

“apocalypse then”: ipv4 address space depletion

cooperative association for internet data analysis

problem statement

environmental problem: running out of addresses!

solution started in 90s, but uptake slower than “expected”

important connection:

the research community has same problem.

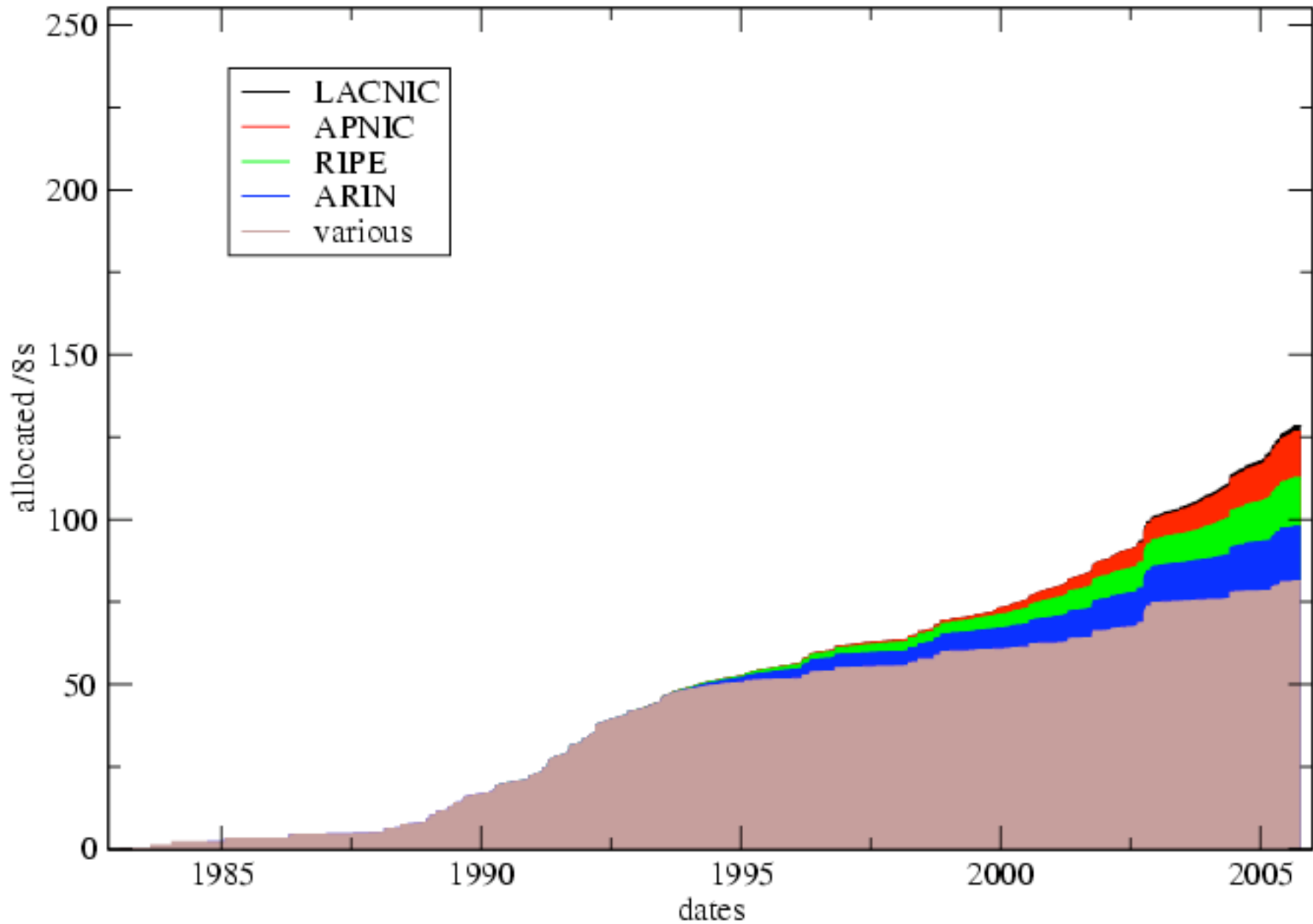
underlying question:

how do we innovate architecturally?

deeper question: how do we leave the Internet better than we found it?

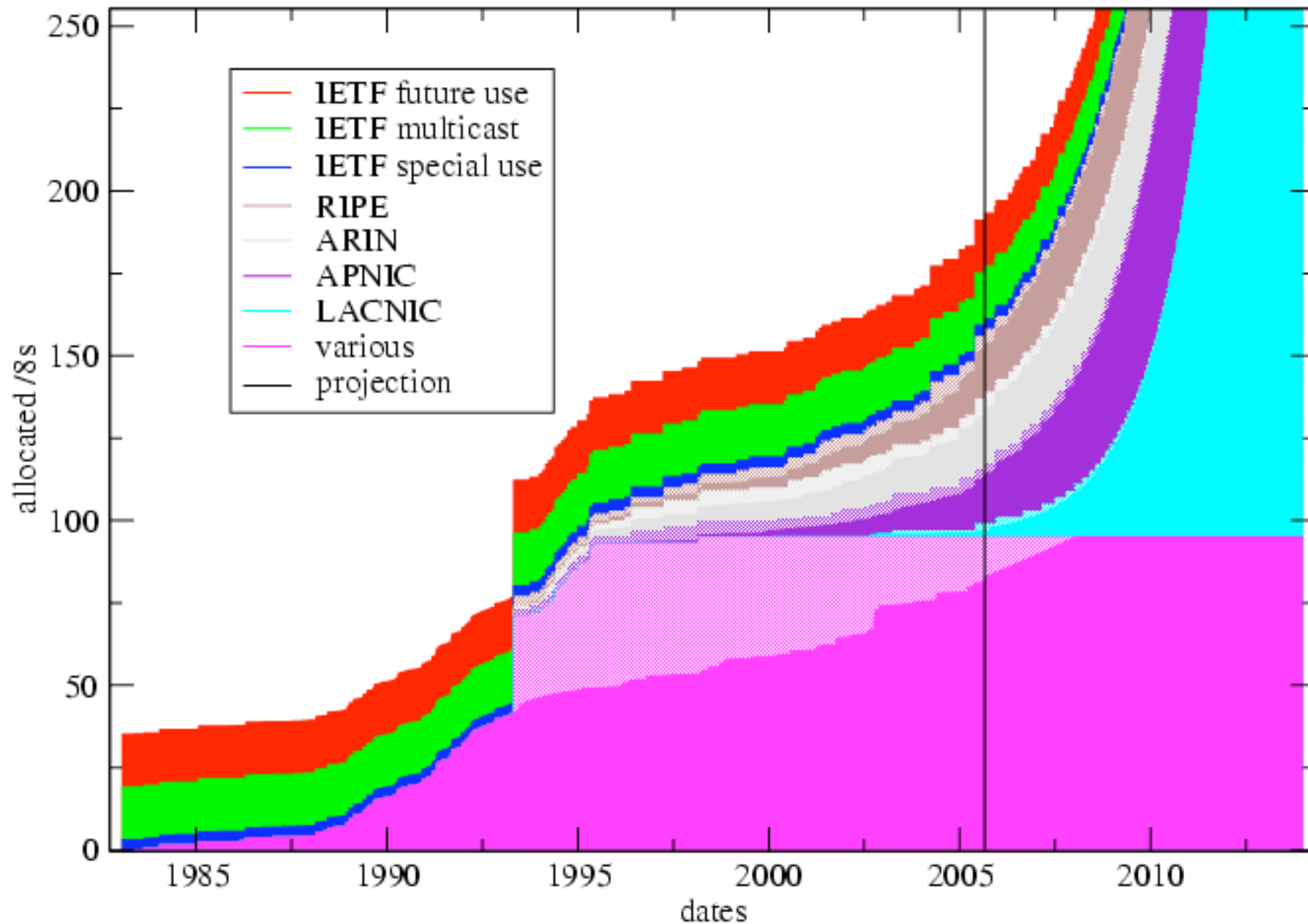
IPv4 allocated /8s (first)

RIR whois dumps and IANA table of top-level /8 allocations



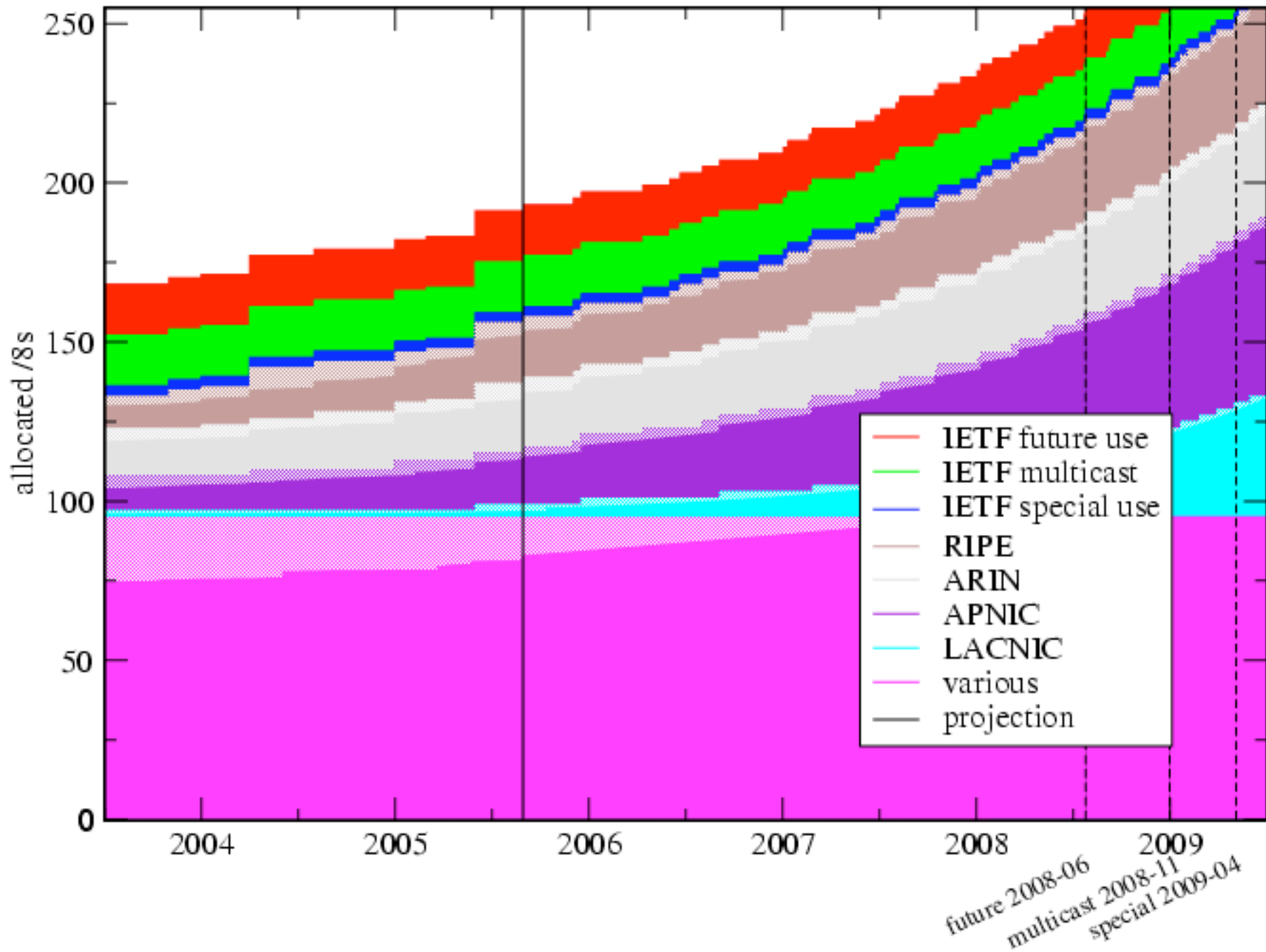
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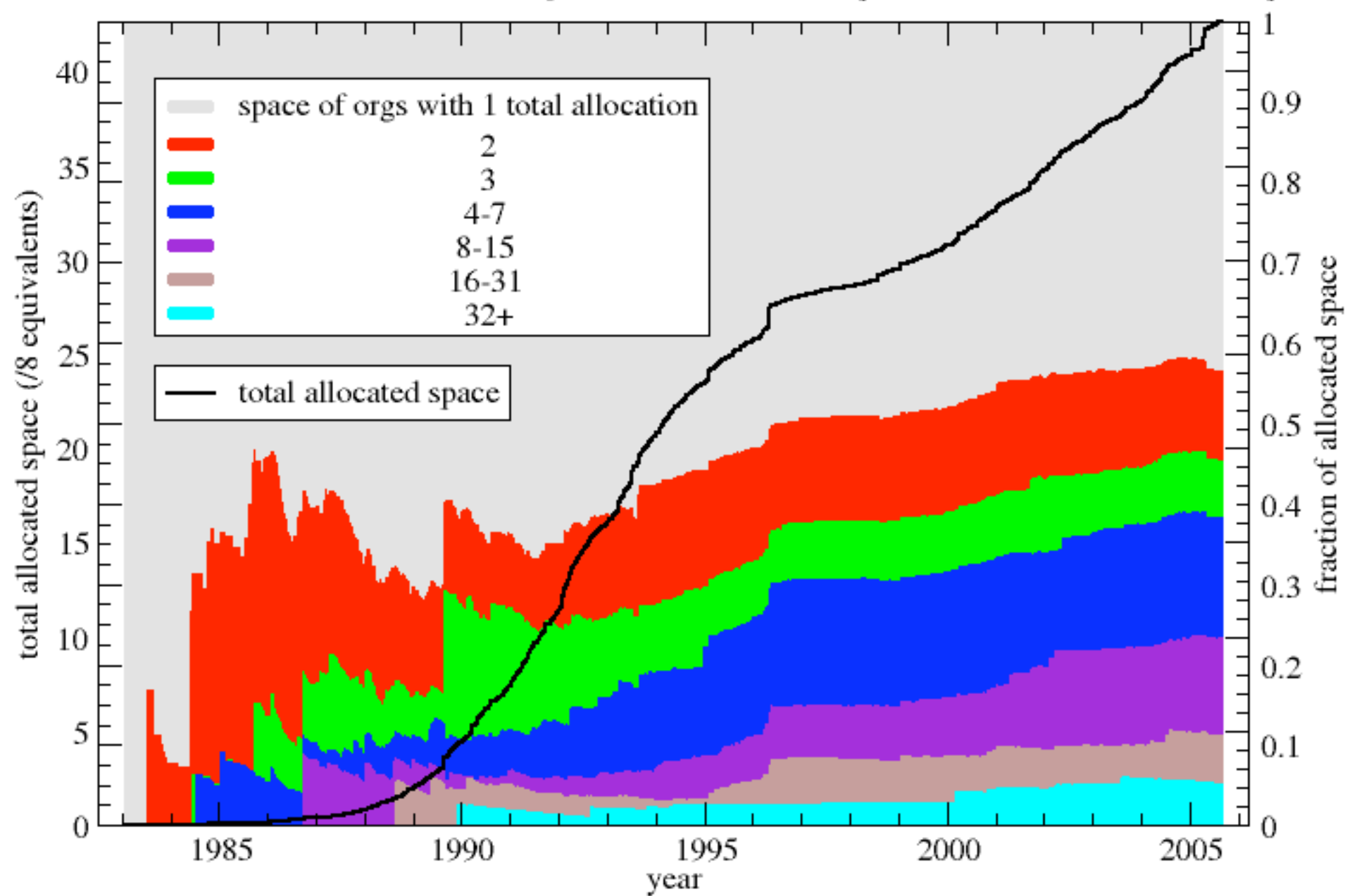
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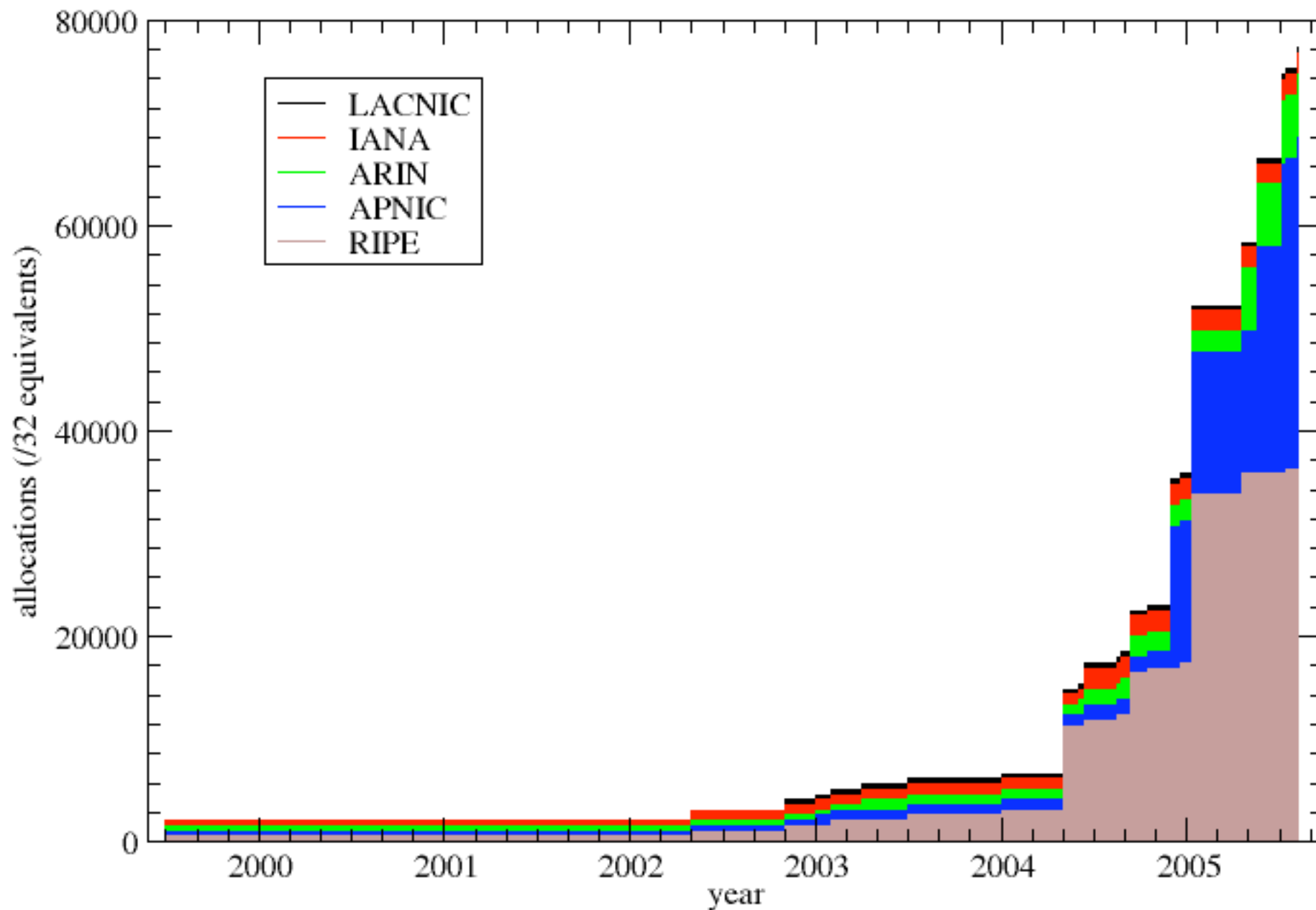
Breakdown by Num Allocations per Organization of ARIN IPv4 Space

ARIN whois data (20050831); excluding DoDNIC, JPNIC, and pre-RIR /8 allocations; stacked plot



IANA IPv6 Global Unicast Allocations to RIRs (stacked)

IANA data (20050808), no whois; excluding 6Bone and 6to4 blocks



the news gets worse.

this isn't even the data we need
to inform a discussion about IPv6 uptake.

what [predicting] the future needs

the numbers that will drive
our future have different
units

innovation
requires
capital.

| INNOVATOR | EPS (\$) | MKT CAP (\$B) |
|------------|----------|---------------|
| MCIW | -11.22 | 6.5 |
| SPRNT/NXTL | -0.31 | 34 |
| VERIO/NTT | 1.98 | 71.6 |
| LEVEL3 | -0.74 | 1.9 |
| SBC/T | 1.41 | 78 |
| QWEST | -0.45 | 7.7 |
| COGENT | -7.42 | 0.2 |
| GLBC | -13.84 | 0.3 |
| SAVVIS | -0.90 | 0.12 |
| ABOVENET | n/a | n/a |
| WILTEL | n/a | n/a |
| TELEGLOBE | -0.74 | 0.2 |
| C&W | 0.70 | 4.7B |
| TWTELCOM | -1.12 | 1.0 |
| (TWARNER) | 0.48 | 82 |
| XO | -2.18 | 0.4 |

source: finance.yahoo.com, 25 oct 2005

where is the capital for innovation?

ironically, it's from where
the innovation is
happening.

we're trying to make the
future safe for innovation,
but we have to innovate
to do so.

| INNOVATOR | EPS (\$) | MKT CAP (\$B) |
|-----------|----------|---------------|
| CISCO | 0.87 | 108 |
| GOOGLE | 3.41 | 97 |
| AMAZON | 1.25 | 19 |
| YAHOO | 1.07 | 49 |
| EBAY | 0.73 | 51 |
| JUNIPER | 0.53 | 13 |
| APPLE | 1.56 | 47. |
| INTEL | 1.33 | 141 |
| VERISIGN | 0.93 | 6.15 |
| DELL | 1.27 | 76.3 |
| MICROSOFT | 1.12 | 269B |

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capital distribution problem

(the ones who need to innovate in the core don't have capital)

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how are we at innovating anyway?

failures:

atm
multicast
qos
rsvp
diffserv
s*bgp
dnssec

what's in common:
competing in middle

successes:

email
http
browser
blogs
bittorrent
search engines
voip

what's in common:
cooperating at edge

IPv6 (in US) blocked on two things

(1) capital

applications, hardware, stable router OS, ops training, users

(2) incentive

“it would have to stop a fatal threat to my business” (cidr,y2k)

“it would have to support things i want to do now but can't”

“it would have to be free”

“it would have to be fun”

(source: nanog voices)

*not only did we forget to include (a source of capital for) a 'bell labs',
we killed the last one the communications industry had. oops.*

choices

- confront how to structure a market in IPv4 addresses (we gave up once)
- confront how to govern a transition to IPv6
- govern reclamation/use of IPv4 addresses
- ask IETF to 'go back and try again'
- ask research community to save us

who pays for any of those? what do they cost?

reclamation 'potential'

(ISI.edu pung entire IPv4 address space in 2003)

2003-06-01

20.2% of prefixes did not respond to probe

3.2 /8 equivalents (4.4% of total routed) could be returned

2003-10-08

18.9% of prefixes did not respond to probe

2.9 /8 equivalents (3.9% of total routed) could be returned

2003-06-01

4,764,826 /24 equivalents in the routing table

74.5% of /24s did not respond to probe

54.2 /8 equivalents (74.5% of total routed) could be returned

2003-10-08

4,872,851 /24 equivalents in the routing table

75.1% of /24s did not respond to probe

55.8 /8 equivalents (75.1% of total routed) could be returned

*sources: isi.edu via
predict.org (ping);
routeviews (BGP)*

historical justification notwithstanding,
policymakers may conclude we haven't nailed stewardship.

historical context

1966: Larry Roberts, “Towards a Cooperative Network of Time-Shared Computers” (first ARPANET plan)

(we are still using the same stuff)

1969: ARPANET commissioned by DoD for research

1977: Kleinrock’s paper “Hierarchical Routing for large networks; performance evaluation and optimization”

(we are still using the same stuff)

1980: ARPANET grinds to complete halt due to (statusmsg) virus

1986: NSFNET backbone, 56Kbps. NSF-funded regionals.

IETF, IRTF. MX records (NAT for mail)

1991: CIX, NSFNET upgrades to T3, allows .com. web. PGP.

1995: under pressure from USG, NSF transitions backbone to competitive market. no consideration of economics or security. kc proposes caida.org

2005: *The Economist’s* cover story: “How the Internet killed the phone business” (September)

what have we done?

we replaced a critical infrastructure with something not designed to be critical infrastructure

historical context explains it but does not address incongruities

and this decade, free markets go up against free speech

“according to best available data”

what do we do in provisioning crises?
and how successful have we been?

- backbone provisioning: free market
- DNS: free market
- address space: _____?

how have free markets been to infrastructure?

- backbone provisioning: profits toward (& below) zero, consolidation toward monopoly, no security, no innovation.

“The design was immediately and grievously flawed for not only was there no plan for the privatization and no criteria by which to measure its success or failure. Furthermore it held unacknowledged economic implications for what was being privatized was the only part of the network that had no customers.” --Gordon Cook, 1992

- DNS: profits toward zero, consolidation, no security, unfinished internationalization. some innovation (“sitefinder”)

“Turning hegemony into democracy by peaceful means has been done only a few time in human history, and the outlook for this time isn t good. --Paul Vixie, 2005, fm.vix.com

- address space: _____?

learning from mistakes

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- most important thing we've learn so far: society is using IP like water.

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learning from mistakes

- most important thing we've learn so far: society is using IP like water.
- market realities require selling wine.
- when you want to move water, you care about 4 things: safe, scalable, sustainable, stewardship.

how have we done?

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- how safe is the Internet? data doesn't look good.

how have we done?

- how safe is the Internet? data doesn't look good.

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- how safe is the Internet? data doesn't look good.
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- how sustainable is the Internet? data doesn't look good.

how have we done?

- how safe is the Internet? data doesn't look good.
- how scalable is the Internet? data doesn't look good.
- how sustainable is the Internet? data doesn't look good.
- how did we do on stewardship? data doesn't look good.

there is good news

- we made something so great, everyone wants it.
- in fact many of us want it more than once! (um..)
- the current industry is a historical artifact of technical and (science & regulatory) policy 'innovations' in the 60s, 70s, 80s, 90s, and 00s
- in the meantime, it became global critical infrastructure.
oops.

who pays for critical infrastructure?

- how is the Internet different from other critical infrastructure? (hint: who protects public interest?)
- what will give? how long will it take?
- according to history: capital will be allocated to architectural innovation

(rural electrification: 48 years, finally using cooperatively owned companies and federal funding act)

what worries me most

- that we won't learn from our own mistakes
- that we will design another architecture with no actual plan for economic sustainability (much less incenting further innovation in a competitive market!)
- that other forces will “code” innovation into the architecture

reality

this isn't a data analysis problem.
it's a **scenario planning** problem.

scenario planning

Peter Schwartz, The Art of the Long View

- of course we should try to change the future: it's the only thing we can change.
- goal: not an accurate picture of tomorrow, but rather making better decisions about the future
- what are long term forces and how do they interact? how are they measured? who is measuring? what tradeoffs do they imply?
- are we leaving a better future than we found? or at least as good?
- are we net gaining or net losing freedom?

network scenario planning

need to bring economists, technologists, policymakers, researchers together to talk about the long view of progress on

- ubiquitous, low-cost, open, secure infrastructure
- modern emergency communications services
- diagnosis and configuration technologies
- economic analysis and regulatory policy

measurement accuracy is the only fail-safe means of distinguishing what is true from what one imagines, and even of defining what true means.

..this simple idea captures the essence of the physicist's mind and explains why they are always so obsessed with mathematics and numbers: through precision, one exposes falsehood.

a subtle but inevitable consequence of this attitude is that truth and measurement technology are inextricably linked.

-- robert b laughlin, a different universe,