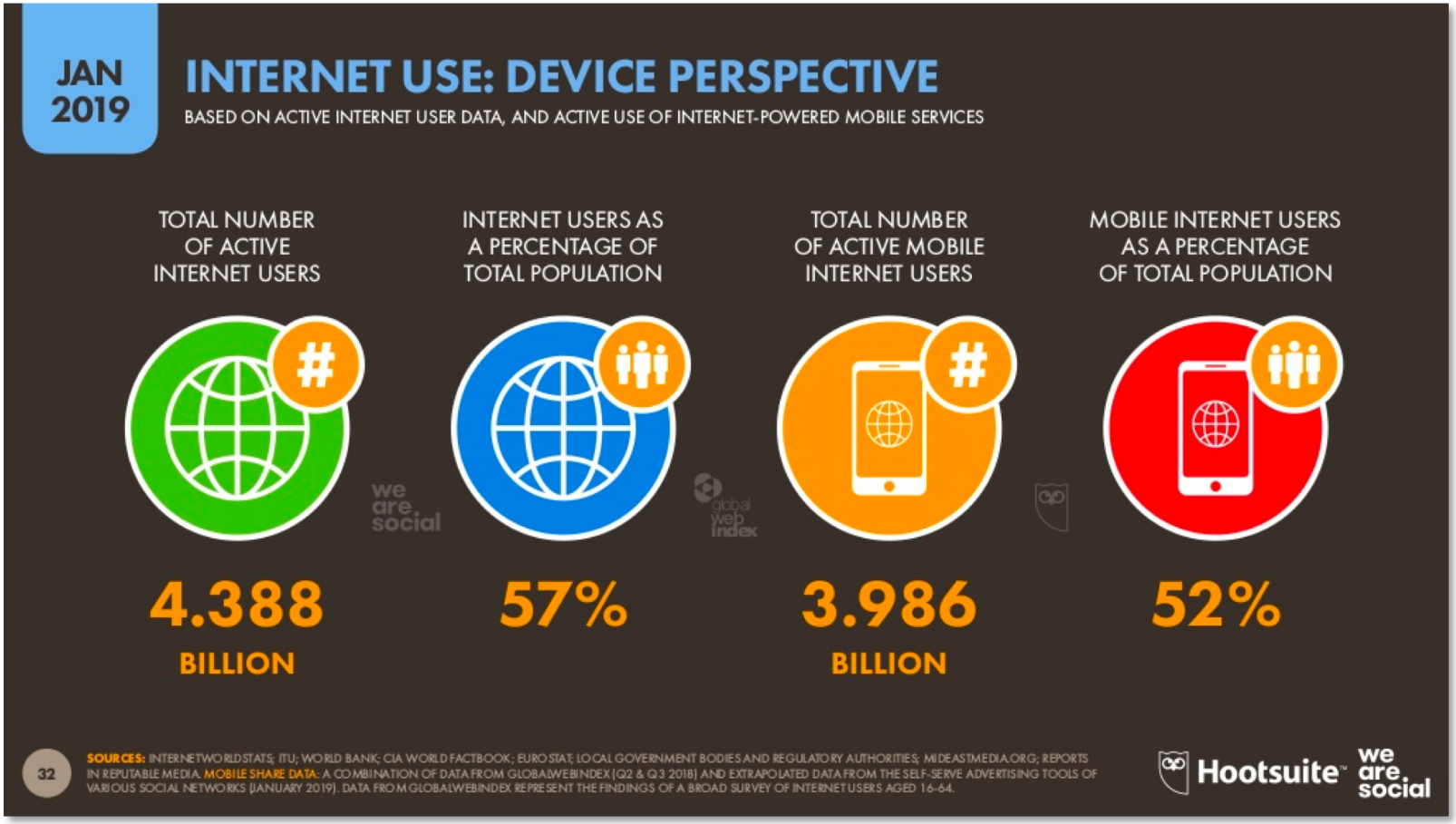
IPv6 for Decision Makers

LOTM Curacao July 2019

Alejandro Acosta
alejandro \@ lacnic.net
@ITandNetworking

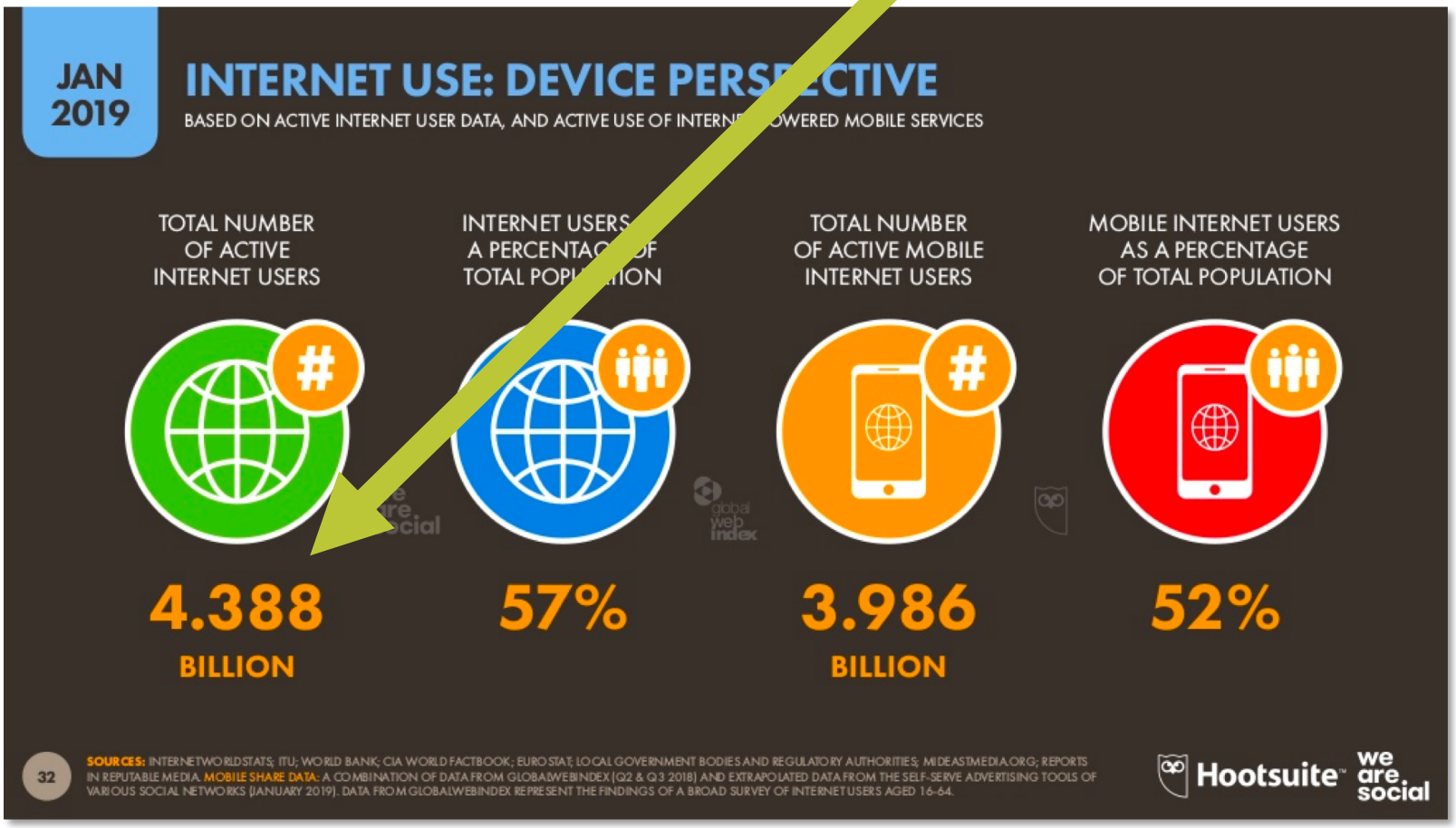
Users Connected to the Internet



Source: https://marketing4ecommerce.net/usuarios-internet-mundo/

Users Connected to the Internet

Do you recognize this number?



Source: https://marketing4ecommerce.net/usuarios-internet-mundo/

Users Connected to the Internet

Do you recognize this number?

That number is very close to

Source: https://marketing4ecommerce.net/usuarios-internet-mundo/

[1] 2**32 = 4,294,967,296

Users Connected to the Internet

Do you recognize this number?

That number is very close to

Yes, the total number of IPv4 address [1]

Source: https://marketing4ecommerce.net/usuarios-internet-mundo/

[1] 2**32 = 4,294,967,296

Users Connected to the Internet

Do you recognize this number?

That number is very close to

Yes, the total number of IPv4 address [1]

But…, actually, only 3.7 billion are public

Source: https://marketing4ecommerce.net/usuarios-internet-mundo/

[1] 2**32 = 4,294,967,296

How many times have you heard that we ran out of IPv4 addresses?

IPv4 Exhaustion

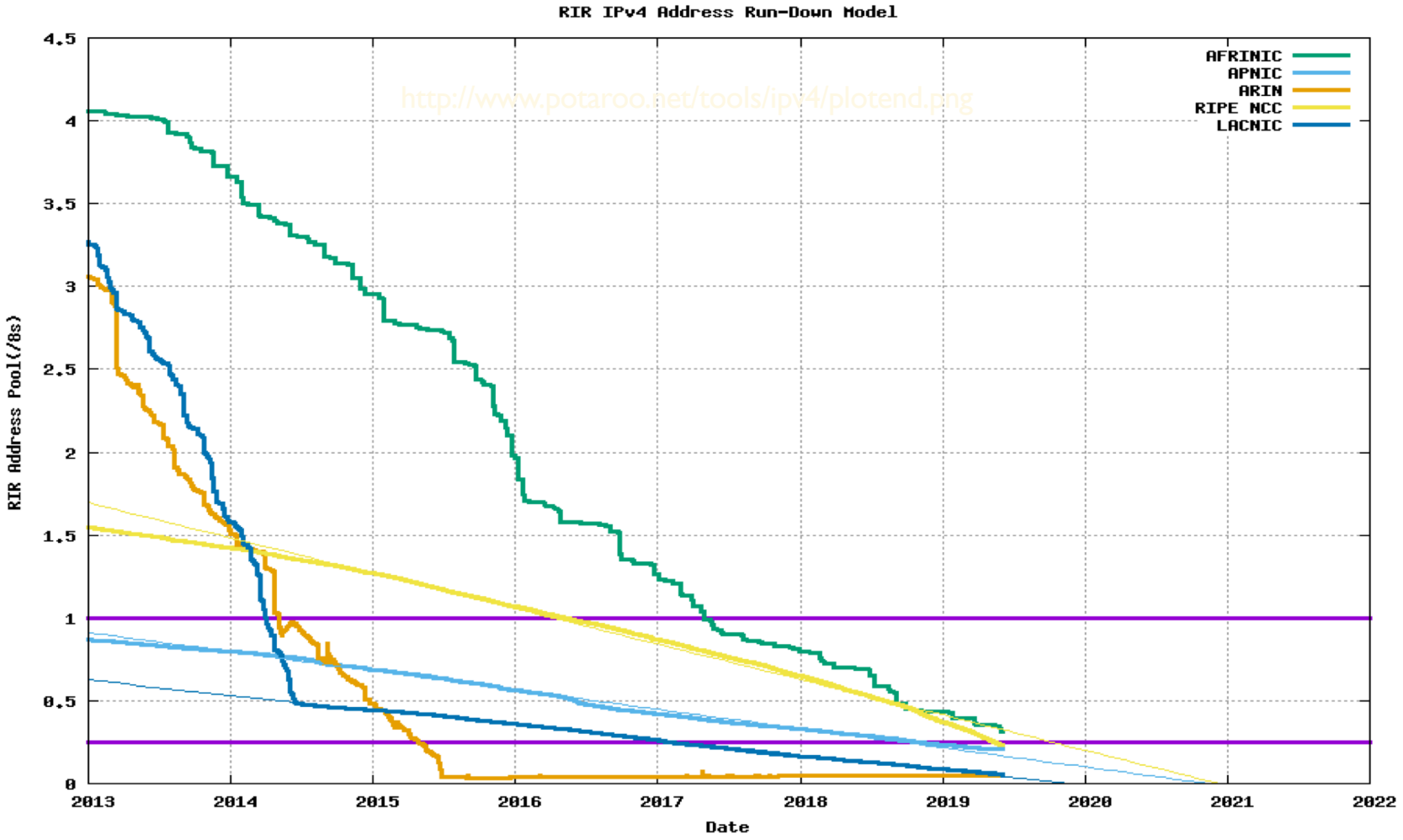
- IANA's pool of IPv4 addresses was exhausted in early 2011

RIR	Status of IPv4 resources
APNIC	The final /8 was reached in April 2011
RIPE	The final /8 was reached on 14 September 2012
LACNIC	IPv4 Exhaustion Phase 3 since 15 February 2017
ARIN	Waiting list for unmet IPv4 requests since 1st July 2015
AFRINIC	Began using its final /8 in April 2017, although the most restrictive policies have not yet come into force (Phase 1)

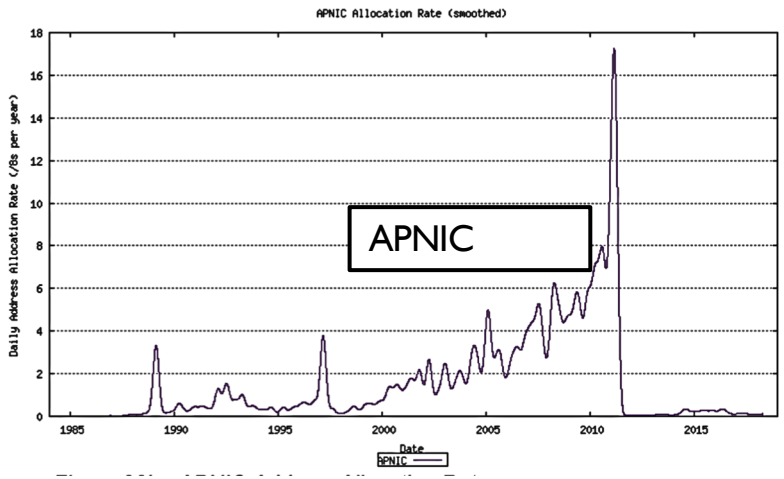
Why Virtual Exhaustion?

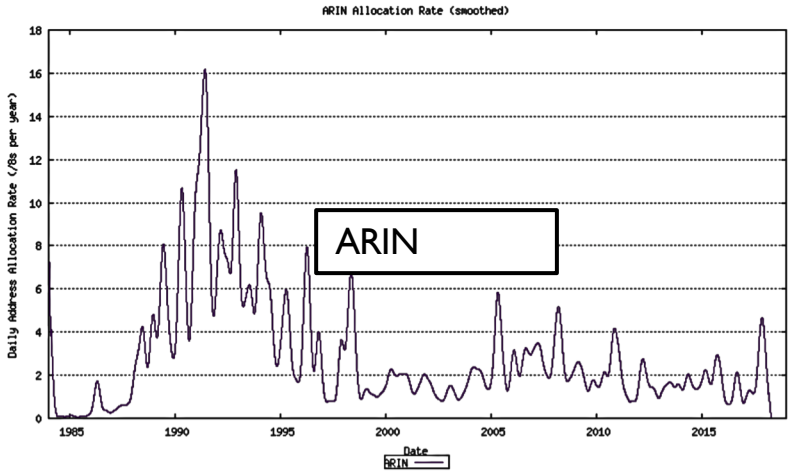
- Because a lower threshold is reached after which restrictive policies come into force
- Before: needs-based assignments
  - Organization size, justification
- Now: fixed maximum of a /22 (1,024 addresses)
  - Regardless of the organization, coverage, etc.

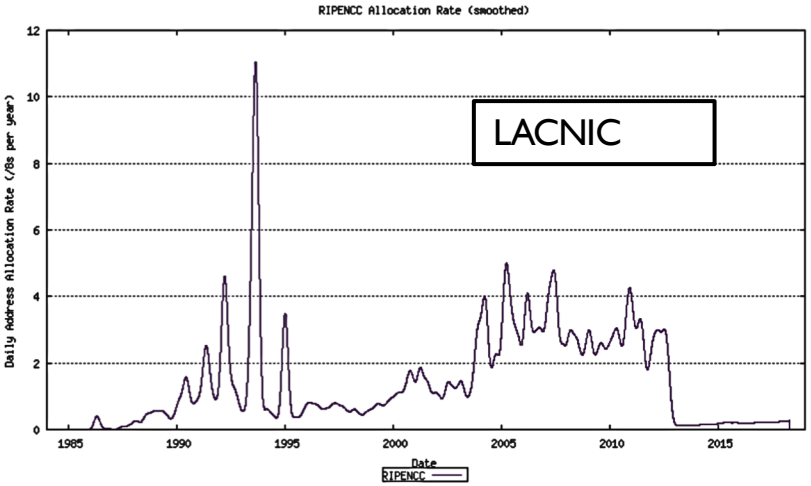
Pool of Available IPv4 Addresses

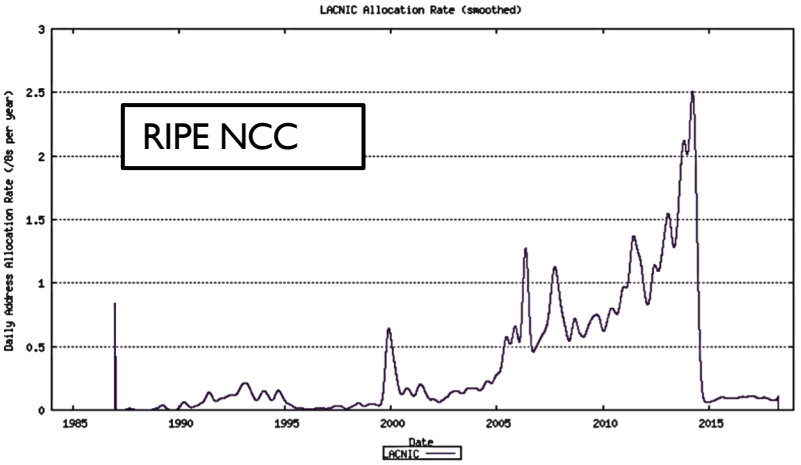


Post-Exhaustion Allocation Rates by RIR

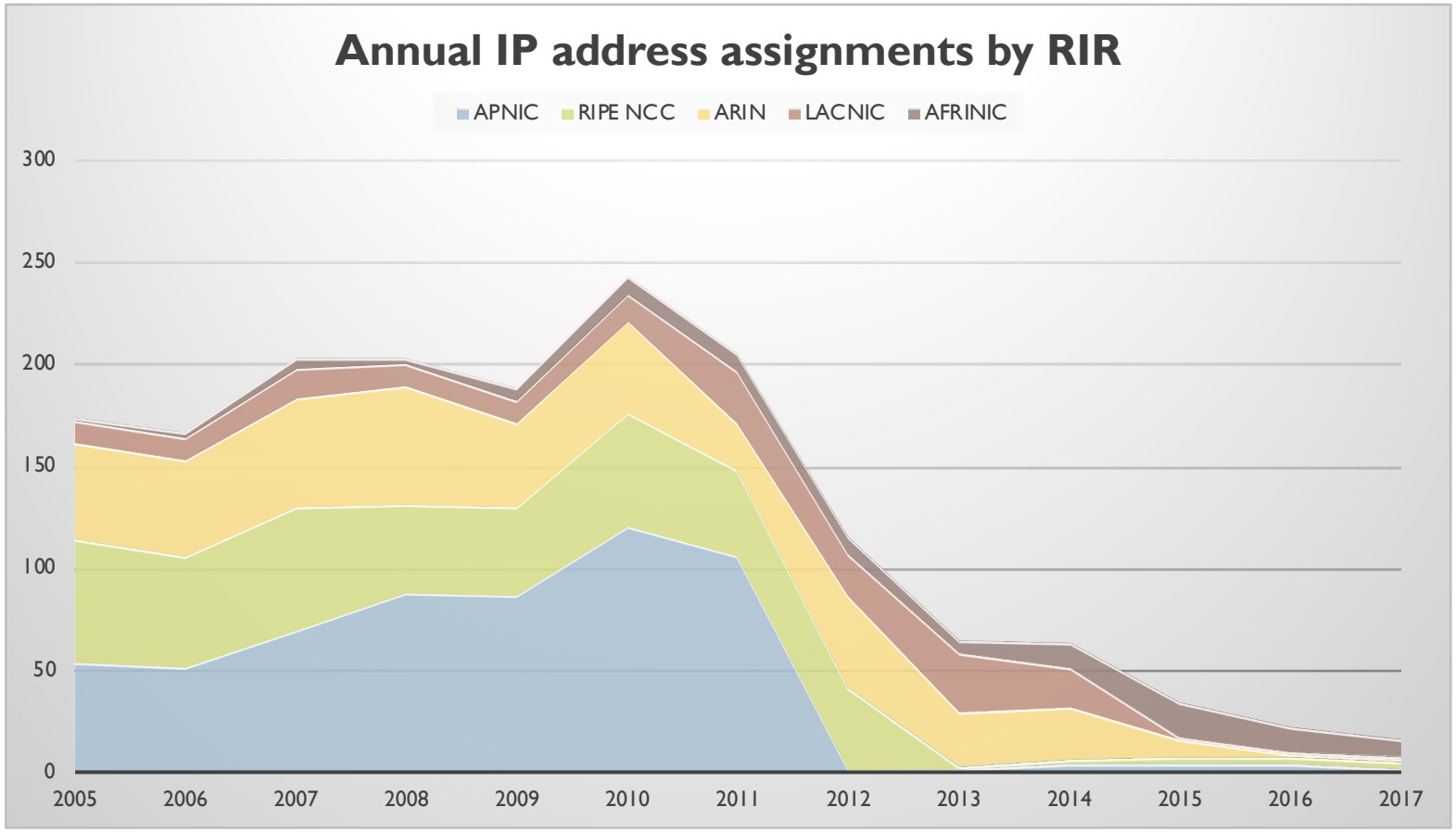








Annual Assignments (millions of IP addresses)



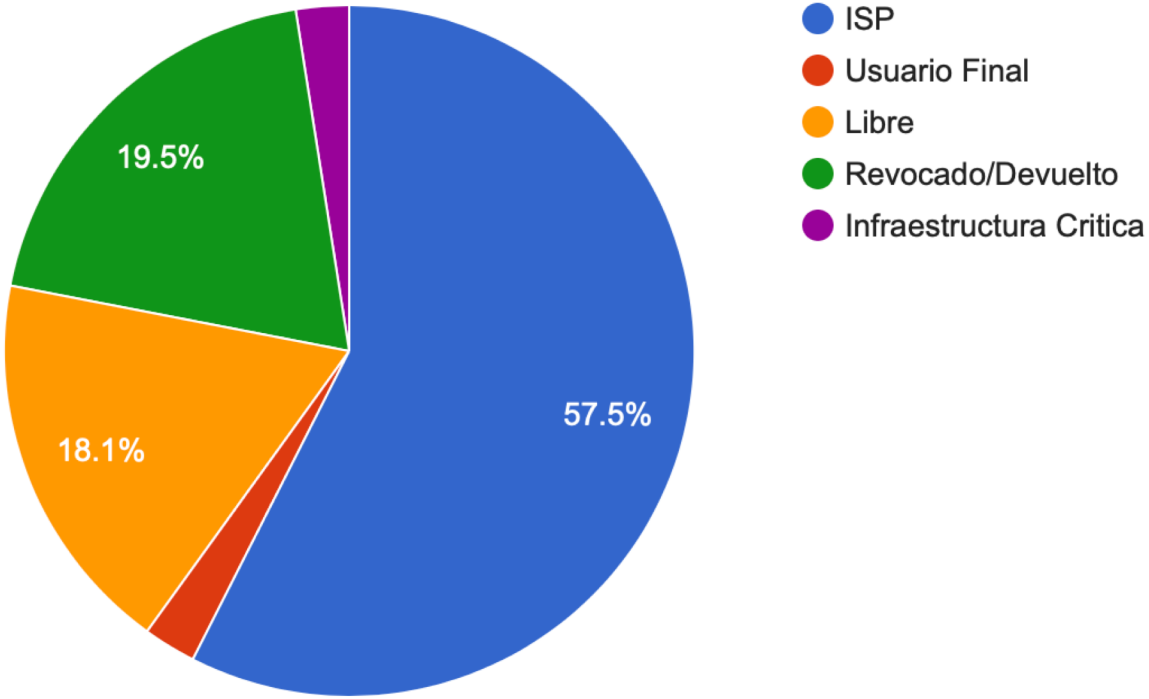
Exhaustion Phases in the LACNIC Region

- The exhaustion period was divided into phases:
- Phase 0: the phase prior to exhaustion
- Phase 1: after reaching a /9
  - More restrictive policies but no limitations on assignment sizes
- Phase 2: after reaching a /10
  - A maximum of a /22 per organization
- Phase 3: after reaching a /11
  - Addresses will only be assigned to organizations that have not yet received IPv4 addresses

Exhaustion in the LACNIC Region

- Currently in Phase 3
  - Entered Phase 3 in 15 February 2017
- Policy in force: new entrants
- In practice, organizations that have received IPv4 resources from LACNIC will not be able to request new blocks
- Important: organizations that have not yet received IPv4 resources still have time to submit a request

Address Pool for Phase 3



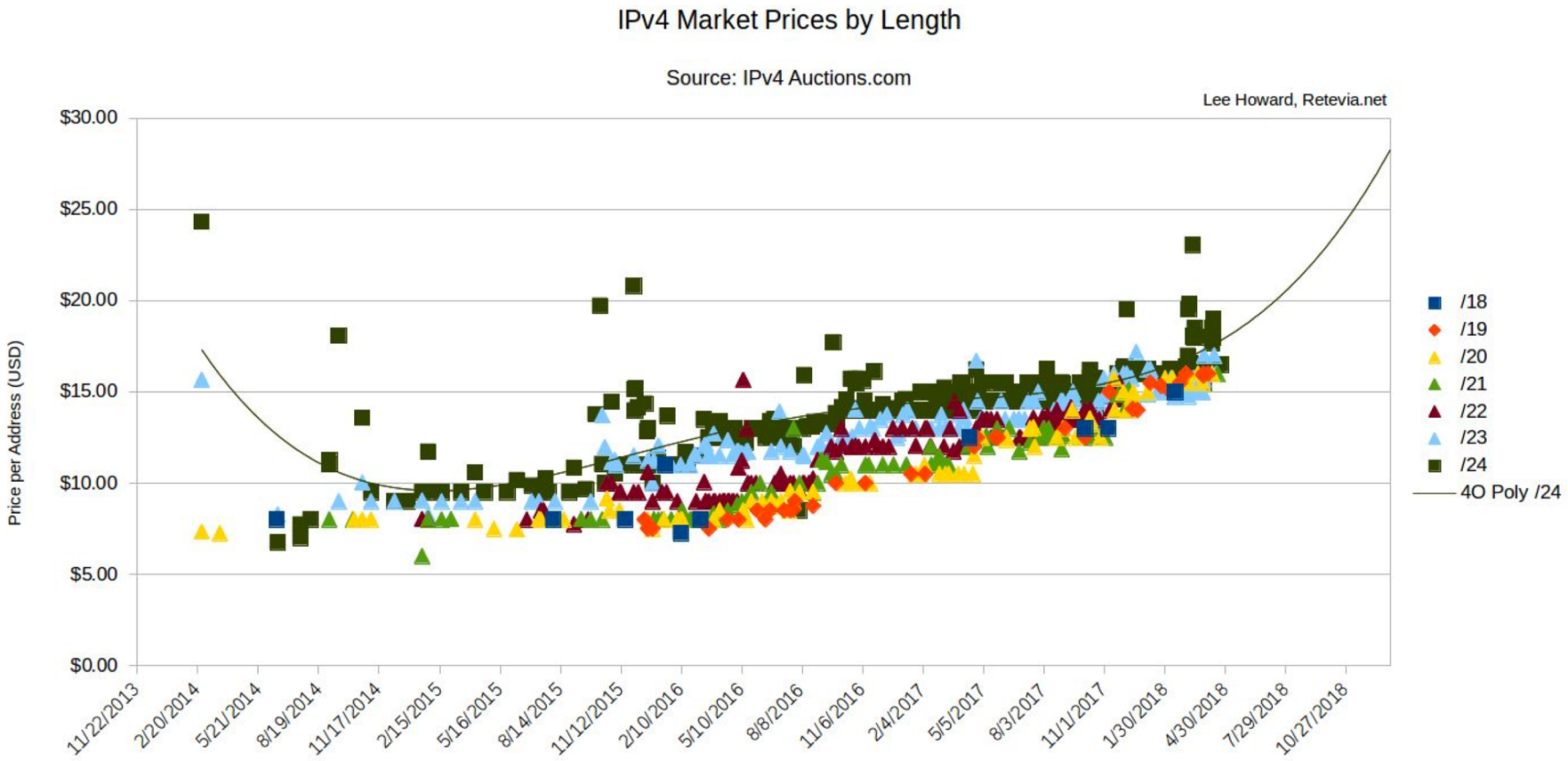
So, now what?

Three Possible Roads Ahead

- Secondary IPv4 markets
  - Increasing costs; short-term solution
- Carrier grade NAT / Large scale NAT
  - Does not scale in the long term
- IPv6 deployment, possibly using transition techniques such as NAT64/DNS64, 464XLAT, MAP, dual stack with CGN

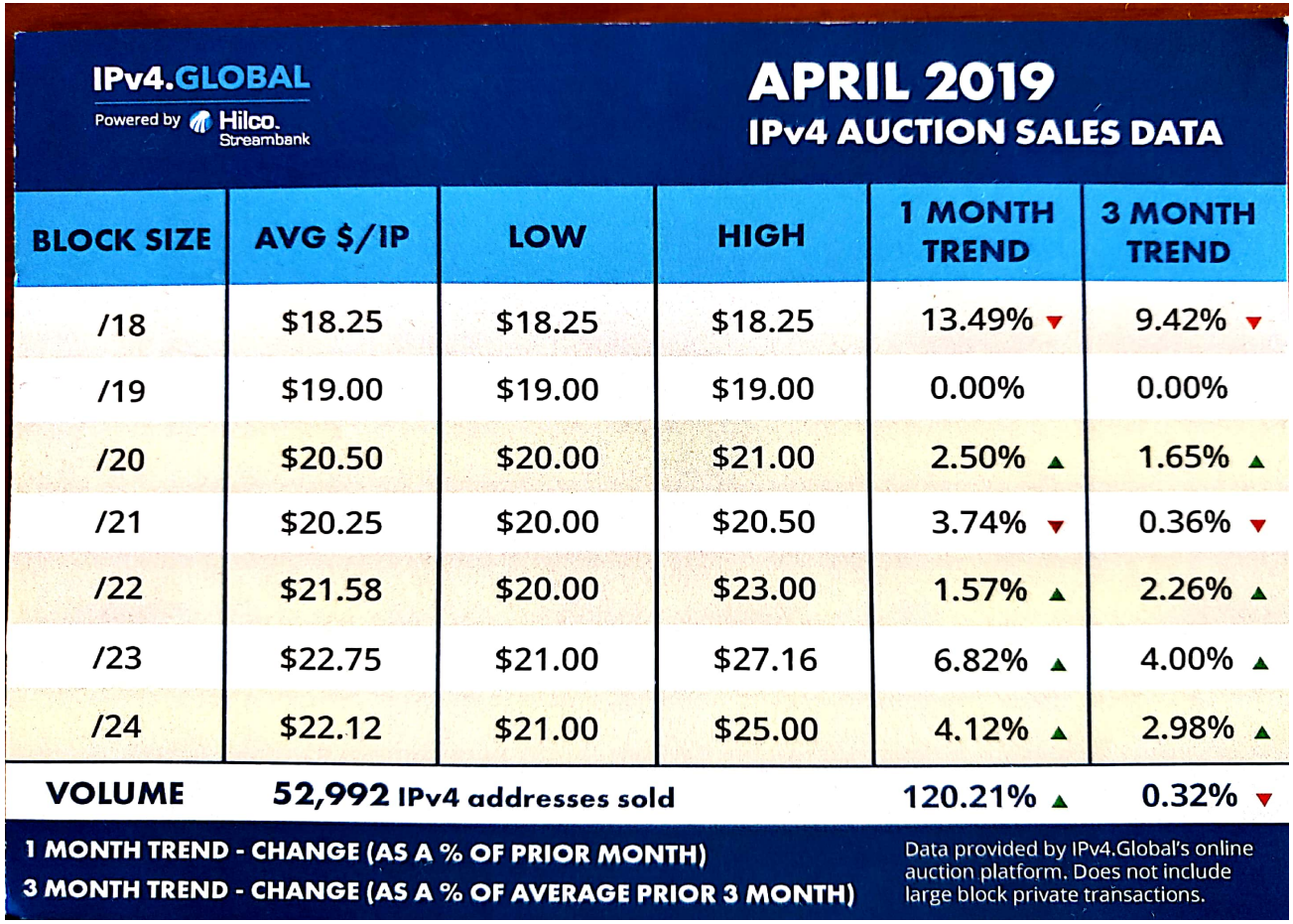
Note: Waiting for 4th way

Evolution of IPv4 Prices in the Transfer Market



Source: http://www.wleecoyote.com/blog/2017prices.htm

Address Market in 2019



IPv4.GLOBAL
Powered by Hilco Streambank

APRIL 2019
IPv4 AUCTION SALES DATA

BLOCK SIZE	AVG $/IP	LOW	HIGH	1 MONTH TREND	3 MONTH TREND
/18	$18.25	$18.25	$18.25	13.49% ▼	9.42% ▼
/19	$19.00	$19.00	$19.00	0.00%	0.00%
/20	$20.50	$20.00	$21.00	2.50% ▲	1.65% ▲
/21	$20.25	$20.00	$20.50	3.74% ▼	0.36% ▼
/22	$21.58	$20.00	$23.00	1.57% ▲	2.26% ▲
/23	$22.75	$21.00	$27.16	6.82% ▲	4.00% ▲
/24	$22.12	$21.00	$25.00	4.12% ▲	2.98% ▲
VOLUME	52,992 IPv4 addresses sold			120.21% ▲	0.32% ▼

1 MONTH TREND - CHANGE (AS A % OF PRIOR MONTH)
3 MONTH TREND - CHANGE (AS A % OF AVERAGE PRIOR 3 MONTH)

Data provided by IPv4.Global's online auction platform. Does not include large block private transactions.

What Are ISPs Doing in LAC?

- Most ISPs use CGN for mass access:
  - Mobile network
  - Residential network (xDSL+HFC)
  - When a user has issues with CGN, they are assigned a public IP address
- For corporate users: a public IP address is typically used
- This is not a good solution

Problems with CGNAT

- Sharing a single IPv4 address modifies the point-to-point communication model
- Applying ACLs (Access Control Lists) to avoid certain attacks can have major unexpected side effects
  - By blocking traffic from a "bad" client, we also risk blocking traffic from many "good" clients
- Logging an IP address is no longer enough to identify which user accessed which services – we must also log port numbers
- NAT boxes can handle a limited number of simultaneous users
- Users from different countries could be accessing the Internet via a single IP address
  - Certain websites targeting specific countries will "think" we are in a different country
  - Gelocation apps will display incorrect location data.
- Does not solve the underlying problem

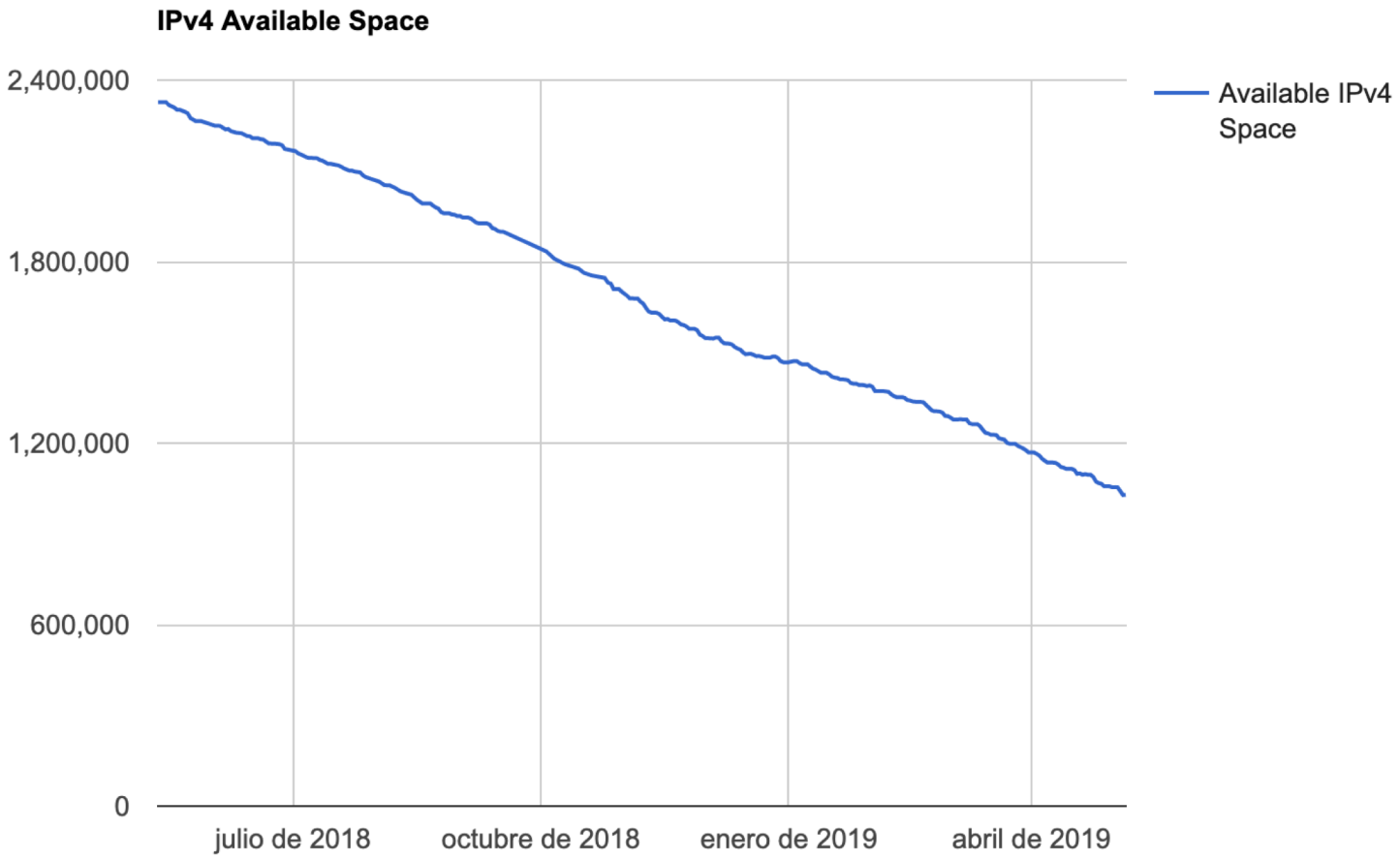
Consequences of IPv4 Exhaustion

- IP address market (e.g. Microsoft purchases Nortel's legacy address space) --- 2011
- Obtaining IPv4 addresses will become increasingly expensive
  - In the transfer market, the average cost of IPv4 addresses is variable: USD 10 to 25 per IPv4 address
- Obtaining IPv4 addresses will be increasingly difficult (change of RIR policies)

Consequences of IPv4 ...stion

- IP address market (e...
  Nortel's legacy...
- Ob...
  ex...
  - I... ... addresses is
    va...
- Obtaini... ...ill be increasingly difficult
  (change o... ...es)

Available IPv4 Space - LACNIC



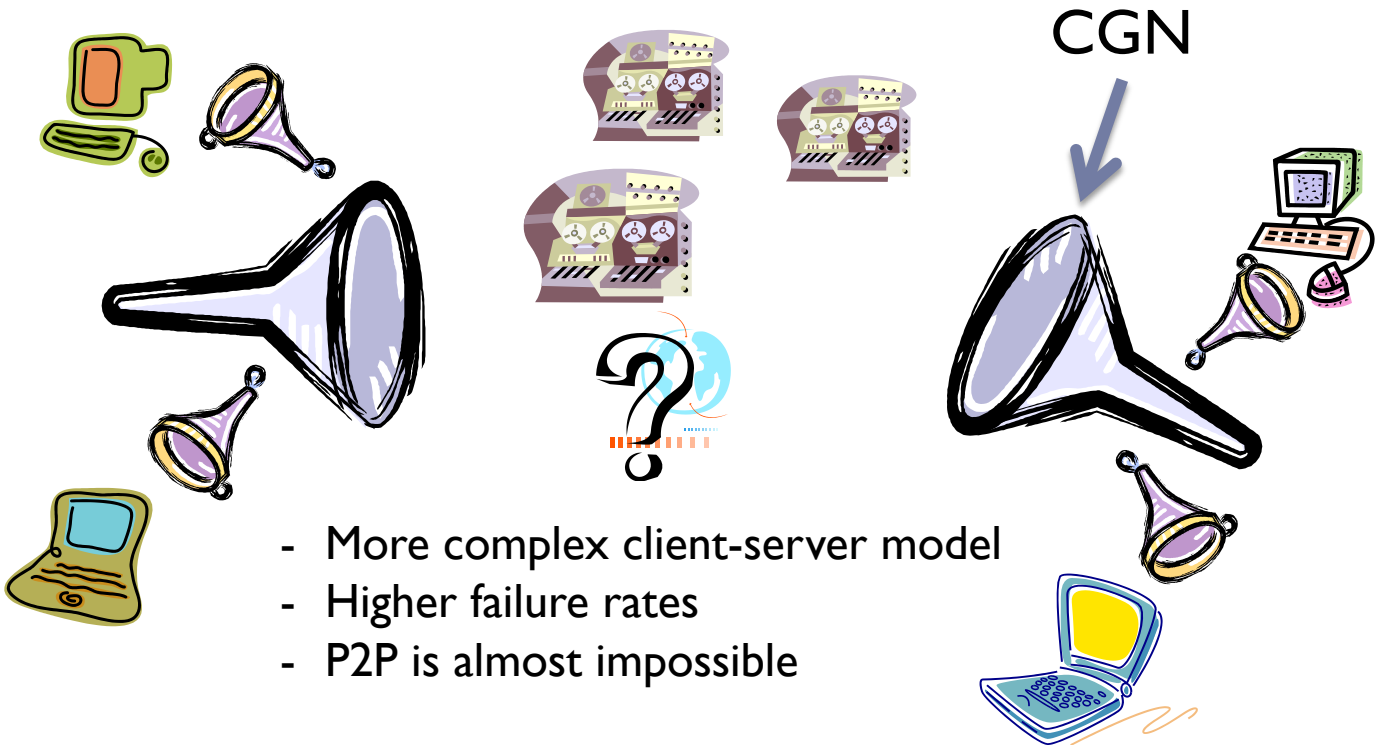
Source: http://opendata.labs.lacnic.net/ipv4stats/graphs/ipv4avail.html

Let's talk a little about NAT (Network Address Translation)

Network Address Translation (NAT)

- Allows sharing a single public IP address among several devices
- Does not scale

Internet Architecture with NATs



- More complex client-server model
- Higher failure rates
- P2P is almost impossible

Problems with NAT

- Sharing a single IPv4 address modifies the point-to-point communication model
- Issues with online gaming
- Applying ACLs (Access Control Lists) to avoid certain attacks can have major unexpected side effects
- By blocking traffic from a “bad” client, we also risk blocking traffic from many “good” clients
- Logging an IP address is no longer enough to identify which user accessed which services – we must also log port numbers

Problems with NAT

- NAT boxes can handle a limited number of simultaneous users (HW & SW Limitations)
- You create a single point of failure
- Users from different regions/countries might access the Internet via a single IP address
  - Country-specific web pages (e.g. Google, Twitter) will "think" we are in a different country
  - Twitter has country-specific policies
  - Gelocation apps will display incorrect location data

Problems with NAT

- NAT is a temporary solution
- IPv6 is a long-term solution!

IPv6

What is IPv6?

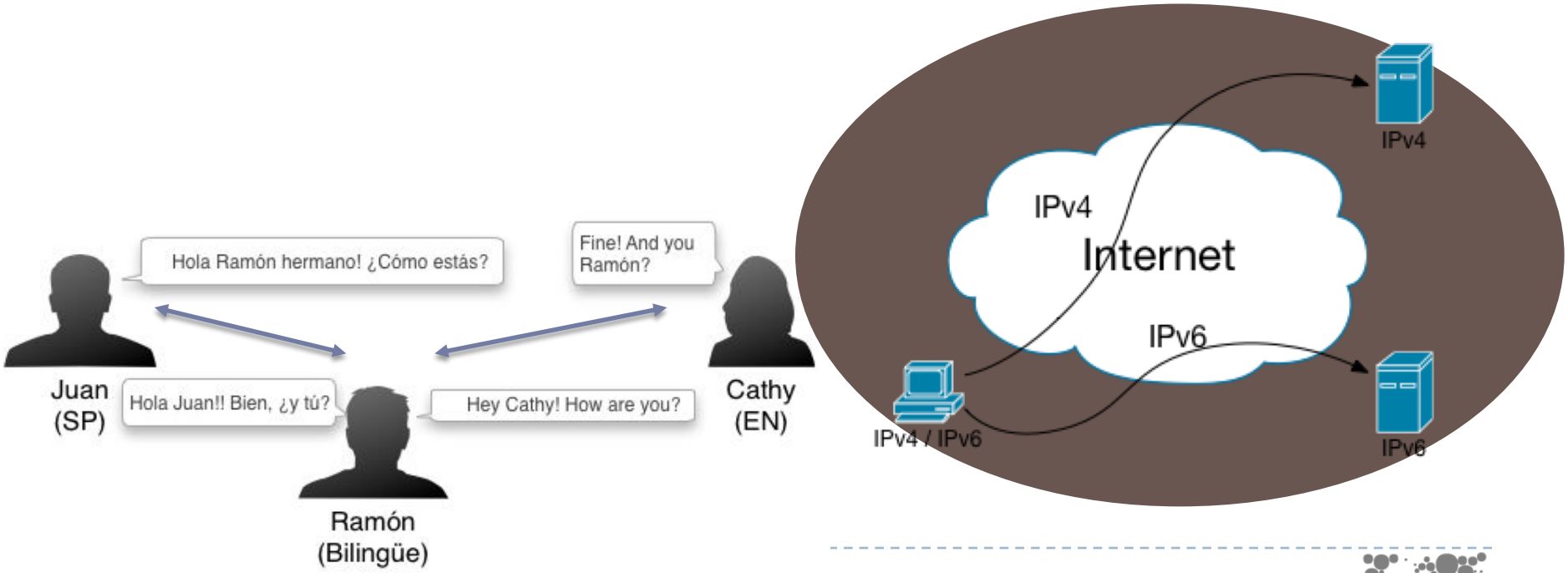
- The new version of the IP protocol
- 340,282,366,920,938,463,463,374,607,431,768,211,456 IP addresses (3.4×10^{38})
- Some say that there are enough IP addresses "to assign one to each grain of sand in the Sahara desert"

But…

- IPv4-only devices can't “talk” directly with IPv6-only devices
  - They need a translator (additional equipment, additional costs, etc.)
  - This translator breaks the communication model

Dual Stack

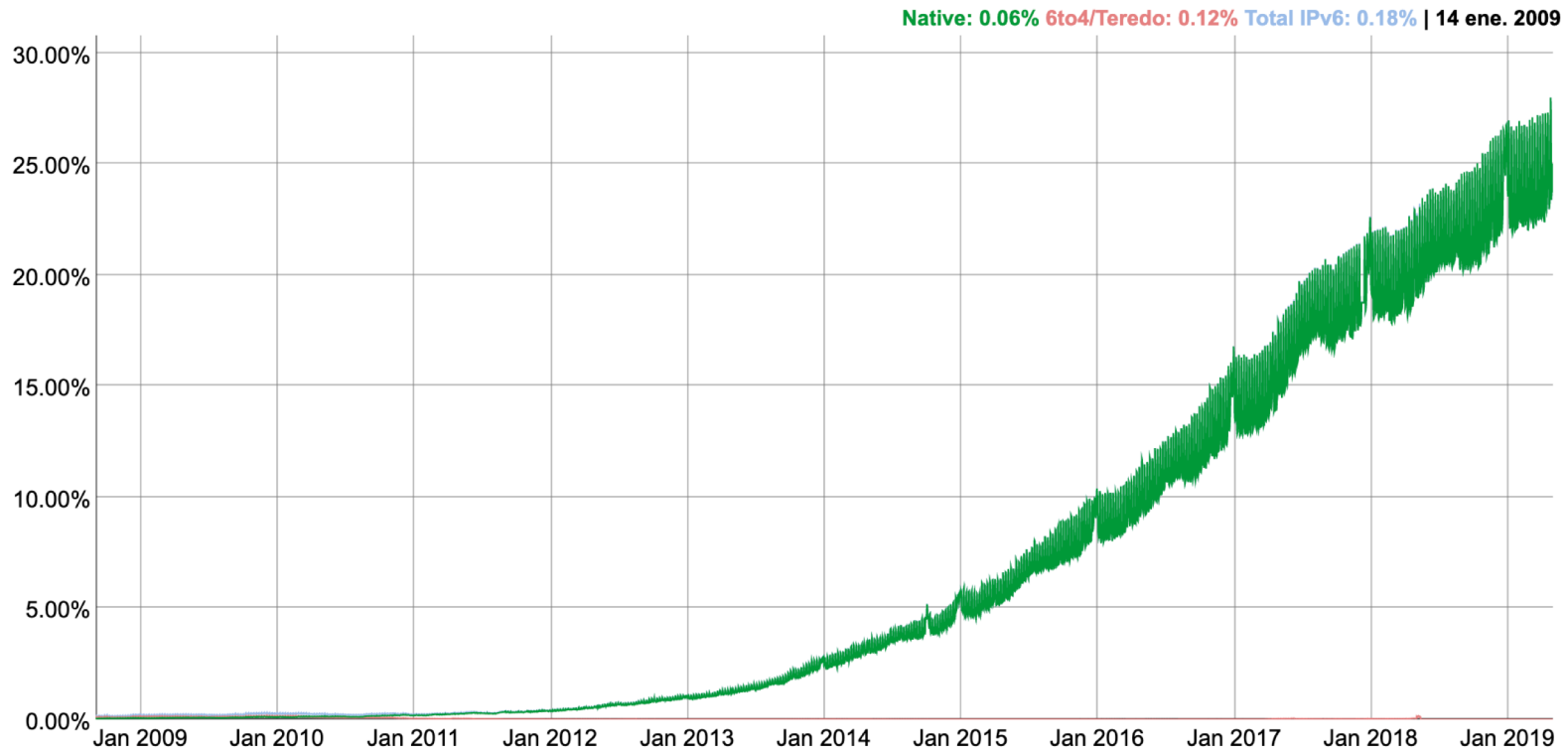
- Best solution
- Dual-stack devices can communicate with other dual-stack devices and with IPv4-only and IPv6-only devices



IPv6 Deployment Worldwide

Adopción de IPv6

Siempre estamos evaluando la disponibilidad de la conectividad de IPv6 entre usuarios de Google. En este gráfico, se muestra el porcentaje de usuarios que acceden a Google a través de IPv6.



Source: https://bit.ly/2J1mi3h

IPv6 Is the Solution

- Proposed in the nineties, IPv6 is the final solution to IP address scarcity
- What does IPv6 change? Basically, it provides more addresses
  – 128 bits
  - 2^128 > 3.40*10^38 IP addresses
- A single LAN can have more addresses than the entire Internet today
- An ISP could have 2^32 subnets (i.e. the same number of addresses the Internet has today)

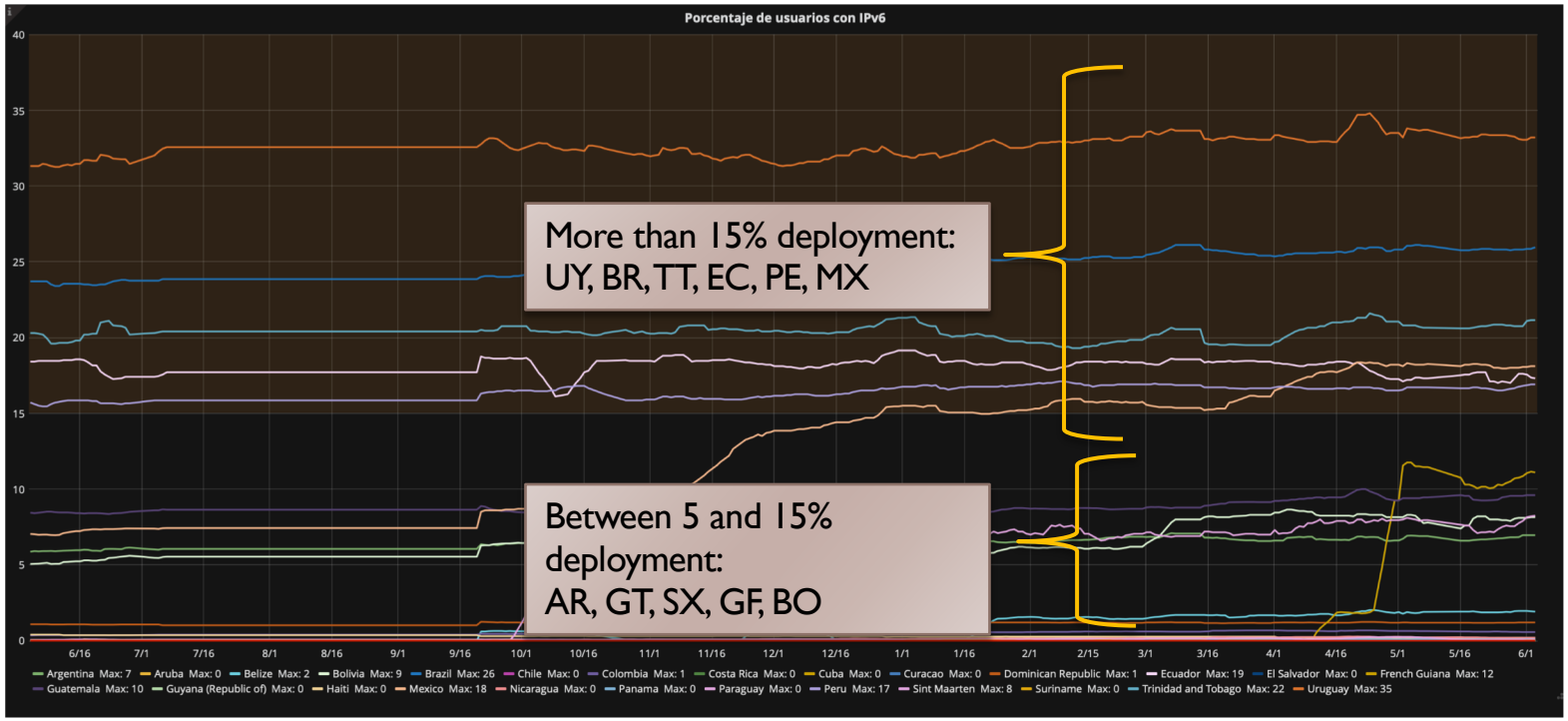
Problem

- IPv4-only devices can't "talk" to IPv6-only devices and vice versa

Important: Both Protocols will Coexist for a Long Time

- Premise for the creation of the protocol
  - Coexistence with IPv4
  - No "D-Day" for transitioning from one protocol to the other
- Definition of transition mechanisms
  - Initially designed for a mostly IPv4 environment
    - Dual stack
    - Different types of tunnels
  - Currently designed for a mostly IPv6 Internet
    - In simple terms: NAT64/DNS64
    - 464XLAT, MAP-T, MAP-E, DS-Lite and others

IPv6 Deployment in LAC (End Users)



Main Issues

- ISPs: deployment to end users
  - CPE are not completely IPv6-ready
  - Provisioning systems and other internal software systems
  - Operator/helpdesk training
- University networks: deployment to CPE; campus: Wi-Fi networks and firewalls are generally unprepared
- Government: systems are unprepared, portals and Wi-Fi networks are unprepared

Why Deploy IPv6 Today?

- Reduces the load on CGN
  - Potentially more than half the traffic could be routed over native IPv6
  - Apps that don't work behind CGN could use native IPv6
  - Apps that use multiple sessions could also use native IPv6
- Less issues with users, less complaints to helpdesks

Why Deploy IPv6 Today?

- The performance of IPv4-only networks will decrease: NAT layers
  - The number of IPv6-only networks is on the rise
- To prepare for the IoT
  - Exponential growth of the number of network devices
  - Need for end-to-end models
  - Abandoning proprietary solutions
- New projects require IPv6
- If you don't implement IPv6 there is a risk of losing connectivity to the rest of the world

Other Possibilities: IPv4aaS

- IPv4 as a Service: a current trend in many networks

- Deployment of 464XLAT on mobile networks
  - Double translation that allows the use of IPv4-only applications
  - Does not require dual stack
  - IPv6-only connectivity for mobile devices
  - RFC 6877: 464XLAT Combination of Stateful and Stateless Translation

- Deployment of IPv6-only datacenters
  - RFC 7755 and RFC 7756
  - SIIT-DC: Stateless IP/ICMP Translation for IPv6 Data Center Environments
  - Description of how to use transition techniques such as NAT64 / 464XLAT for IPv6-only datacenters
  - RFC 7269: NAT64 Deployment Options and Experience

Summary about other countries regulation about IPv6

País	Reglamentación
Argentina	RESOL-2018-4-APN-STIYC#MM
Colombia	Resolución Número 002710 de 2017
Costa Rica	Directriz 049-MICITT-2013
Cuba	Instrucción No 5 2007 Resolución No. 138 / 2008 Resolución No. 140 / 2008 Resolución No. 156 / 2008
Ecuador	Acuerdo N 007-2012
México	DOF 04-02-2016
Perú	DECRETO SUPREMO N° 081-2017-PCM
República Dominicana	Resolución-No-021-15

Summary about other organizations suggestions regarding IPv6

Organización	Reglamentación
UIT	Resolución 63-CMDT17 Resolución 64-AMNT16 Resolución 101-PP14 Resolución 102-PP14 Resolución 133-PP14 Resolución 180-pp14
CITEL	CCP.I/REC.2 (XII-08) CITEL RES.58 (V-10) CCP.I/REC. 7 (XVIII-11) CCP.I/REC. 15 (XX-12) CCP.I/REC. 27 (XXXII-18)
CTU	CIGPF-Issue-3.0-2016

Transition Mechanisms

Transition Mechanisms

- The entire structure of the Internet is based on the IPv4 protocol
- An immediate change of protocol is not feasible due to the network's size and penetration
- IPv6 adoption must be gradual
- There is a period of transition and coexistence of the two protocols
- IPv4 networks will need to communicate with IPv6 networks and vice versa
- To facilitate this process, certain techniques were developed seeking to maintain the compatibility of IPv4 networks with the new IPv6 protocol

Transition Mechanisms (2)

- **Dual stack**
  - Allows a device to participate in IPv4 and IPv6 networks simultaneously
- **Tunneling**
  - Allows IPv6 packet traffic on the structure of the existing IPv4 network
- **Translation**
  - Allows communication between IPv6 nodes and nodes that only support IPv4

Workshop time !

2 teams

TEAM A

Case:

Your boss does not want to implement IPv6. You will try to convince him to do it.

What would you do?

TEAM B

Case:

The company wants to implement IPv6 but it looks you have no money to do it.

What would you do?

So, you want to deploy IPv6 !!

So, you want to deploy IPv6 !!

NICE !!!

The Importance of Early Planning

- Gathering information on existing equipment and software
- Training
- Investment planning
- Implementation

Gathering Information

- Equipment
  - Understand which devices support IPv6 and which do not
  - Do we need IPv6 in the entire network and in all our equipment?
- Wi-Fi networks: are they configured to provide IPv6?
- ISPs
  - Does the service they offer support IPv6?
- Content providers: do hosting providers support IPv6?
  - Portals, government websites, universities
- Do our software systems support IPv6?

Training

- Initial research of the technology
- Provide proper training for operators and system administrators
  - Networks and systems
  - Provide training to helpdesks
  - Other non-technical departments within an organization
- Internal communications on the importance of deploying IPv6
- Analyze the different options to find the solution best suited to your needs

Investment Planning

- Develop a project proposal
- Consider IPv6 in equipment renewal cycles
- Compare the possibility of investing in a short-term solution (CGN) vs. investing in a final solution (native IPv6 with dual-stack or NAT64)
- Analyze the latest transition technologies (464XLAT, MAP, lw4o6)

Implementation

- Design a detailed IPv6 network architecture
- Define a numbering plan
- Conduct pilot tests in non-critical areas of the organization
- Define security policies, procedures, monitoring practices, etc.
- Mass deployment and operation in production
  - Begin by stages and then progressively increase the number of services

Recommendations

- Research existing technology
  - Look for training opportunities
  - Participate in IPv6 conferences
  - Take advantage of existing literature, courses, etc. (see final slides)
- Take IPv6 into account when planning your IT infrastructure
- Obtain your own IPv6 prefix and prepare a numbering plan
  - Don't think like you did for IPv4

Initial Considerations

- Proper training for operators and system administrators
  - Using the LACNIC Campus (https://**campus.lacnic.net**)
  - Participating in IPv6 conferences
- Internal communications on the importance of deploying IPv6
- Review the different options to find the most appropriate solution

Infrastructure Analysis

- Check if your **transit providers** already support IPv6
- Check if your **equipment vendors** already support IPv6
- Take IPv6 into account when designing or upgrading IT infrastructure

Application Analysis

- Test whether your applications are IPv6-compatible
- Any application (web, mobile, etc.) that uses the Internet will require IPv6 support
- Verify the organization's management software

Investment Planning

- Develop a project proposal
- Compare the possibility of investing in a short-term solution (CGN) vs. investing in the final solution (native, dual-stack IPv6)

Investment Planning (2)

- Take advantage of the equipment's “natural” life cycles and the organization's procurement processes to acquire IPv6-enabled equipment
- Think about your clients: they don't care whether the service they receive is IPv4- or IPv6-based, they simply want a good service

Implementation

- Development, testing and pilot implementation
- Develop security policies, procedures, etc.
- Mass deployment and operation in production

Architecture Design and Development

- If possible:
  - Maintain IPv4
  - Use dual stack
  - Avoid tunneling
  - Native IPv6 transit
- Assign one IP address per host (avoid NAT)
- Create an IPv6 addressing plan (2001:db8::/32)
- Manage IPv6 security, monitoring and logging

Pilot Testing and Mass Deployment

- Test web applications
- Test network devices
  - Routers, CPEs, etc.
- Analyze logs
- Test security devices
- Perform packet captures and monitor traffic
- Test network connectivity and routing protocols

IPv6 Deployment Survey (NRO)

- Conclusions
  - Those who were not considering having an IPv6 assignment stated that the biggest hurdle they would face was the cost and relegated the lack of vendor support to the 4th place
  - Those who had already received an IPv6 assignment cited the lack of vendor support as the main obstacle and mentioned the cost in 3rd place

IPv6 Deployment Survey (NRO)

- Conclusions
  - Both groups agreed that the lack of adequately trained personnel is the second biggest hurdle
  - They also agreed that “Explaining the business case to non-technical decision makers” is among the four biggest obstacles (the reason for this presentation)

Stop Waiting for Others!!

- Start testing now!
- Don't wait for others to deploy IPv6
- The longer we delay IPv6 deployment, the more expensive it will be
- Don't wait until we start losing customers (or until we are unable to deploy services and increase our customer base)

Advantages

- Take advantage of the opportunity to re-design your network
- When creating your design, consider security, scalability, etc. without the restrictions of IPv4 run-out

Myths

- There is no IPv6 content, there is no traffic
  - In a full-IPv6 network, approximately 30-40% of the traffic is IPv6 traffic
- Implementing IPv6 is expensive
  - Only if we don't take advantage of natural investment cycles
  - Not when compared to the cost of IPv4 (transfers and cost of CGN per user)
- Lack of a business case

Information and Documentation

- http://portalipv6.lacnic.net
- http://www.labs.lacnic.net
- http://eventos.lacnic.net/
- http://www.lacnog.org
- IPv6 for Network Operators:

http://portalipv6.lacnic.net/wp-content/uploads/2014/12/ipv6_operadores_red.pdf

Available Information and Resources

LACNIC Campus

- e-Learning platform offering different courses
- Current offerings:
  - Basic IPv6
  - Advanced IPv6 (tutored)
  - BGP and RPKI (tutored)
- Several editions each year

In-Person Courses

- During LACNIC events
  - Workshops and courses including theory and practice
  - Advanced IPv6
  - BGP
- By request
  - The institution is responsible for the location and logistics
  - LACNIC provides the instructor
  - Open to all LACNIC members

Thank you

Questions?

Alejandro Acosta
alejandro \@ lacnic.net
@ITandNetworking