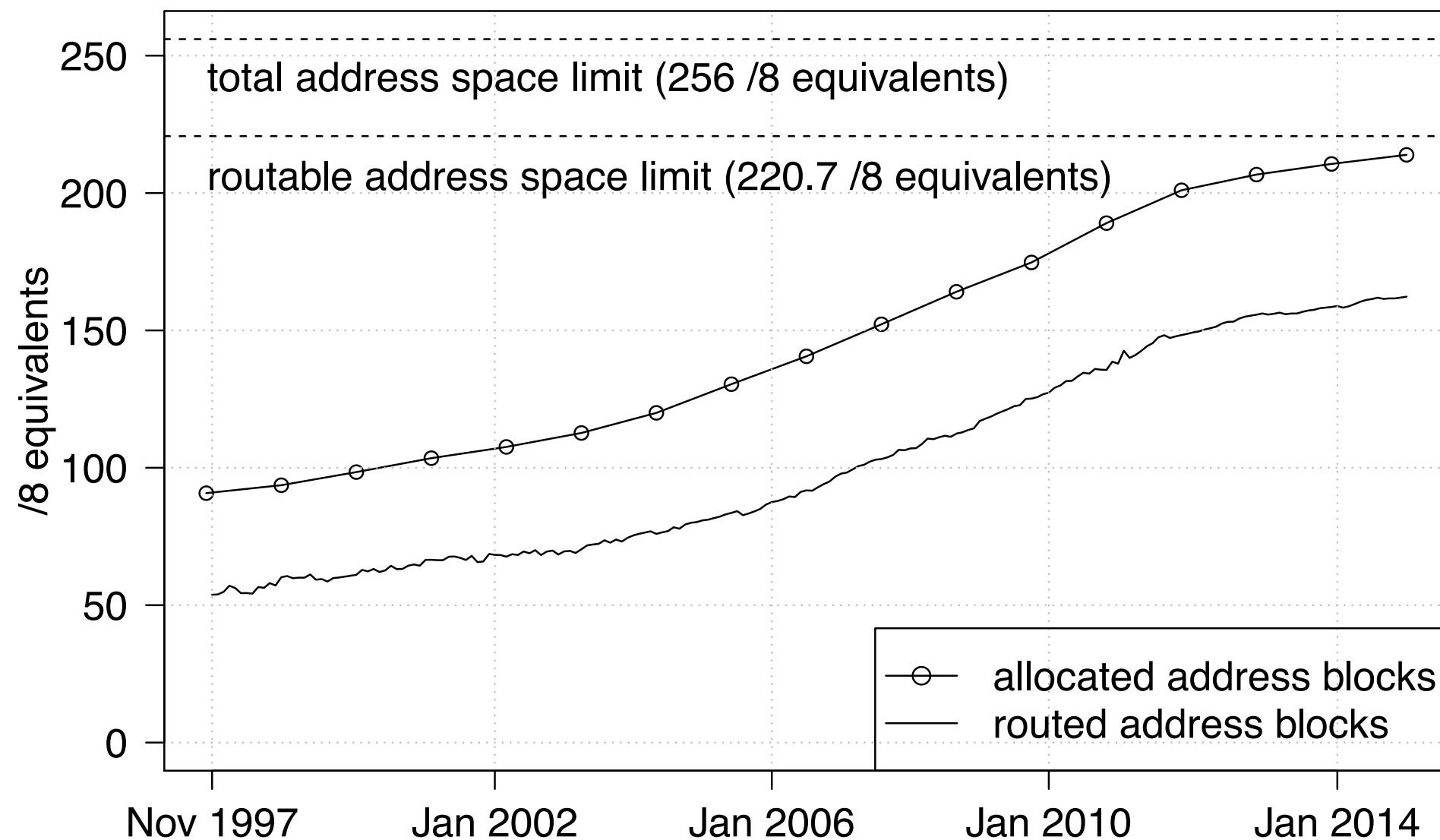
A History of Allocations



Agenda

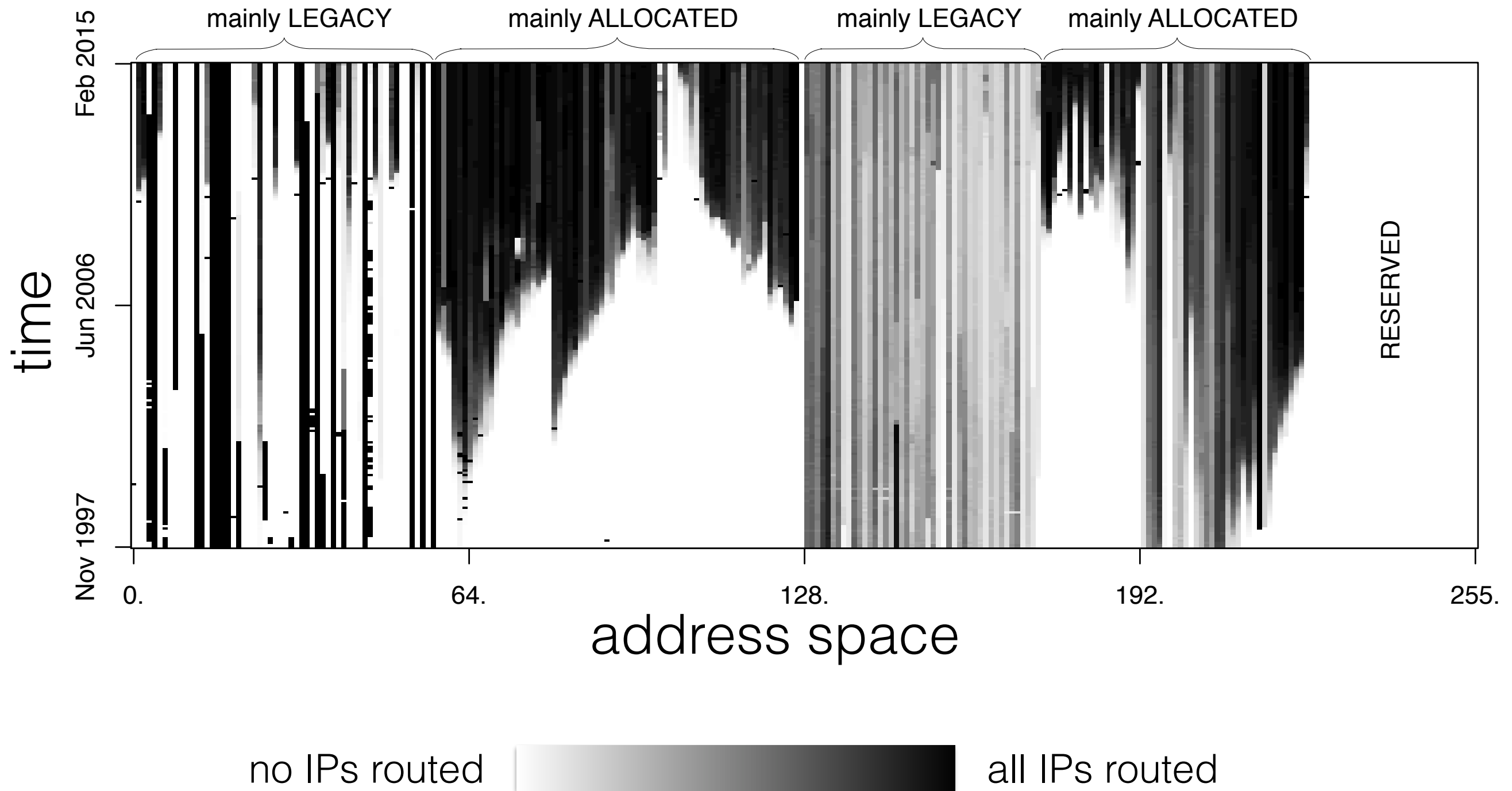
- The History of IPv4 Address Space
 - ➔ Management
 - ➔ Allocation
 - ➔ **Routing**
- IPv4 Addresses: A Virtual Resource
- The Emerging Address Market

The Routing Gap

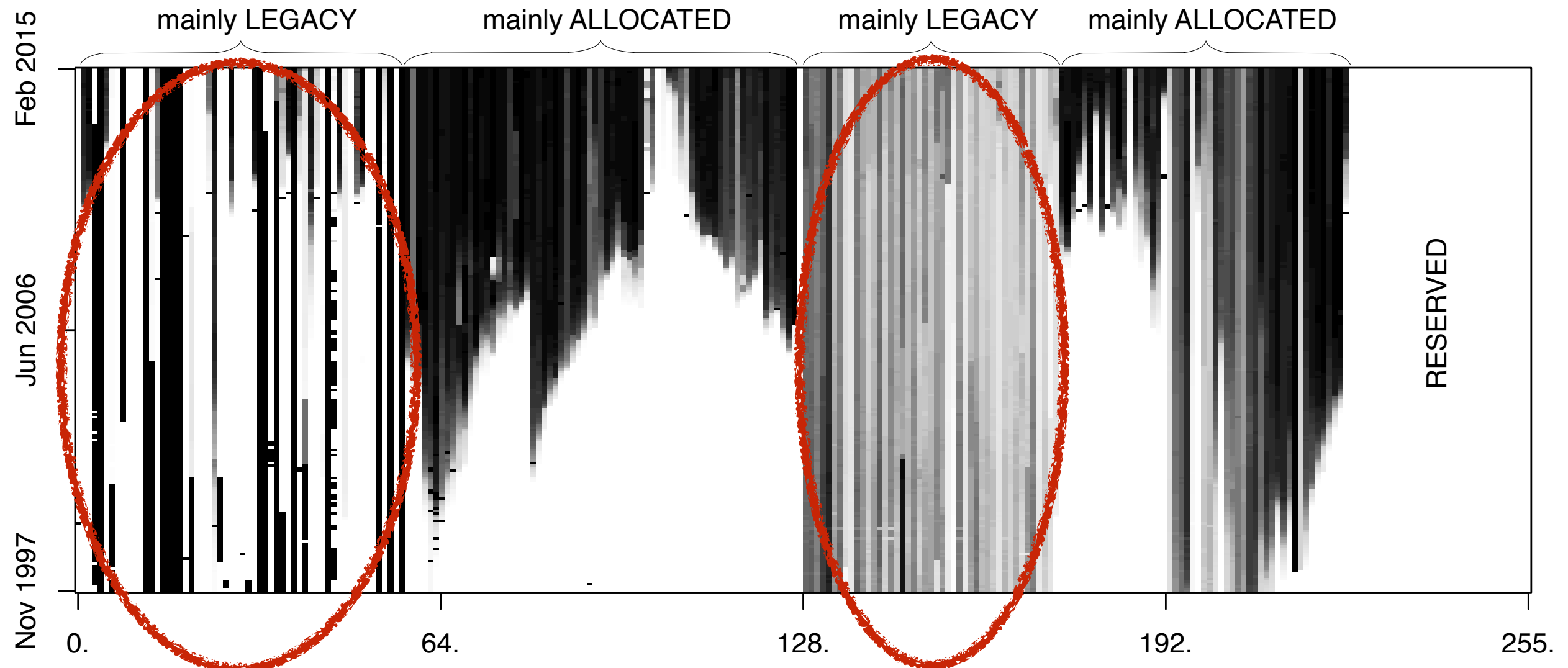


Large amounts of address space unrouted

A Spatiotemporal View of the Address Space

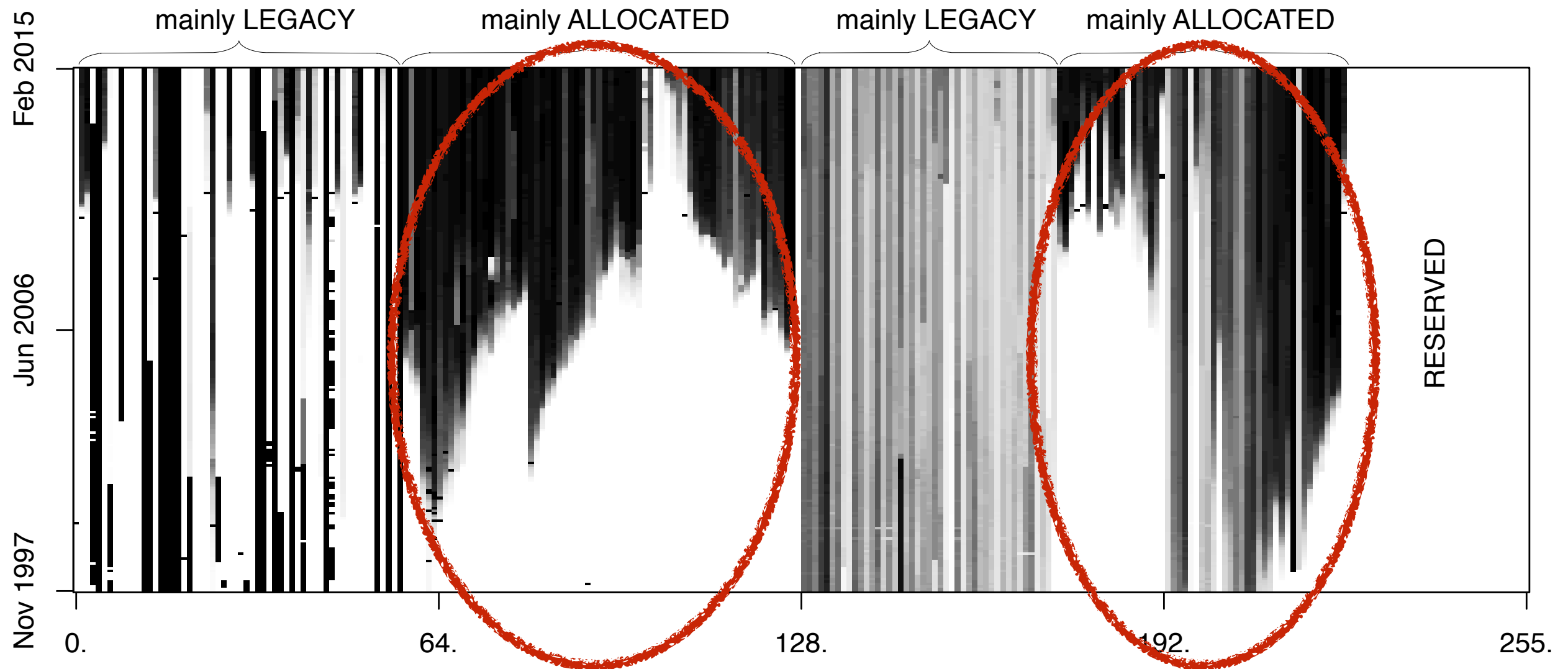


A Spatiotemporal View of the Address Space



LEGACY ranges: poor utilization; little change over the years

A Spatiotemporal View of the Address Space



ALLOCATED ranges: higher utilization, policies show effect

Agenda

- The History of IPv4 Address Space
 - ➔ Management
 - ➔ Allocation
 - ➔ Routing
- **IPv4 Addresses: A Virtual Resource**
- The Emerging Address Market

IPv4 Addresses: A Virtual Resource

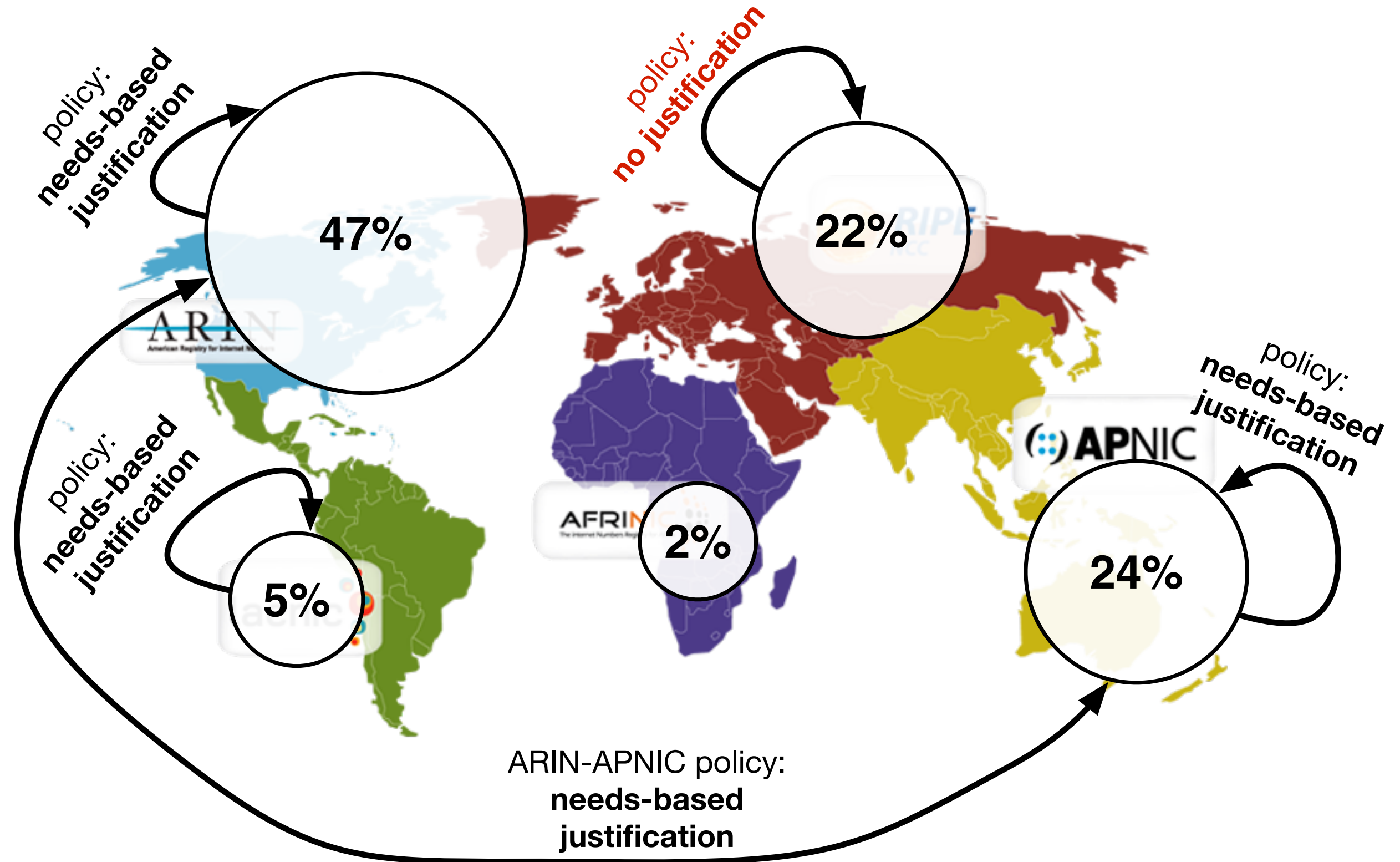
- For 30 years, IPs were handed out “for free”**
 - ➔ Availability of IPs was not an entrance barrier for ISPs
- Now, the RIRs have very few blocks left
 - ➔ IPv4 addresses are goods exchanged on markets



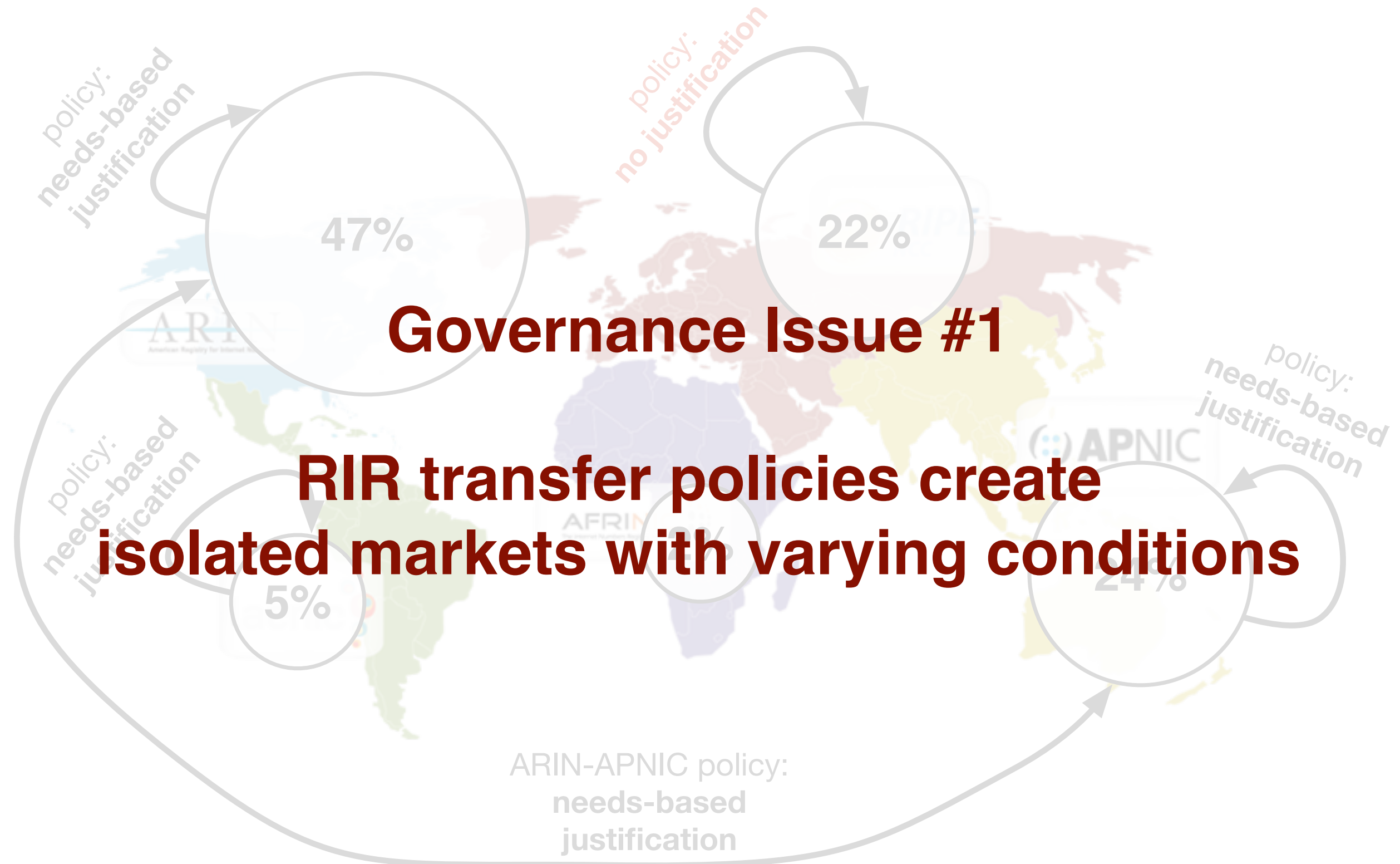
Internet Governance Issues

**albeit administrative fees, RIR membership etc.

IP Addresses and RIR Transfer Policies



IP Addresses and RIR Transfer Policies



Transfer Policies for Everybody?

- ~40% of the address space is of type LEGACY
- Registrations from the 80's and 90's
- Administration was later shifted over to the RIRs
- Grandfathering principle?
- **Are LEGACY blocks subject to RIR policies?**

Transfer Policies for Everybody?

- ~40% of the address space is of type legacy
- Registrations from the 80's and 90's
- **Governance Issue #2**
- Administration was later shifted over to the RIRs
- Relationship RIRs <-> LEGACY holders?
- **LEGACY address blocks harbour the largest supply of unused addresses.**
- Are LEGACY holders subject to RIR policies?
- **Their legal status is still unclear.**

Resource Certification

- IP Addresses are virtual resources
- BGP has no means of validating route announcements
- Solutions: Routing Registries, RPKI
- Large portions of the address space not covered
- Prominent cases of address hijacking

Resource Certification

- BGP was not designed for IPv4 scarcity

Governance Issue #3

- No means of validating route announcements

Address Management (RIRs) is de-coupled from the actual usage.

- Solutions: Routing Registries, RPKI

Policy Enforcement?

- Large portions of the address space not covered

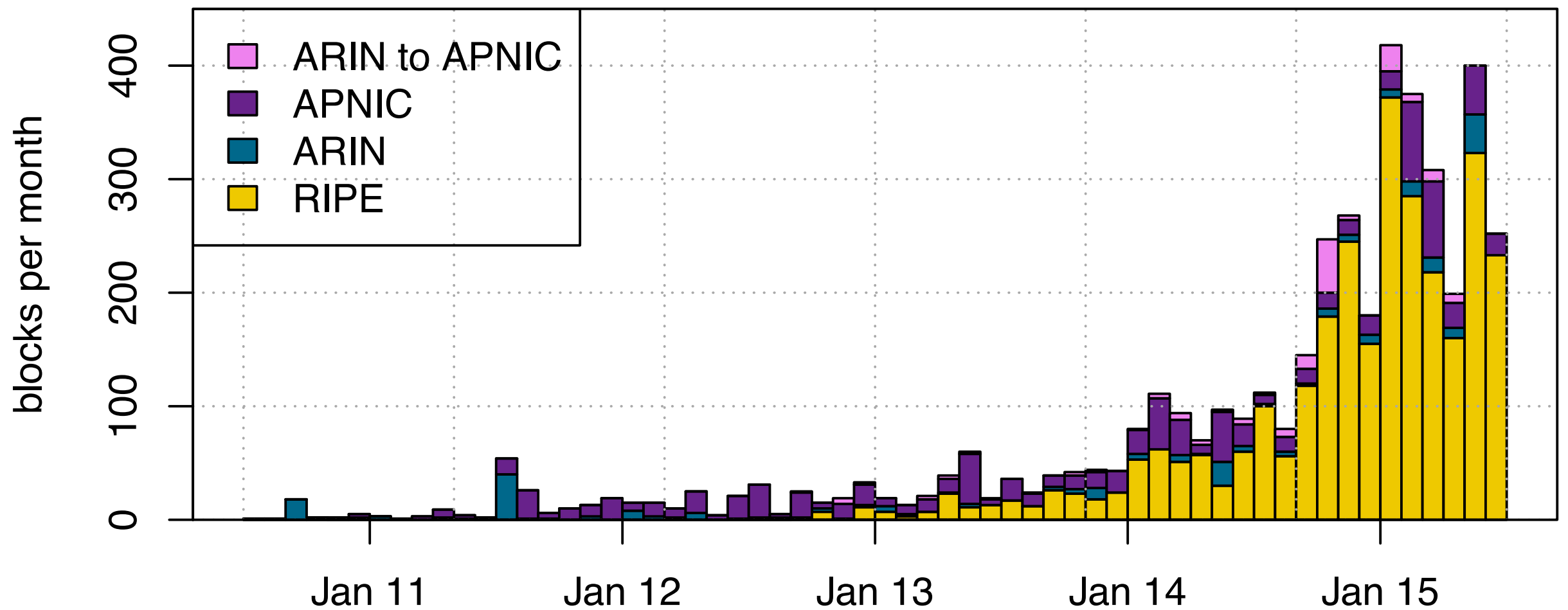
- Prominent cases of address hijacking (YouTube)

Black Market?

Agenda

- The History of IPv4 Address Space
 - ➡ Management
 - ➡ Allocation
 - ➡ Routing
- IPv4 Addresses: A Virtual Resource
- **The Emerging Address Market**

The Emerging Address Market



data source: RIRs

total transferred: 3.6 /8s (1.7% of routable space)

Prices?

- Not publicised! Only partial data from brokers

Prices?

- Not publicised! Only partial data from brokers

	ARIN	APNIC	RIPE
/16	\$360K \$5.5/IP	\$425K \$6.5/IP	\$537K \$8.2/IP

data: www.ipv4marketgroup.com

Policies directly affect prices

Conclusion

- IPv4 addresses are now a virtual resource
- Scarcity problem is not only protocol-related
- New challenges for the community
 - How to adapt policies to this situation?
 - How to provide resource certification?
- ➔ How to ensure further growth of the Internet?

Conclusion

- IPv4 addresses are now a virtual resource
- Scarcity problem is not only protocol-related
- New challenges for the community
 - How to adapt policies to this situation?
 - How to provide resource certification?
 - ➔ How to ensure further growth of the Internet?

IPv4 Scarcity might impact the growth of the Internet

Internet Governance impacts IPv4 Scarcity