Size Does Matter!

From the Age of Closed-Loop to the Age of Open-Loop

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Premises

• The Internet has many flaws
  – Security
  – Predictability
  – Manageability
  – Etc.
• But it keeps growing at an unabated rate

And then some more…
So How Do We Control or Influence

- Something that already looked like this in 1999
- Grew to something like this by 2005, and keeps expanding!

Implications

- Whether we like it or not, the Internet has a "life" of its own and will continue expanding
  - It’s hard to redesign or upgrade a fast moving train
- Scale makes most hard problems harder
  - Optimization, control, prediction, etc.
- But scale also offers many opportunities
  - Not everything goes wrong everywhere at the same time

Directions

- So what should we do if we want to make the Internet more robust and more reliable?
  - Don’t try to control the uncontrollable
  - Devise solutions that exploit scale
- Solution space with two main components
  1. Diversity as a means to robustness
     - It’s been pretty successful in other settings (physical layer)
  2. Open-loop approaches
     - Proactive rather than reactive
More Concretely…

- Having diversity is one thing, making it accessible and knowing how to use it is another
  - Realizing this has both control path and data path implications, for instance:
    - **Control path**
      - Routing should seek to maximize the number of available paths
      - Possibly distributing traffic unevenly across them as a function of "quality" (akin Cisco’s EIGRP variance)
      - Some interesting challenges on both the algorithmic and scalability fronts
    - **Data path**
      - Systematic redundancy and packet replication function in end-hosts and possibly routers
      - Packets from the same flow should not be sent on the same path
      - Decisions on how to leverage diversity should be mostly an open-loop process

Some Attempts at Justifications (1)
**Generic Arguments**

- A growing body of solutions that effectively leverage the Internet’s diversity
  - Path switching
  - CDN and/or P2P overlays
- A resurgence of open-loop proposals
  - Oblivious routing
  - Diversity (multi-path) routing and coding
  - Multi-topology routing for standby backup paths
- With many approaches combining the two

Some Attempts at Justifications (2)
**“Pet” Projects**

- Improving throughput stability through path diversity and diversity coding
  - Exploring the trade-off of higher load versus increased success probability
- Algorithms for multipath maximization
  - Waste some bandwidth but provide as many backups as possible to everyone
  - Do it in a distributed way while preventing loops
- Leveraging multi-topology routing for joint performance and robustness optimization
  - Applicable to both intra and inter-domain routing
Implications for the Future Internet

• Hosts (or maybe access gateways) will
  – Encode all their data with some level of diversity coding (and obviously decode it…)
  – Distribute packet transmissions across multiple paths, when feasible, or ask the network to do it for them
  – Form groups of “trusted” peer relays to use as occasional backups
• Routers will
  – Compute multiple paths to each destination, including backups
  – Distribute packets across available paths
  – Be capable of “intelligent” packet replication

Implications for Future Internet Experimentation

• Experimental Internet platform should support
  – [control path] Deployment of routing protocol extensions (or new protocols) that enable computation and use of pre-computed backup routes
  – [data path] Large-scale exploration of the trade-off associated with packet replication (higher load vs higher resiliency)

  Basically, what happens when “everybody” does it…

Sources

• Internet growth statistics taken from
  – http://www.potaroo.net/tools/asns
  – http://www.isc.org
  – http://www.opte.org/maps/