SimLIR &
Beyond the Yellow Brick Road

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Background

- This talk attempts to answer three questions:
  - Is it possible to meaningfully defer the IPv4 exhaustion point?
  - What will the immediate consequences of exhaustion be?
  - What might post-exhaustion look like, to the community and to the RIRs?

Background

- Why are we talking about this at all?
  - Geoff Huston's seminal work (http://ipv4.potaroo.net).
    - Shows conclusion of current trends; a top-down curve-fitting approach.
    - I wanted to play "what-if"; a bottom-up behaviour modelling approach.
    - Not too concerned about matching dates yet; want to model and compare behaviour.

Simulation

- SimLIR models full LIR → RIR → IANA hierarchy.
  - Currently we map LIR to country.
- Roughly 6000 lines of Python.
  - To be open-sourced at Google Code page, as soon as we clean up the code and trademark searches.
- Uses the same RIR data as Geoff's work.
- Design allows to change "policies" and observe effects on consumption.

Simulation

- Discrete event simulation.
- Crudely model BGP de-aggregation factors.
- Map micro-world to macro-world comparatively, after approximate calibration.
- Various unrealistic assumptions generally hold for simulation: e.g. when an RIR runs out, the LIRs just stop.
  - Please get the software and fix it (when it’s released).
- Provisional results - take with pinch of salt!

Results

- Static /15 per month - not terribly realistic.
  - IANA exhausts 2008-01, RIRs 2008-03.
- Replay last year model - more realistic.
  - IANA exhausts 2009-05, RIRs 2010-04.
- Shrink new LIR allocation.
  - Puts back date by < 1 week.
- Gold rush.
  - Brings forward date by ~4 months.

Other Ideas?

- Within the context of our current policy process,
  - They all boil down to giving out fewer addresses to everyone.
- I argue that this brings on the problem sooner.
  - Depends on your definition of “the problem”.
- It doesn’t seem that simple policy tweaks within our ambit are useful.
  - Hardly enough time to enact, never mind measure effect.

Other Ideas?

- Go hunting for verifiably allocatable space!
  - This is not a simple solution.
  - For a start, it is unlikely to result in enough material to satisfy the run rate in time.
- Let’s all move to IPv6 instantaneously!
  - This is not a practical solution.
- This is a hard problem.

I’ve finally decided my future lies
Beyond the Yellow Brick Road
-Elton John,
Goodbye Yellow Brick Road

Beyond the Yellow Brick Road

Niall Murphy, Dave Wilson

What's immediate exhaustion look like?

- Existing businesses solely predicated on additional public IPv4 addresses fail.
  - SSL website hosting, IPsec VPN end-points, ...
  - There are work-arounds. Will they be ready and deployed in time?
- Existing operations scramble to make new processes, buy new equipment, train staff, etc, before and after.
  - Expensive, and not yet well-understood.
  - Likely to lead to turmoil.

What's immediate exhaustion look like?

- Increased costs for existing operators applies to both transitioning to IPv6 *and* staying with IPv4.
- More importantly, new entrants have a *very* high barrier to entry.
  - You need an IPv4 DFZ entry to play.
  - Quality of service difficult to ensure when hosting in someone elses' network.
  - Extending PA from one single upstream unsatisfactory.
  - Competition authorities and regulators unhappy.

What's immediate exhaustion look like?

- Measuring distinct clients through multiple NAT/proxies becomes harder.
  - Quality of whois information goes down.
  - DDoS becomes harder to track and prevent.
    - Unhappy network operators, unhappy law enforcement.
  - Overall connection quality across the Internet goes down as a function of growth behind gateways.

What's immediate exhaustion look like?

- Decision makers don't realise implications yet.
  - We've been given false confidence by the ease of solving the client problem (NAT-PT).
  - Server problem, and routability significantly harder.
- RIR billing model under pressure.
  - RIR services, in particular whois, under pressure.
  - Unhappy network operators, unhappy law enforcement.

What's immediate exhaustion look like?

- In the absence of a vision, financial support or other motivating factor to the contrary, we can expect the following:
  - Greatly increased use of NAT on the client end.
    - Previously publicly numbered resources in e.g. dialup move to hosting or other higher-value products.
    - Some IPv6 deployment.
  - Desperate new entrants and/or existing businesses pay money to treat PA space of upstream as PI.

What's immediate exhaustion look like?

- Increased attention from government/quasi-governmental agencies of many kinds, including but not limited to:
  - Competition authorities, regulators, law enforcement, industry representative bodies, the media, ITU, ...
- Increased churn in the routing table as we de-aggregate and hijack prefixes in an uncoordinated and haphazard manner.
  - Back door deals will proliferate, but we'll be too busy to be ship-shape.

What's immediate exhaustion look like?

- Increased turmoil will probably (in our interconnected world) affect:
  - Stock prices
  - General Internet growth prospects
  - Volatility of business deals, particularly new entrant ones

What’s immediate exhaustion look like?

- Not pretty.
- What’s the scale of the problem?
  - Proportional to growth.
- To me, it looks as if we should do something about it.

Characterise the problem(s)

- The above is a list of symptoms.
- The problems are:
  - We are dependent on the system as-is.
  - We haven’t really wanted to change that fact.
    - It’s expensive, time-consuming, will take a lot of effort, and doesn’t get us new features.

Characterise a solution

- We will still need unique and un-used IPv4 addresses after the time of exhaustion.
- There'll be a lot of other changes going on; it would be maximally convenient if the interface to getting these addresses looked like an RIR.
- Ideally we don't spend time on open-ended efforts that may or may not work before the deadline. We need something we can do relatively quickly, and refine quickly.

Solution assumptions and vision

- The end-game cannot be an Internet confined in perpetuity to IPv4 alone.
  - We may be able to technically do it, but it has all the disadvantages already pointed out.
- We know we like the old world of address plenty more than the new world of scarcity.

Solution assumptions and vision

- The end-game is an IPv6 Internet, or enough of one to keep off address scarcity for a workable subset.
- Stated this way, the problem is the transition - the gap between the end of the old way and the start of the new way.
- We can make the gap shorter, or make it less painful.
  - Shorter: start IPv6 operations; get top 20 websites on native IPv6; actually do transition work.
  - Less painful: help IPv4 dependency; somehow get addresses to them.

Solution assumptions and vision

- Things that won’t make the gap shorter or less painful.
  - Hijacking prefixes.
  - A voluntary release service probably won’t service the run-rate, and certainly won’t be predictable. (Any grey market may well eliminate this possibility.)
  - Making IPv4 addresses arbitrarily difficult to get towards exhaustion point just brings on the effects of scarcity sooner.

Solution assumptions and vision

- Let’s express this in terms of groupings.
- We have a group that needs money to do the right thing. They essentially get money by means of IPv4 addresses.
- We have another group that has IPv4 addresses, but no real incentive to free up that space.
- We don’t want to endlessly recycle prefixes; we want to provide a leg up.
- We need address liquidity.

Solution theorising

- There’s no way to continue the old system.
- Turn the question around - if centralisation doesn’t work, what about decentralisation?
  - The effort/reward ratio that makes it not worth the RIRs time to reclaim serious amounts of space is not as bad for individual organisations.
  - We need to make it worth their while to increase liquidity.
    - This probably means money.

Solution Proposal

- We need an address space trading exchange.
  - Organisations with mutually corresponding needs can meet and help each other.
  - We give IPv4-requiring organisations a limited drip-feed while the industry scrambles to build out infrastructure.
    - Note: “IPv4-requiring organisations” is currently ~100% of the Internet.
      - (Do we expect this number to be greatly reduced at time of exhaustion onset?)

Solution Proposal

- How would such an exchange work?
  - More concerned with systemic incentives than what the website will be called.
  - The model is to attempt to manage scarcity while we find some greener grass. Therefore not proposing this as long-term solution; it supports search for greener grass, not renders it unnecessary.
  - Let’s run through some basic parameters of operation, given what we know of organisational behaviour and basic economics.

Exchange Properties

- We would like to maintain as many properties of the old system as possible.
  - Stability
  - Fairness
  - Neutrality
  - Transparency etc
  - Whois remains maintained
  - Aggregation

Exchange Properties

- Keeping those in mind, who should run the exchange?
  - Neutral organisation, good existing service contracts.
  - Should prevent onward sale/transfer to a different organisation with “different values”.
  - Community input with transparency.
  - In a position to co-ordinate and take the reins quickly, with a good understanding of the issues.
  - For various reasons (to be discussed) a membership structure is good.

Exchange Properties

- Funny co-incidence: this looks quite like our favourite RIR.
- We *could* set up another industry association, but the latency and risk are increased thereby.
- We *could* just outsource it to eBay, but we have no idea what's going to happen, and we'd like it in closer control.
- Good engineering discipline: when you're doing something inherently risky, keep the other factors the same.
- The psychology of continuity.

Exchange Properties

- Let's talk about market design theory.
  - Relatively new field of economics; see Al Roth (Harvard), Muriel Niederle (Stanford).
  - Thickness
  - Avoid congestion
  - Safety
  - Avoid repugnance
- The market has to be more appealing than back-door deals. (Remember iTunes Music Store.)

Exchange Properties

- Thickness.
  - We need to be able to attract enough participants to the market.
  - How do we attract buyers?
    - This won’t be a problem.
  - How do we attract sellers?
    - Unclear that we can do better than the monetary reward for selling (from a strictly economically-rational point of view.)

Exchange Properties

- Avoid congestion.
  - We need to attract participants, but not too many, otherwise the choice might become overwhelming.
  - A membership-limited participation seems sensible in the short-term.
  - Somewhat, but not *very* worried by excessive liquidity.
  - Furthermore, product is highly homogenous.

Exchange Properties

- Safety.
  - Market participants have to be assured that their partaking will result in successful transactions.
  - No backing out, no fraud, ...
  - RIR can provide certification and run exchange with community protection in mind.

Exchange Properties

- Let’s talk about pricing.
  - (No-one yet knows how this is going to work out.)
  - Data to support pricing calculations: average revenue earned per address, operational costs averaged over all addresses held, costs of transition, ...
  - RIRs should not set starting prices because they don’t have the data to do it.
    - Think regulation if nothing else.

Exchange Properties

- What will be sold?
  - One obvious candidate is the right to use a prefix.
  - RIR contracts are useful here, since they establish clear title.
  - Want to avoid land registry scenario, where all history of prefix must be checked.
    - RIR intermediation model helps.
  - From a “product” point of view, we can’t only sell prefixes of one particular size.

Exchange Properties

- Things we want to avoid.
  - Speculation.
  - Monopolisation/Hoarding.
  - Cartels.
  - Price fixing, etc.
  - Prices too high, prices too low.
  - Regional disadvantage.

Exchange Properties

- Speculation - short-term dealing; no use expectation.
  - Limit participation to members. Maybe also limit purchases per day, but this can always be gamed.
  - Natural rate-limiting imposed by the periodic nature of route-filter generation.
    - You can certainly buy and sell quickly, but you can’t expect to use it with confidence until DB etc updates.

Exchange Properties

- Hoarding - medium/long-term; no use expectation..
  - Is bad for “us” because it reduces liquidity.
  - Is bad for hoarder because the long-term value of the asset (in theory) decreases.

Exchange Properties

- Cartels
  - Unclear whether enough organisations with enough spare address space to make a difference could actually agree on this...
  - Competition authorities probably already paying close attention.
- Price fixing
  - As above, plus setting a price is non-trivial.

Exchange Properties

- Price “too high”.
  - Bad: liquidity decreases. Small wallets might have less or no choice.
- How to control?
  - More sellers. Fewer buyers. Co-operating buyers.
- Price “too low”.
  - Good: Small wallets still play.
  - Bad: IPv6 deferred, therefore locking in to scarcity.
- Balance to be struck.

Exchange Modes

- Marketplace
  - Good - market sets price, RIR not culpable.
  - Bad - Product reasonably homogenous. Not much to differentiate sellers. Rate limiting harder.
- Auction House
  - Good - market sets price, probably over many auctions, RIR not culpable. Rate limiting easier.
  - Bad - could be frenzy initially (unless e.g. Dutch auction).

Exchange Properties

- RIR business model can benefit from exchange.
  - Per transaction costs, or other variables.
  - Membership to play.
  - RIR brings valuable things to table (as discussed).

Exchange Properties

- RIR structure is the best shot at providing stability/fairness/neutrality/etc.
  - In particular, the whois maintainance implications of exchange requires an organisation in a position to evaluate health of transaction.
- Sadly, aggregation is a big problem, except there is a significant routability bonus to shorter prefixes.
  - Some simulation work seems to imply additional effect of market not serious.
  - Need more work on this, by actual experts.

Open Questions

- How do we do this?
  - A lot of details remain to be teased out.
  - We need to agree on those details.
- Do we have the time to do this?
  - Depends on what prediction you believe today, but given the size of the task, speed would appear to be important.
- Can we construct emerging market such that we maintain aggregation?

Recommendations

- Continue working with simulation to understand parameters of the end. But don't obsess.
- We need to have a recommendation for *something* to do come the end. Need it quickly, at a high level, so we can authorise the detailed work later once we've subscribed to direction.
  - Need to engage with economists, global RIR folk, simulators, regulators, ...
- We need to actually *choose* an outcome. Then, when we end up in the soup, we can say we chose the flavour.

Thank you and questions

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- http://www.avernus.net/exhaustion/
  - These slides plus further papers to come
- http://code.google.com/p/simlir/