On the Number of Distributed Measurement Points for Network Tomography

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Motivation

• Tomography in real life:
  - NIMI
  - MINC
  - Matrix.net
  - SPAND
  - and many others...

• Why does it work?
• When does it work?
Previous Work

- Heuristics for location of the beacon set [Jamin et al. Infocomm 2000]
- Marginal utility of beacons [Barford, Bestavros, Byers, Crovella IMW 2001]
- Tomography in multicast networks of arbitrary topology [Bu, Duffield, Presti, Towsley Sigmetrics 2002]
Definitions and assumptions

- Strategically located computers called **beacon set**
- Ping/traceroute used to discover network topology
- BGP-like routing
- **Goal**: measure link state of every (advertised) link in the network
Theory

Difficult to find minimum set of beacons in general

**Theorem** NP-hard to find minimum set of beacons on arbitrary network topology (reduction to set cover)
Theory

Even good approximations are hard

**Theorem** Hard to approximate optimum beacon set to factor of $\log n$ ( $n = \# \text{nodes}$ ).
Theory

Some networks require an impractically large number of beacons

Theorem There exist a network that requires n/3 beacons to recover the topology.
Practice

=> We could lose our ability to do tomography under chaotic network growth.

• However...

we know tomography works in the Internet today
Better model

- Focus only on nodes with alternative routing paths

Forks in the road: Higher arity nodes

Theorem: Higher arity nodes form a beacon set.
Higher Arity Nodes (HAN)

- Internet is *mostly* a tree => the number of HAN nodes is low
- In fact, it can be estimated from routing tables
- Somewhere around 10K
- Proposed cap at 32K [RFC draft, Savola 2003]
- Beacons set of about 10K within range of a commercial organization (e.g. Akamai, Google)
HANs on the RON

Said beacon set covers every fork in the network, induces a RON

=> enables all paths routing, via forwarding

⇒ A commercial organization could provide all paths routing using this RON (Sockeye, Internap, RouteScience)
Conclusions

- Tomography does not work in general.
- Works (mostly) in current internet, can be made exact using 10K nodes.
- It could stop working, if network growth were to be chaotic.
- Higher arity nodes form a beacon set.
- HANs form an all-paths routing RON via packet forwarding.