IPv6-only? You're kidding, right?

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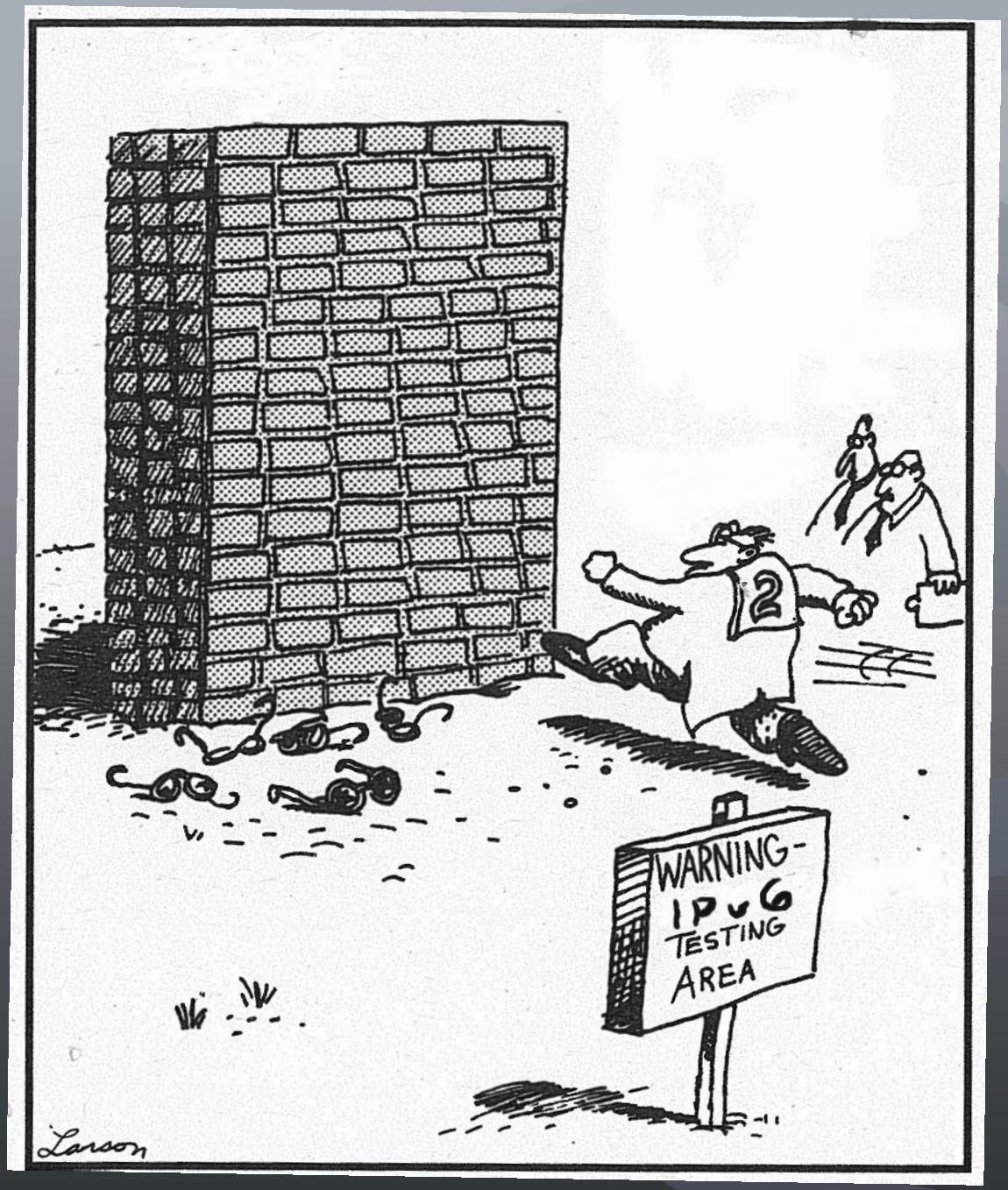


Why IPv6-only, Why now?

- Dual-stack isn't the end state, it's the **midpoint**
  - Scaling problems:
    - Not enough IPv4 to keep growing your network
      - IPv4 {reclamation, purchase, sharing} = Expensive, complex
    - IPv4 routes + IPv6 routes = bigger routing table = more expensive hardware
  - Operational Complexity: Requires maintaining two parallel networks
    - IPv4 and IPv6 configuration similar, but separate
    - Troubleshooting and monitoring must be done separately for IPv4 and IPv6

Why IPv6-only, Why now?

- **Single stack (IPv6-only) is the end state**
  - Design for it now to ease transition & rework later
- IPv6-only (IPv4-sunset) can happen in phases
  - Corollary: don't need to wait for universal IPv6 support
  - IPv6-only Datacenters [1]
  - Some services go IPv6-only
  - Use NAT64 in front of legacy IPv4-only equipment to enable IPv6
    - Small IPv4-only or dual-stack island so that you can disable IPv4 wherever possible

[1] https://ripe64.ripe.net/presentations/67-20120417-RIPE64-The_Case_for_IPv6_Only_Data_Centres.pdf

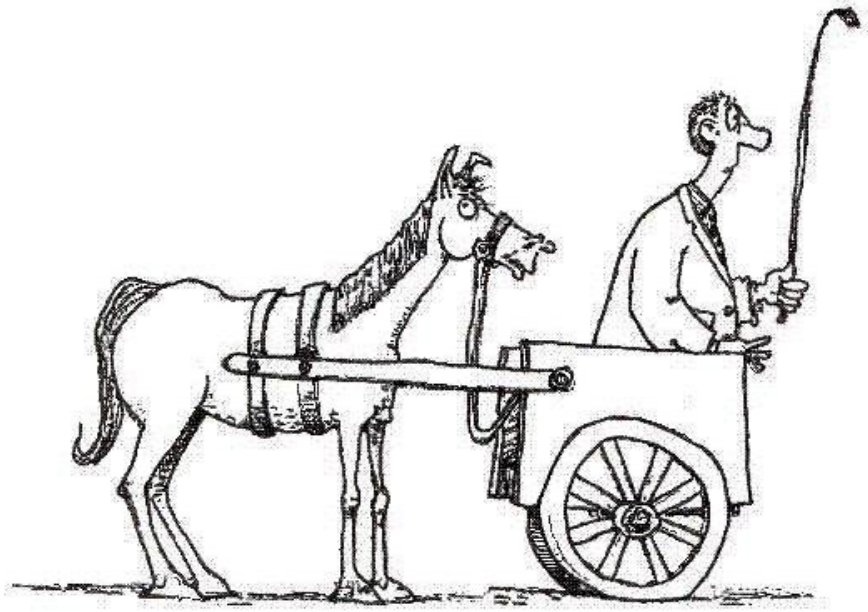
The Business Case for IPv6

- Before “move to IPv6-only” comes “deploy IPv6”

- Deploying IPv6 is the “right” thing to do
  - But…IPv6 has deployment costs, but no revenue
- How do you justify deploying IPv6?
- How do you explain why it should be done now?

- What will it cost to use CGN?
- What will it cost to run dual-stack?
- What will it cost to buy IPv4 addresses?

https://ripe67.ripe.net/archives/video/12/



What will it cost to run CGN?

What Does CGN Cost?

- CGN reportedly breaks things[1]
- How many users affected (out of 10,000)?

Use	Number of Potential Users[2]	Number Affected	Number of Support Calls[3]	Number of Lost Users[3]
PS3	1100	550	137	137
P2P	1500	1200	300	300
Netflix	1200	60	15	15
Misc.	800	800	200	200
	6,700	2,610	652	652

[1] RFC7021

[2] North American sales per ten thousand homes, per various sources.

[3] Arbitrary guess. Spreadsheet at http://www.asgard.org/documents.html

Cost of CGN

Per 10,000 users

- Capital
  - Hardware, software, logging systems: US$90,000 ?
- Operations Expense
  - System support, maintenance: US$10,000?
  - If support call cost is $20, 652 calls = US$13,040.
- Lost Revenue
  - If (ARPU) is $400/year, the annual revenue lost to CGN is: $400 * 652 = US$260,800 per year.

Total CGN Costs per 10,000 Users
(USD)

Year 1	Year 2	Year 3	Year 4	Year 5	
$18,000	$18,000	$18,000	$18,000	$18,000	CAPEX (depreciation)
$10,000	$10,000	$10,000	$10,000	$10,000	OPEX
$13,040	0	0	0	0	Customer support
$260,800	$260,800	$260,800	$260,800	$260,800	Lost revenue
$301,840	$288,800	$288,800	$288,800	$288,800	TOTAL: $1,457,040

Detailed paper at http://www.asgard.org/documents.html

What will it cost to use CGN?

CGN costs US$1.5 million (R$3.375M) for every 10,000 users it’s used for, or $30 (R$68) per user per year.

What will it cost to run dual stack?

Cost of Dual-Stack

- Asked experts on various industry segments
  - Data Center/Host/Content
  - ISP
  - Enterprise
- Deployment Cost
- Operational Cost

Deployment Costs

Data Center, Hosting, Content	Security appliances, Monitoring systems	$1 per user
	Application development	$6 per user
ISP	Training 2-3 hours of training	$0.15 per user $150 per support/NOC employee 1 support staff per 1000 subs
	CPE	$25 per user $50 each, but only half need upgrades
Consumer Electronics	Labor	$0.30 per device

Capital expenditures are reduced if spread over a longer period of time, when upgrades were planned anyway.

So, start four years ago and it's cheap.

Operations Costs

	Develop	Operate
Content Data Center, Hosting,	$6 *pupy* +10-30% Application development Lower for hosting	$0.08 *pupy* 20% of OpEx increases by 1-5%
ISP	$6.40 *pupy* Device code	$0.25 - $1.27 *pupy*
Consumer Electronics	$0	$0

pupy = “Per User Per Year”

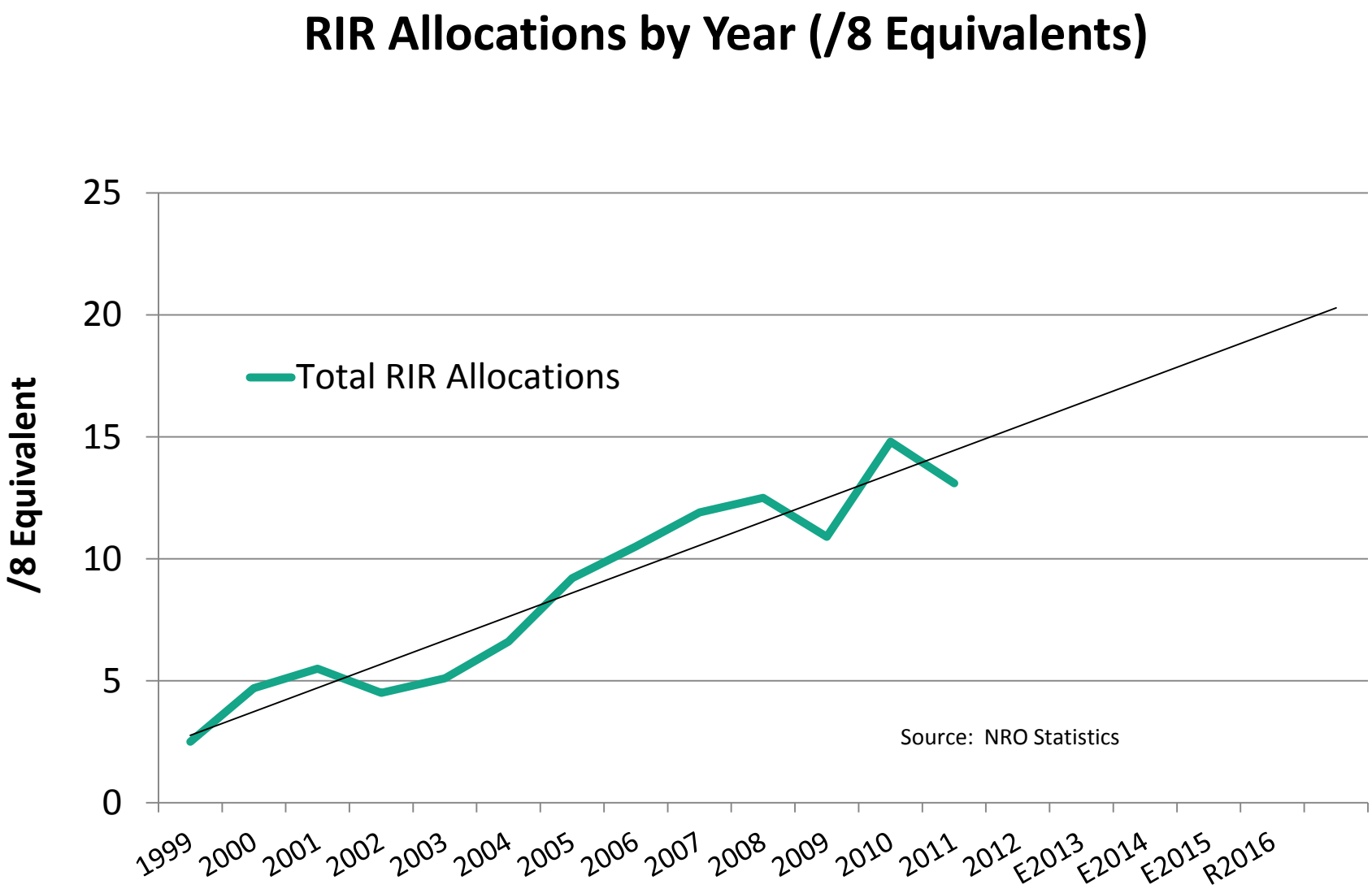
What will it cost to run dual-stack?

	Deploy	Operate
Data center Hosting Content	$7 (R$16) per user	$6.08 (R$14)per user per year
ISP	$25 (R$56) per user	$7.50 (R$17) per user per year
Electronics	$0.30 (R$0.68) per device	$0 per device

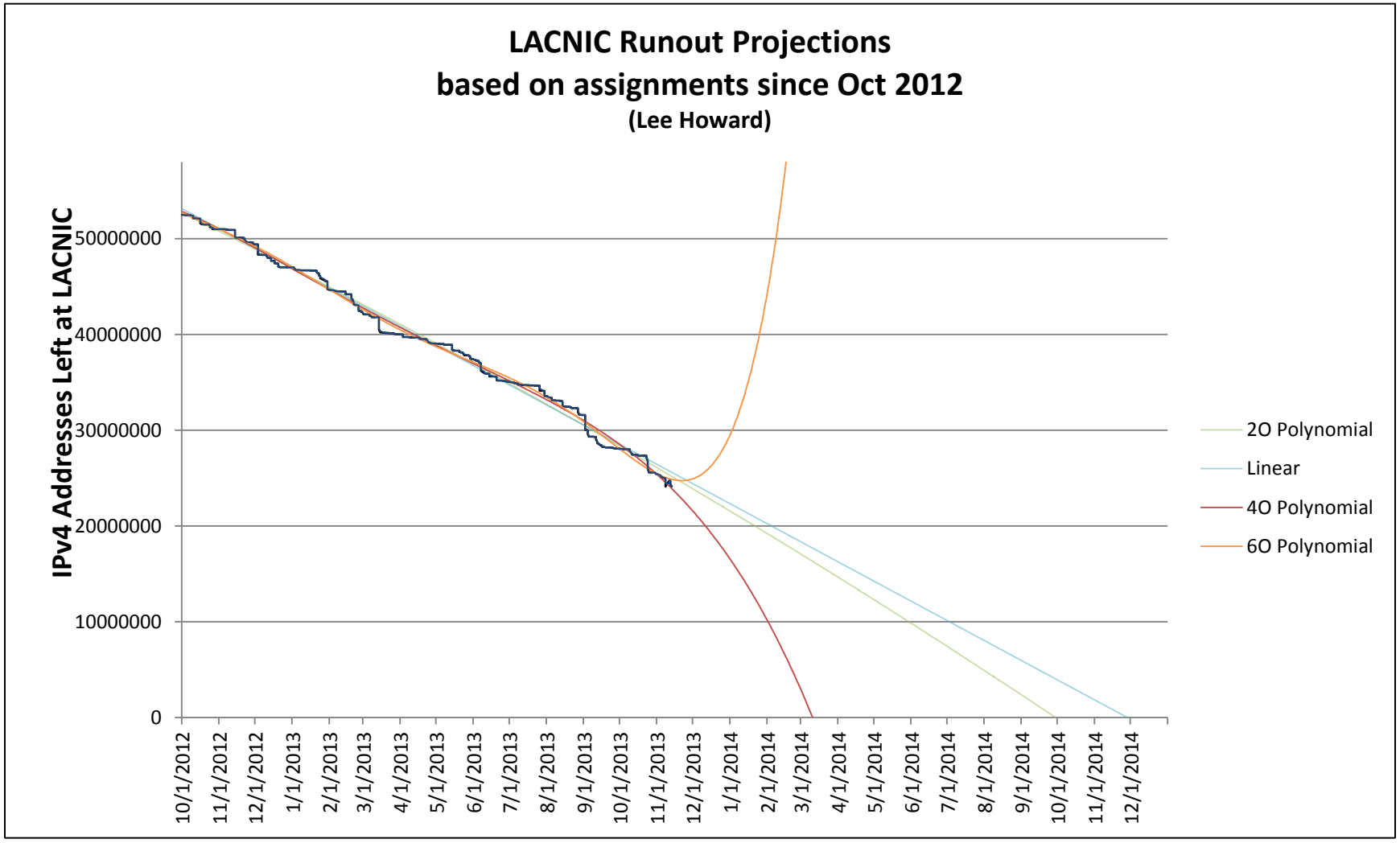
- Costs listed err to the high end
- Reduce deployment cost by starting sooner
- Reduce operation cost by limiting time dual-stack is supported

What will it cost to buy IPv4 addresses?

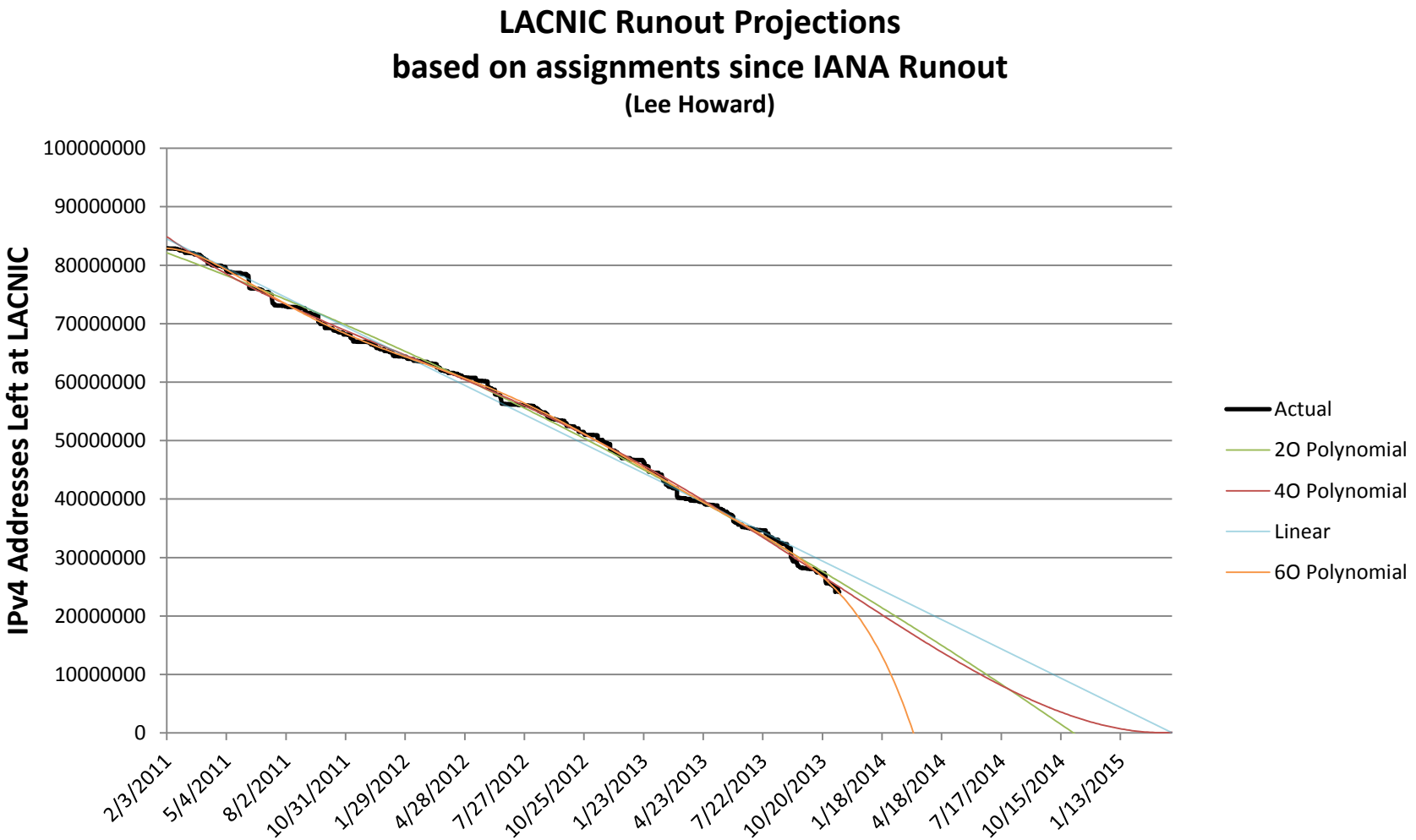
IPv4 Demand


RIR Allocations by Year (/8 Equivalents)
/8 Equivalent
25
20
15
10
5
0
Total RIR Allocations
Source: NRO Statistics
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
E2013
E2014
E2015
R2016

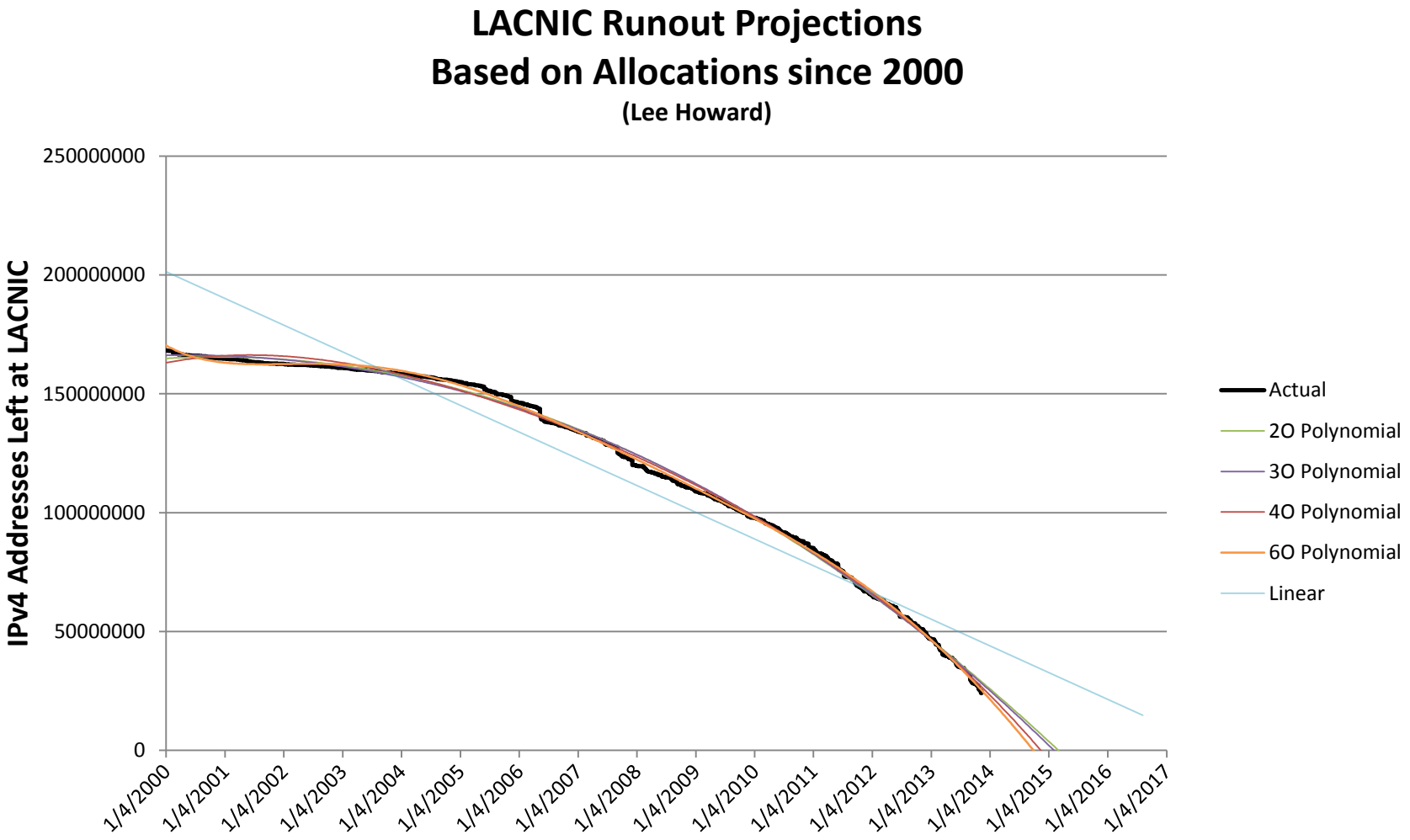
LACNIC IPv4 exhaustion



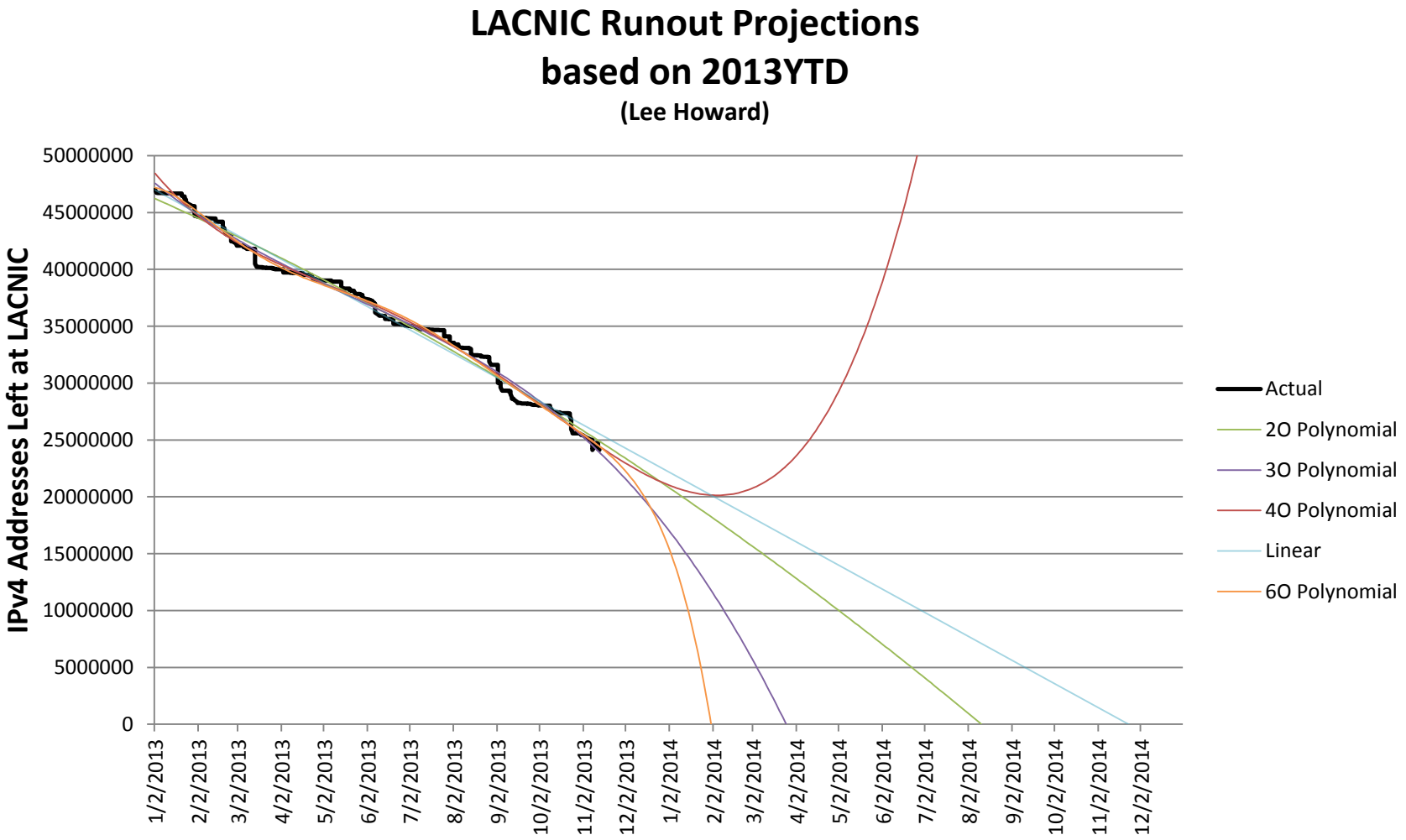
LACNIC IPv4 exhaustion



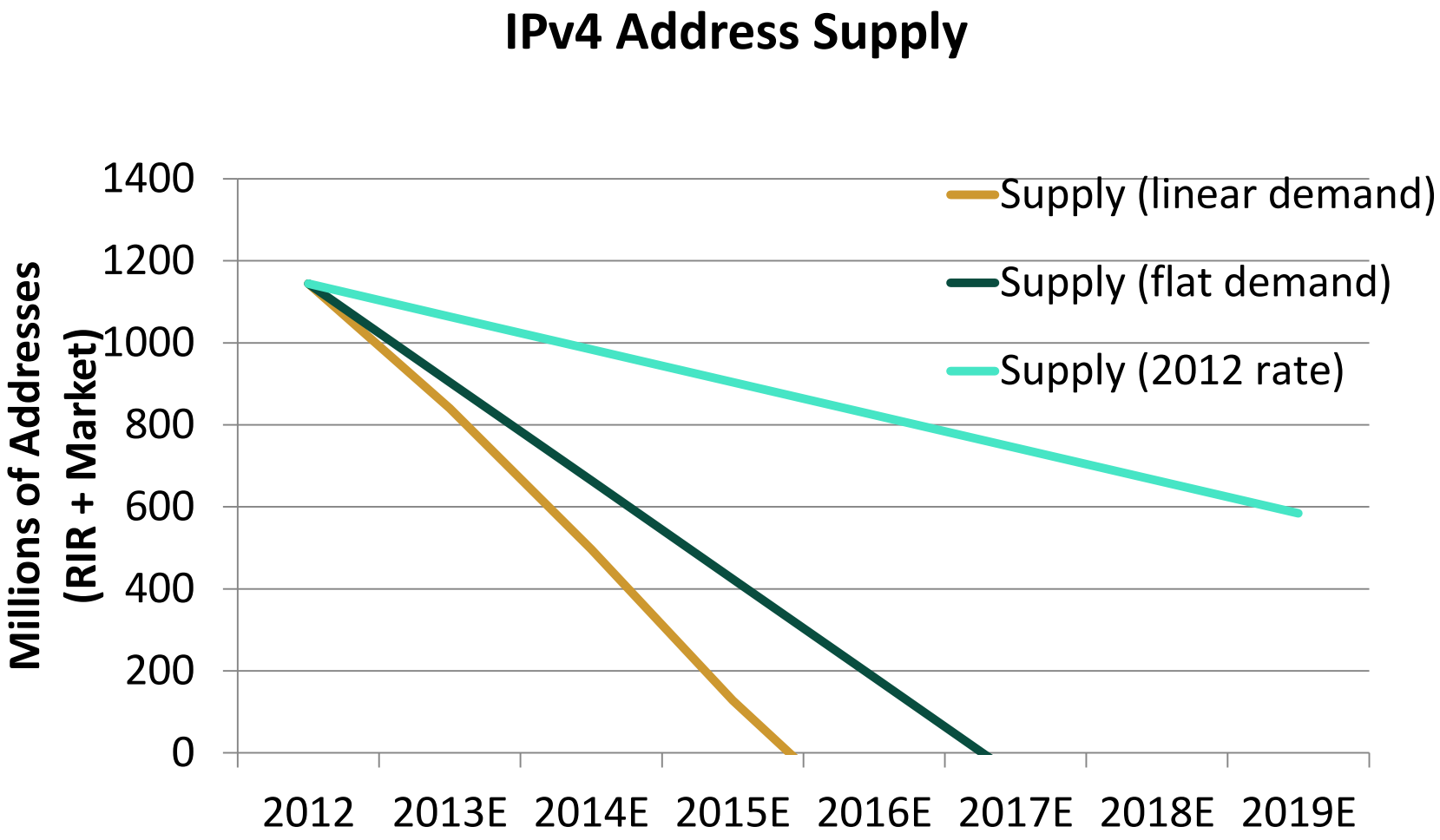
LACNIC IPv4 exhaustion



LACNIC IPv4 Exhaustion



IPv4 Supply


IPv4 Address Supply
Millions of Addresses (RIR + Market)
1400
1200
1000
800
600
400
200
0
2012
2013E
2014E
2015E
2016E
2017E
2018E
2019E
Supply (linear demand)
Supply (flat demand)
Supply (2012 rate)

IPv4 Supply

At what price would someone sell an IPv4 address?

Tier	Summary	Cost per Address[1]	Addresses Available[2]
Tier 0	Remaining RIR space	$0.03 - $4 (R$0-9)	144,000,000
Tier 1	Unused	$9 – 12 (R$20-27)	480,000,000
Tier 2	Underutilized	$10 – 16 (R$23-27)	520,000,000
Tier 3	Substitutable	>$100 (>R$225)	All IPv4

[1] “Cost” is not the same as “Price.”

[2] Source: ARIN, LACNIC, AfriNIC; RouteViews

What will it cost to make more IPv4 addresses available?

	2014	2015	2016	2017
Demand	280M	310M	330M	350M
Supply (Abandoned)	410M	100M	0	0
Supply (Underutilized)	520M	520M	290M	0
Cost[1]	$9 – 12 (R$20-27)	$9 – 16 (R$20-36)	$16-20 (R$36-45)	$n

[1] "Cost" is not the same as "Price."

- ***Expectation*** of price is not reflected; may be much higher.
- How many IPv4 addresses might be made available by substituting CGN (at US$30 or more)?

Resolution

Q: What will it cost to use CGN?
A: $30 (R$68) per new user per year

Q: What will it cost to run dual-stack?
A: (ISP) $7.50 (R$17) *pupy*
A: (Content) $6 (R$14) *pupy*

Q: What will it cost to buy IPv4 addresses?
A: *At least* $9-20 (R$20-45) per new user per year until 2017.

Q: How can I reduce my costs?

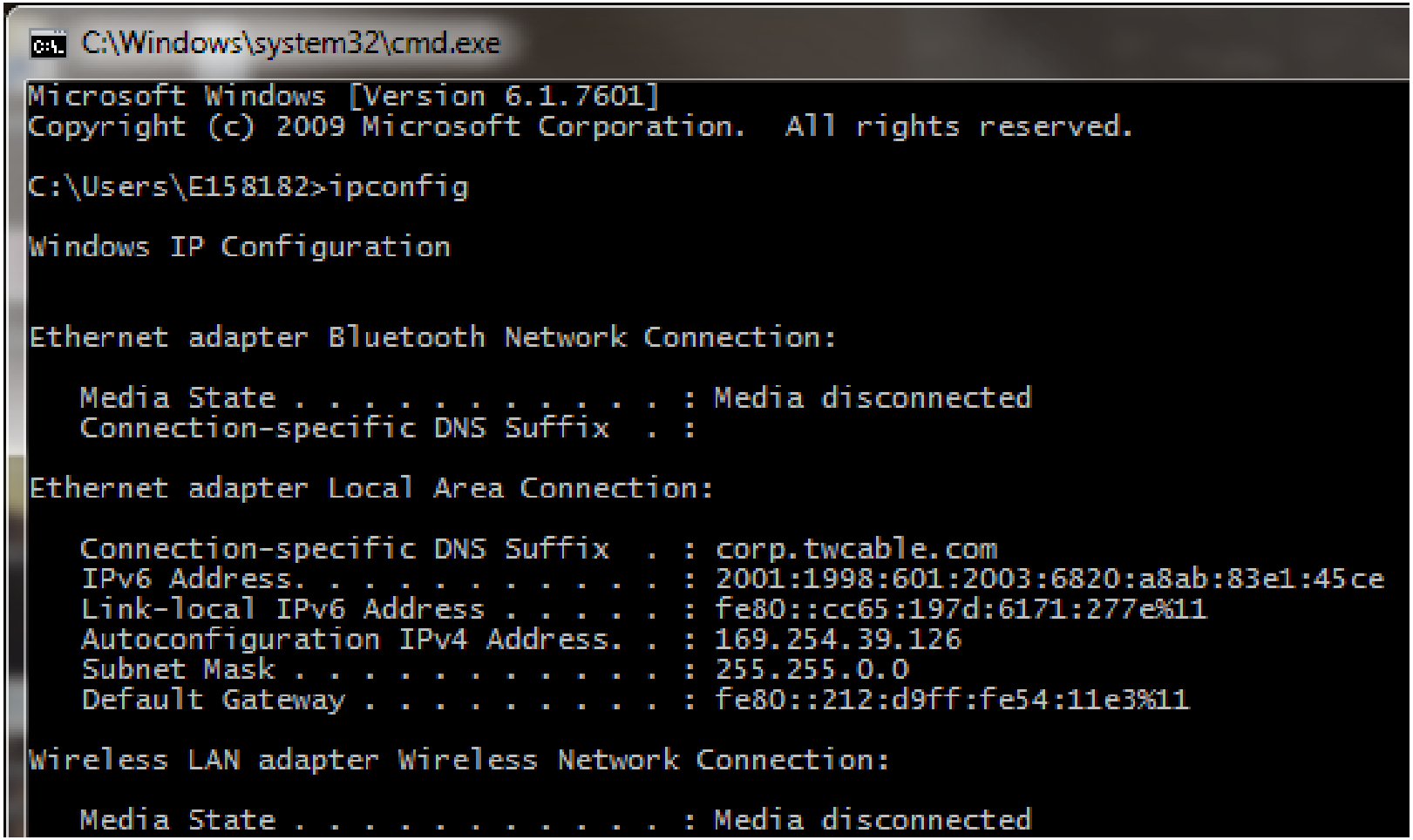
Why IPv6-only, Why now?

- Reduced costs
  - IPv6 bypasses CGN – reduces required CGN capacity
  - Smaller routing table
    - Cheaper hardware, better performance/scale, or longer life for existing hardware
- Reduced complexity
  - Less parallel configuration, troubleshooting
  - Reduced security exposure
    - Reject all IPv4 traffic at edges of IPv6-only network areas
- IPv4 Address usage/conservation
  - Prioritize IPv4 for customers, legacy equipment

Getting to IPv6-only

- Evaluating your network
  - IPv4 not needed vs. IPv4 too costly
  - Internal services - local to your network
    - Common administrative control
    - Management and Monitoring (SNMP, SSH, etc.)
    - Major IPv4 address usage (millions of edge devices)
  - External Services
    - Acceptable level of brokenness vs cost of transition tech (NAT64/DSLite/464xlat)
    - Communities of interest
    - Analysis to group customers by tier, destination

What happens when all you have is IPv6?



Let’s turn off IPv4 and find out…

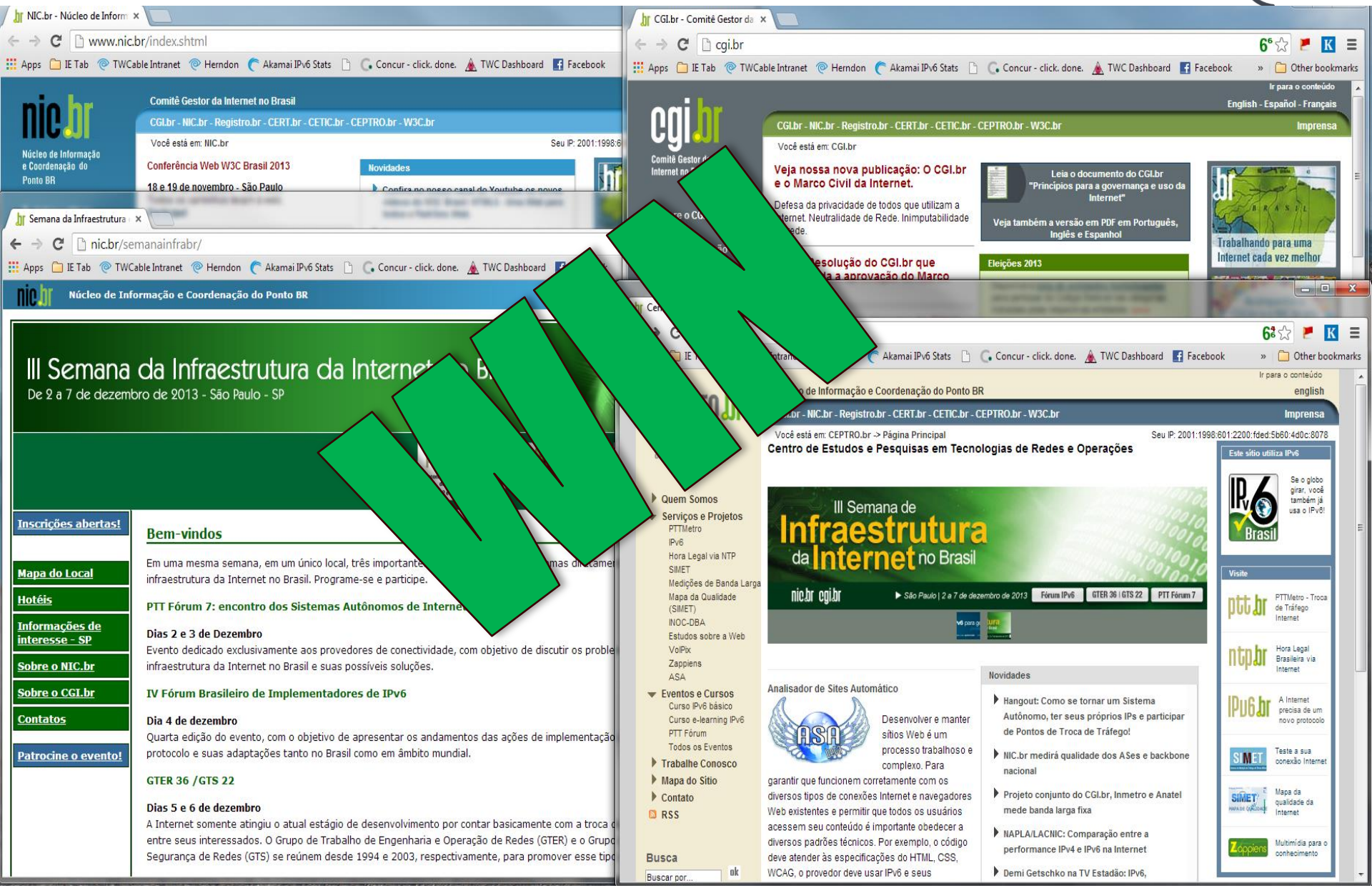
Test Environment/OS Notes

- Cable Modem filtering IPv4, first directly connected to the host under test, then with host behind a D-Link DIR-655 via WiFi
- Host receives IPv6 prefix and IPv6 DNS via DHCPv6
- Windows (7/8) – Works
- Mac OS (10.7+) – Works, but disabling IPv4 makes things quicker
- Ubuntu (13.04) – Works
- Android – no DHCPv6/RDNSS support = no DNS servers
  - https://code.google.com/p/android/issues/detail?id=32621
    - filed in 2012, Medium priority enhancement, **no owner**
  - No IPv6 UI https://code.google.com/p/android/issues/detail?id=57231
- iOS – sorta works
  - Some testing details available from Andrew Yourtchenko's Ripe 66 talk here: https://ripe66.ripe.net/archives/video/1196/
  - No IPv6 UI – need to open an enhancement req w/ Apple

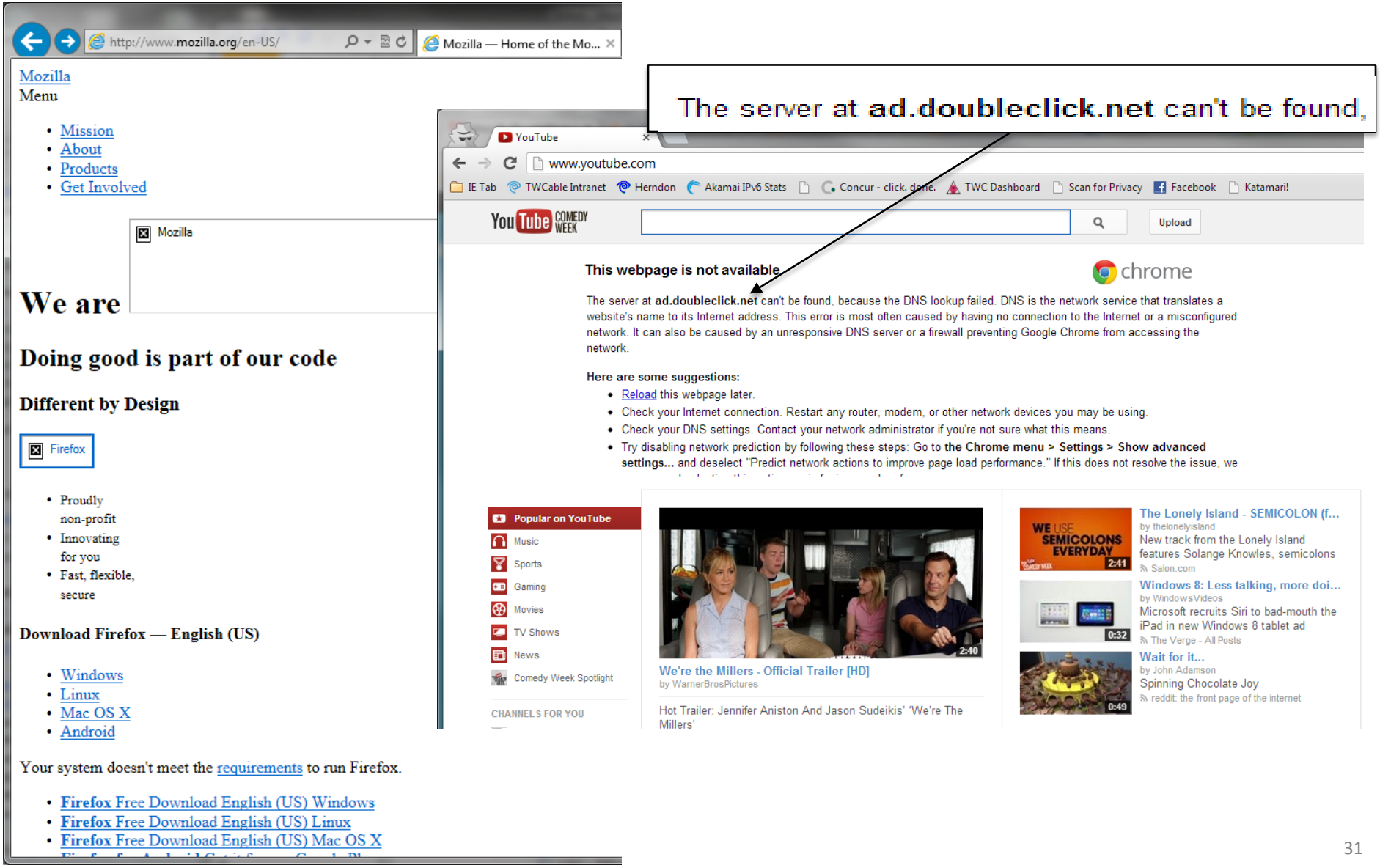
Major Security Issue!

- OS supports IPv6-only by default, but can't get software updates over IPv6
  - Apple: MacOS, Apple Software Update (PC), iTunes app store
  - Windows 7 (they tell me 8 should work, haven't tested)
  - Java
  - Adobe (Flash, Reader, Air, etc)
  - Firefox
  - Antivirus/Anti Malware, Firewall/IDS signature updates
  - Reported to each company's security team, felt ok to disclose because it's not a zero day by itself
  - Probably hundreds of others, these are just the most exploited

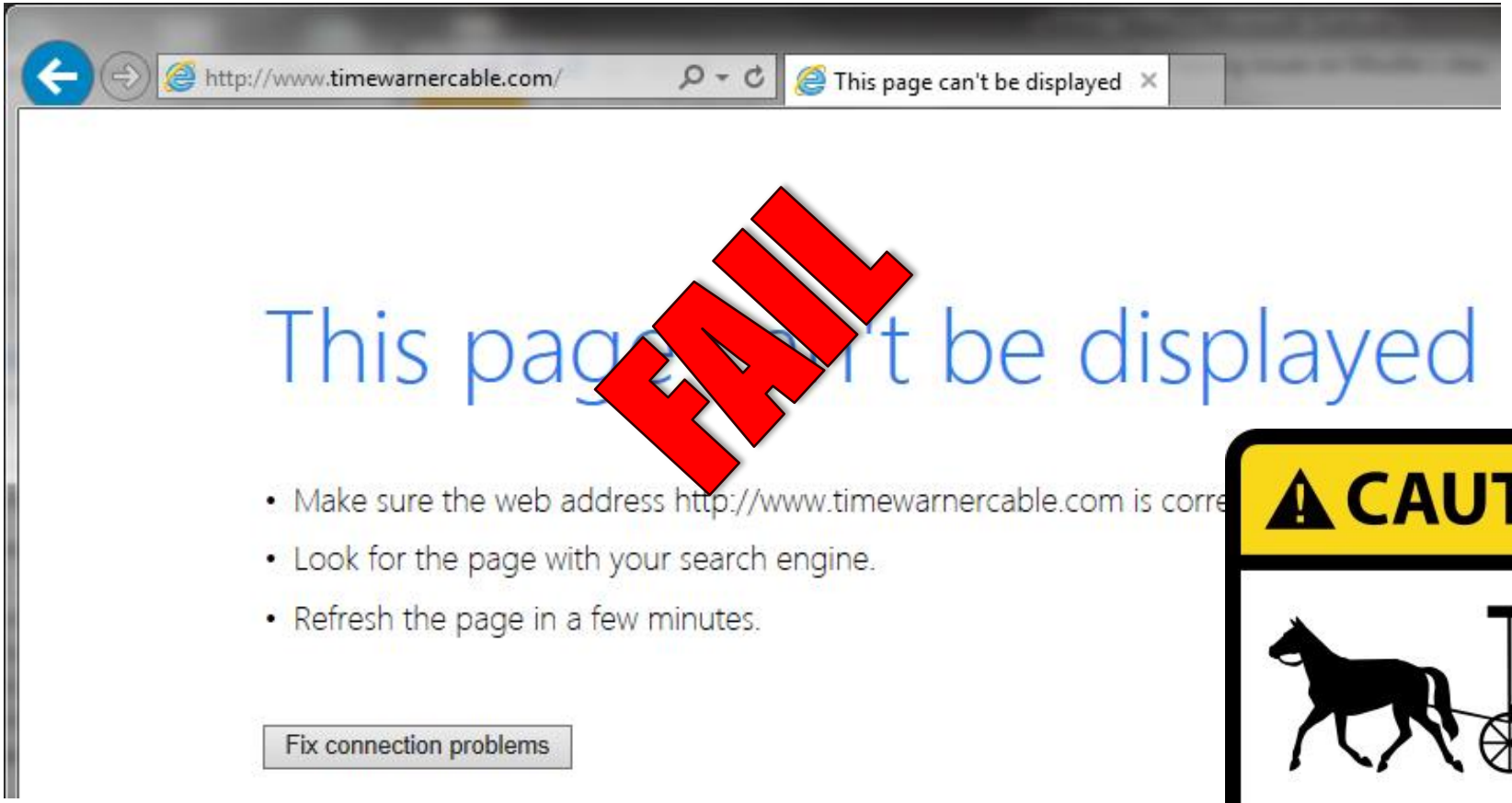
It just works!



… for some values of “work”



Except… when it doesn't



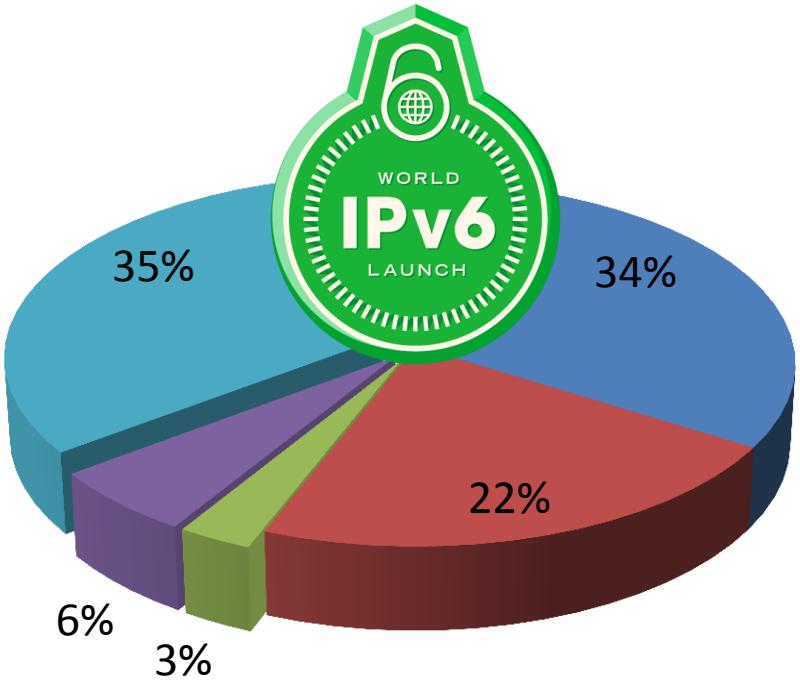
IPv6-only Testing

- Automated Website testing
  - First test: Pass/Fail IPv6 reachability
    - find AAAA, wget -6
  - Second test: If Yes, does the whole page work?
    - Perl to parse HTML: Follow local links, download images, CSS
    - report failures, provide % numeric score (good/total)
  - https://github.com/wesgeorge/IPv6-only-web-testing/tree/patch-1
- New Wiki to track IPv6-only/NAT64 issues:
  - http://wiki.test-ipv6.com/
  - Need more people testing and contributing

Test results – Do webpages work over IPv6-only?

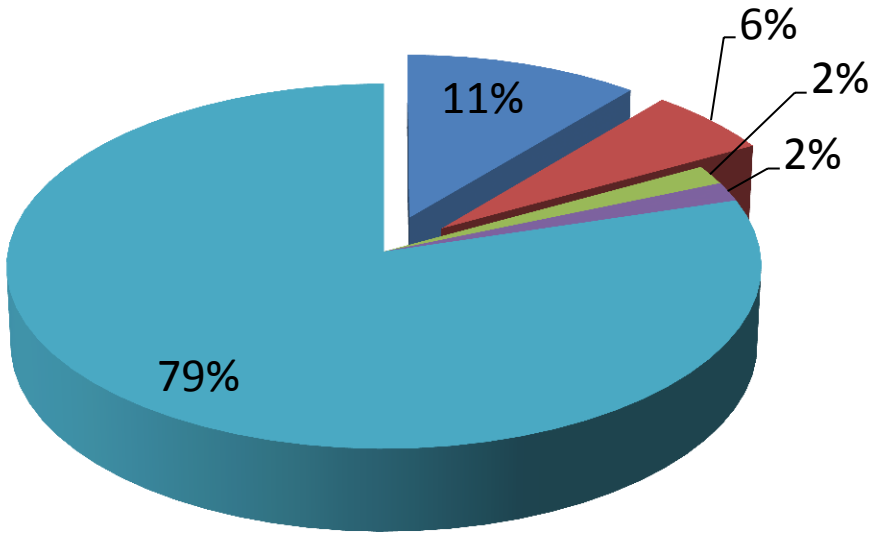
World IPv6 Launch Participants

Sites tested: 2999



Other sites

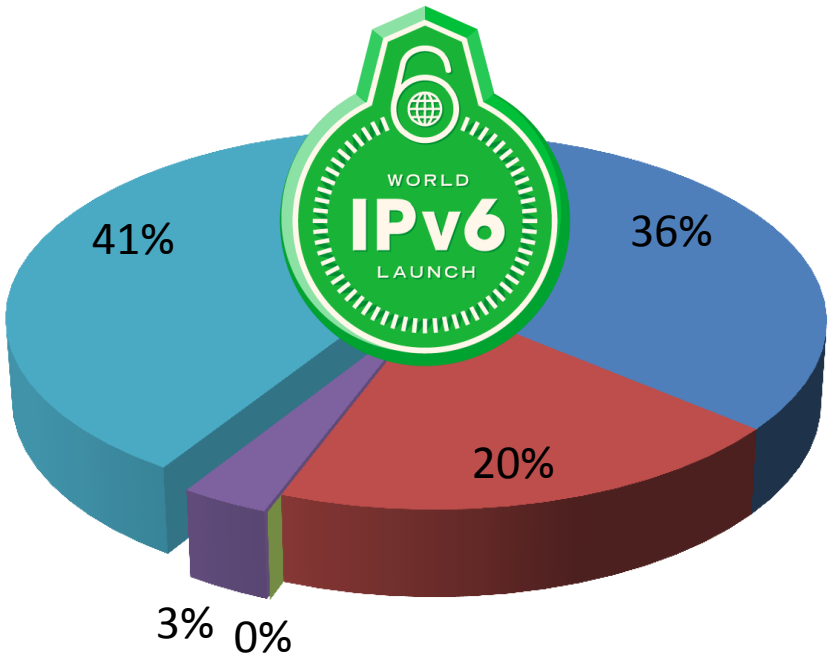
Sites Tested: 119



- Fully working (100% score)
- Mostly working (>85% score)
- Sorta working (84%-26% score)
- Reachable, but broken (<25% score)
- Unreachable (no AAAA or Timeout)

Test results – Do webpages work over IPv6-only?

Brazil (.br) World IPv6 Launch sites tested: 61



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FAIL

IT Conversors

FAIL WIN

Lessons Learned

- Need to start testing IPv6 websites and apps with IPv4 disabled
  - Dual-stack (especially with Happy Eyeballs) masks problems with your IPv6 connectivity
  - In the future, IPv6 SHOULD work, IPv4 MAY be NATted or otherwise broken (so don't rely on it)
- Monitor your IPv6 site just like you monitor your IPv4 site
  - Can't fix what you don't know is broken
  - An IPv6 outage should have the same urgency as an IPv4 outage – now affects >2.5% of your customers!
  - Again, single-stack IPv6 is better at exposing problems

Pushing more IPv6 deployment

- Name and Shame sites w/o external IPv6
  - Companies that consider themselves technology leaders
  - Content sites that feature articles about IPv6, but have no AAAA
- Vendor pressure
  - IPv4 costs money (CGN or buy addresses)
  - IPv4 is for **customers** (don't waste on internal stuff)
  - IPv6 from **ALL** vendors, not just technology vendors
  - RFPs, Contracts, etc: All products, support sites, etc MUST NOT require IPv4

Conclusion

- IPv4 and CGN costs money, stifles growth & innovation
  - Avoid/reduce by aggressively deploying IPv6
  - The more native IPv6, the less CGN capacity required to handle growth
  - Content should apply pressure to service providers
  - Service providers should apply pressure to content
  - Both should apply pressure to equipment vendors
- Plan for IPv6-only now
  - Provides maximum flexibility for remaining IPv4 space
  - Communicate to vendors early to give them time to find and fix problems