the Internet as emerging critical infrastructure: what needs to be measured?

cooperative association for internet data analysis

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(http://www.nitrd.gov/subcommittee/lsn/jet/)
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outline of talk

what is critical infrastructure

top problems of Internet

historical context (incongruity)

what have we learned and how can we apply it?

[case study: scalability (separate talk)]

what we (all) can do to help

critical infrastructure

what is it? how does it get that way?

what are common characteristics?

is the Internet one? or will it be soon?

what are the implications for public and private sectors?

underlying goals: innovation, economic strength, democracy, freedom, health, science, arts, society.

it really is about living in a better world...

16 operational internet problems

- security
- authentication
- spam
- scalable configuration management
- robust scalability of routing system
- compromise of e2e principle
- dumb network
- measurement
- patch management
- “normal accidents”
- growth trends in traffic and user expectations
- time management and prioritization of tasks
- stewardship vs governance
- intellectual property and digital rights
- interdomain qos/emergency services
- inter-provider vendor/business coordination

persistently unsolved problems for 10+ years

(see presentations at www.caida.org)

why we're not making progress

- top unsolved problems in internet operations and engineering are rooted in **economics, ownership, and trust (EOT).**
- even the most theoretical computer scientists are convinced.

does not mean there aren't useful technical problems to study. but there will be no technical solutions to these problems that don't solve the EOT issues.

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

what have we learned?

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

- strong implications for an industry structuring itself to sell wine. but that's what the data shows.

- when you want to move water, you care about 4 things: safe, scalable, sustainable, stewardship.

the 4 S's

- safety: is the data toxic upon arrival?
- scalable: can we route/name/address earth's needs?
- sustainable: is it economically viable?
- stewardship: will the provisioning and legal frameworks we choose leave our children -- and democracies -- better or worse off?

none of these are purely technical issues,
but they all require deep technical (among other) understanding to get right.
and they're all connected.

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

failure (to measure progress) on 4S's poses risks to economics and democracies:

- that we won't learn from our own history. e.g.,not only don't we understand the economics, but we don't understand that we don't understand the economics, and thus must set policy based on unvalidated assumptions
- 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 (free markets vs free speech)

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
- people are starting to study interplay, but they're undercapitalized
- in the meantime, it became global critical infrastructure. oops.

“science of the Internet”

The wonderful thing about science is that eventually nature tells you when you are fooling yourself. real objects can be measured again and measured by somebody else -- false signals will eventually be weeded out.

Robert Kirshner, The Extravagant Universe

but if what you need to measure is economics..

Knowing what to measure and how to measure it makes a complicated world less so. if you learn how to look at data the right way, you can explain riddles that otherwise might have seemed impossible.

Steven Levitt, Freakonomics

understanding and enlightened evolution of the Internet

(1) sound measurement and analysis methodologies were, are, and will always be the key to enlightened policy.

(2) the free market has failed thus far to achieve these goals on its own.

(end of part 1 of talk)

(part 2)

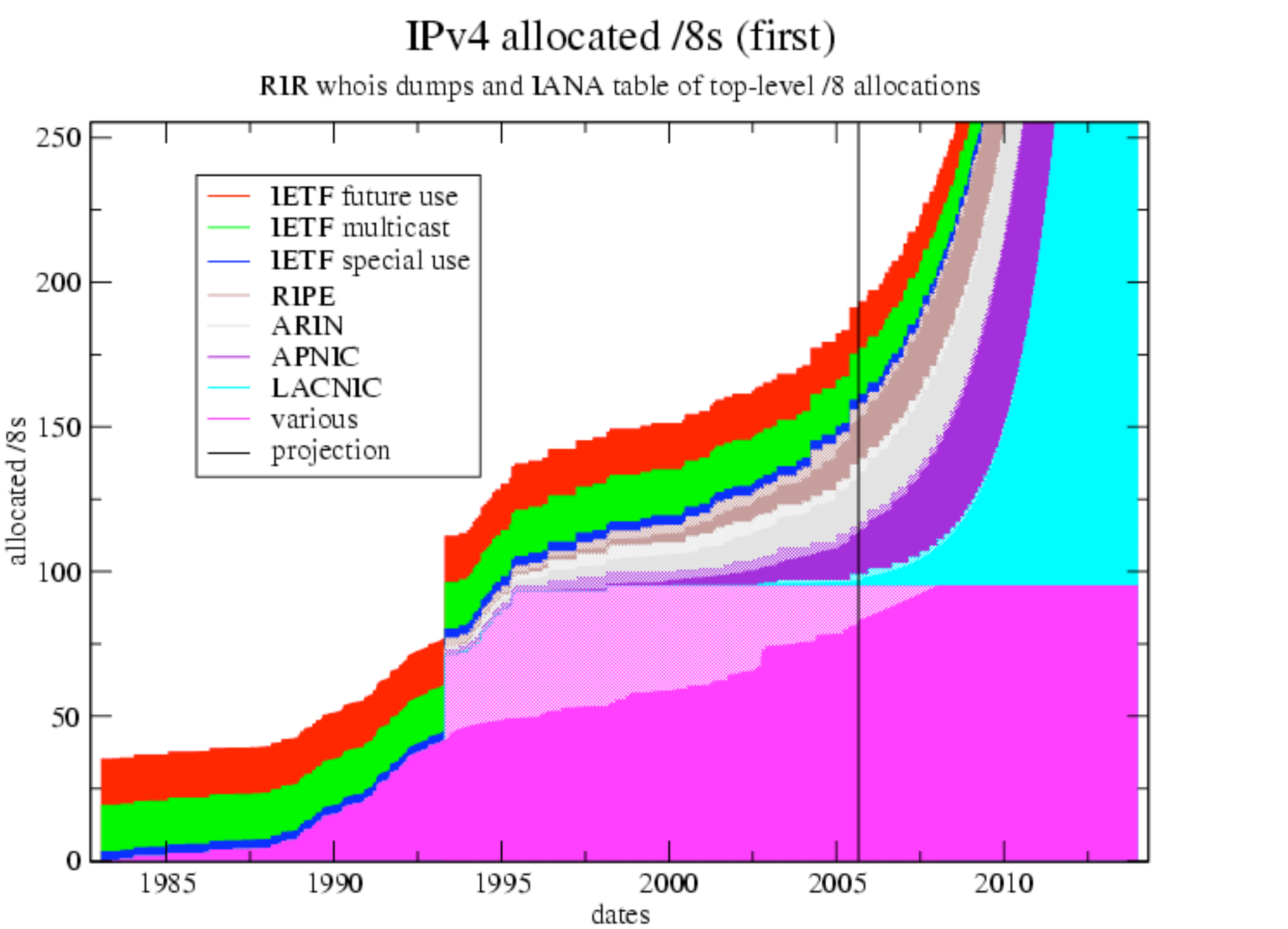
case study: scalability

environmental problem: running out of addresses!

solution started in 90s, but uptake slower than "expected".

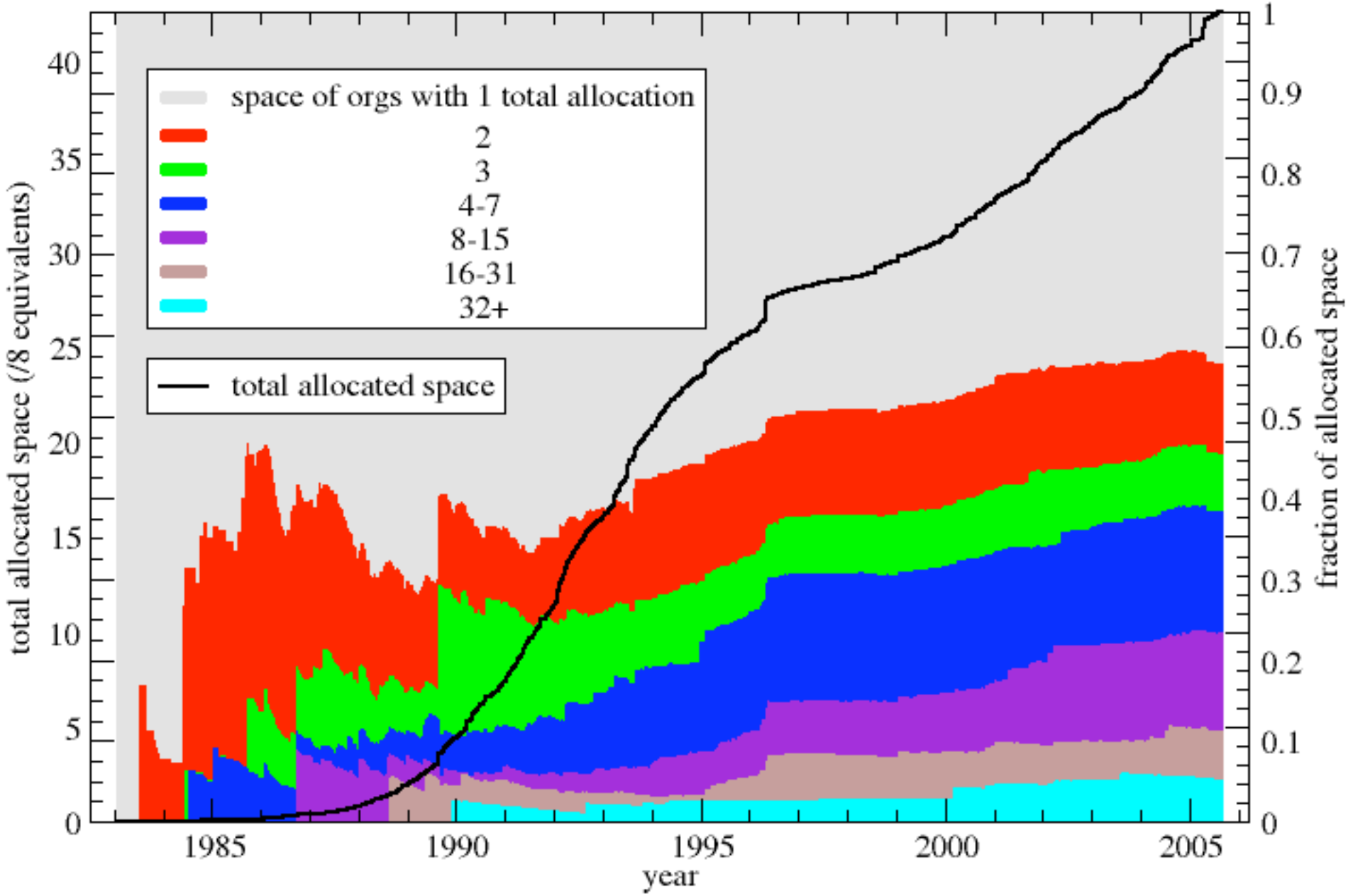
important connections:
(1) [this instance of] scalability requires innovation
(2) the research community has same problem

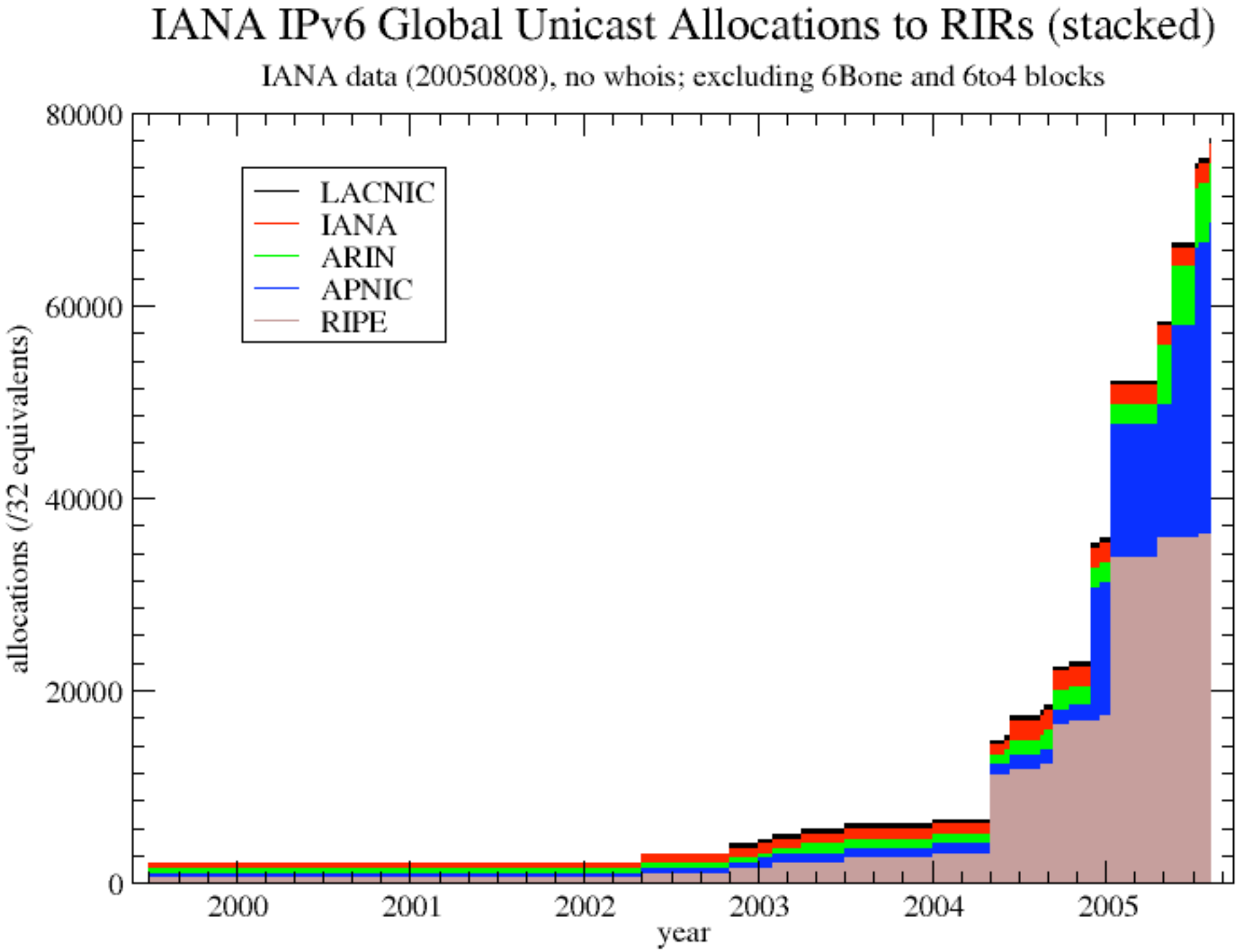
underlying question:
how do we innovate architecturally?
deeper question: how do we leave the Internet better than we found it?


IPv4 allocated /8s (first)
RIR whois dumps and IANA table of top-level /8 allocations
IETF future use
IETF multicast
IETF special use
RIPE
ARIN
APNIC
LACNIC
various
projection
allocated /8s
250
200
150
100
50
0
1985
1990
1995
2000
2005
2010
dates

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
LACNIC
IANA
ARIN
APNIC
RIPE
allocations (/32 equivalents)
80000
60000
40000
20000
0
2000
2001
2002
2003
2004
2005
year

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

source: finance.yahoo.com, 25 oct 2005

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:	successes:
atm multicast qos rsvp diffserv s*bgp dnssec	email http browser blogs bittorrent search engines voip
what's in common: competing in middle	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.

the 4 S's and addressing crisis

- safety: no perceived increase
- scalable: current hacks offer local optima
- sustainable: IPv6 economically viable
- stewardship: how to get unused addresses back?

none of these are purely technical issues,
but they all require deep technical (among other)
understanding to get right.
and they're all connected.

other provisioning crises

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: _____?

reminder: there is good news

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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)

network scenario planning

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

parting thought

the Internet we want to leave our children will require:

- interdisciplinary focus
- long-term view

both are new to this young field, and
vehicles for progress are few.

NSF's GENI has potential if it can fund rigorous interdisciplinary work.

good time for interagency cooperation