The Collateral Damage of Internet Censorship by DNS Injection

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Internet Censorship: Background

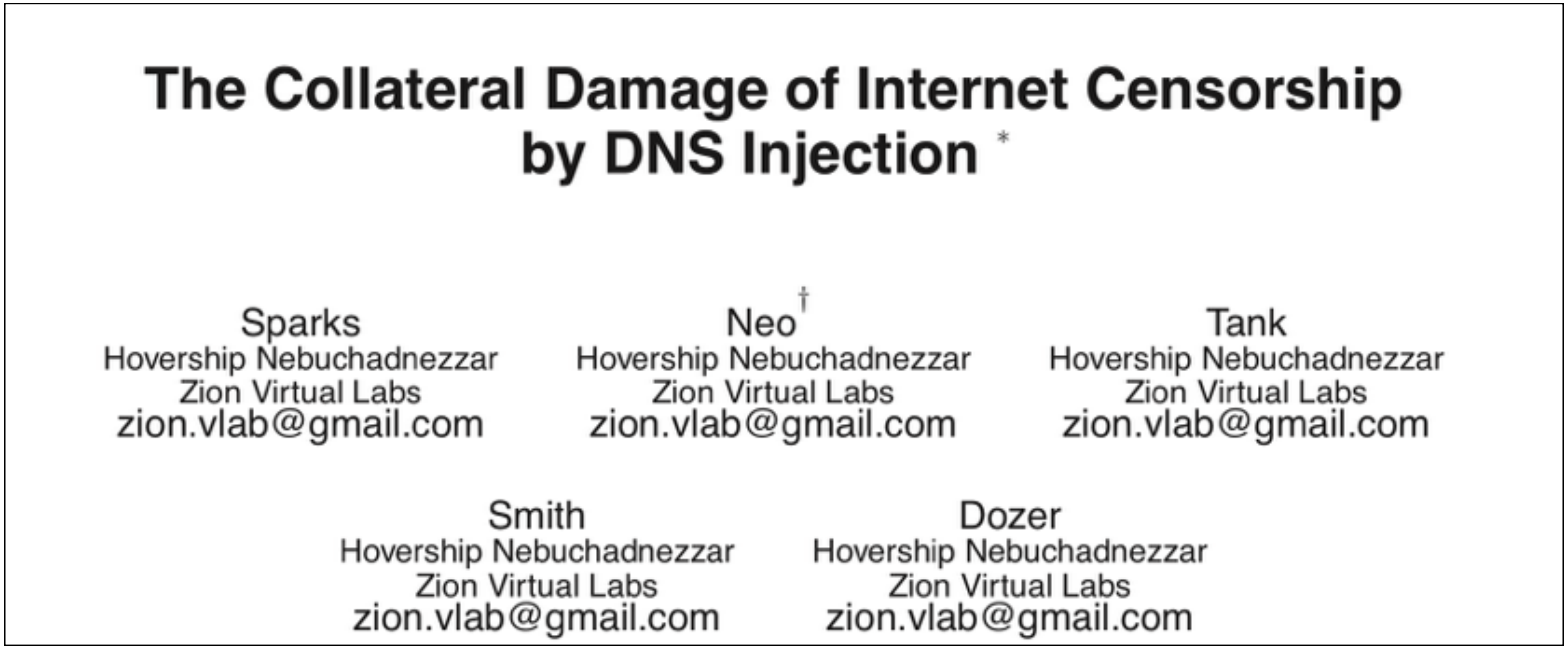
- Some nations' governments block their citizens' access to Internet content deemed politically sensitive or "indecent"

- Widely known example: Great Firewall of China (GFC)

  - Blocks access to sites such as **`twitter.com`**, **`facebook.com`**

  - Major implementation approach: prevent DNS queries for these domain names from returning correct IP addresses for sites

Today's Topic: Collateral Damage in Censorship



The Collateral Damage of Internet Censorship by DNS Injection [*]

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- GFC sends forged DNS responses with incorrect IP addresses to queries for domain names it wishes to censor

- Anonymous paper presented at SIGCOMM 2012 offered experimental finding: GFC causes collateral damage to Internet access by users outside China—it often censors content for Internet users outside China

Censorship Mechanism: DNS Injection

- Install injector on ISP’s link that sees all DNS query packets that traverse that link

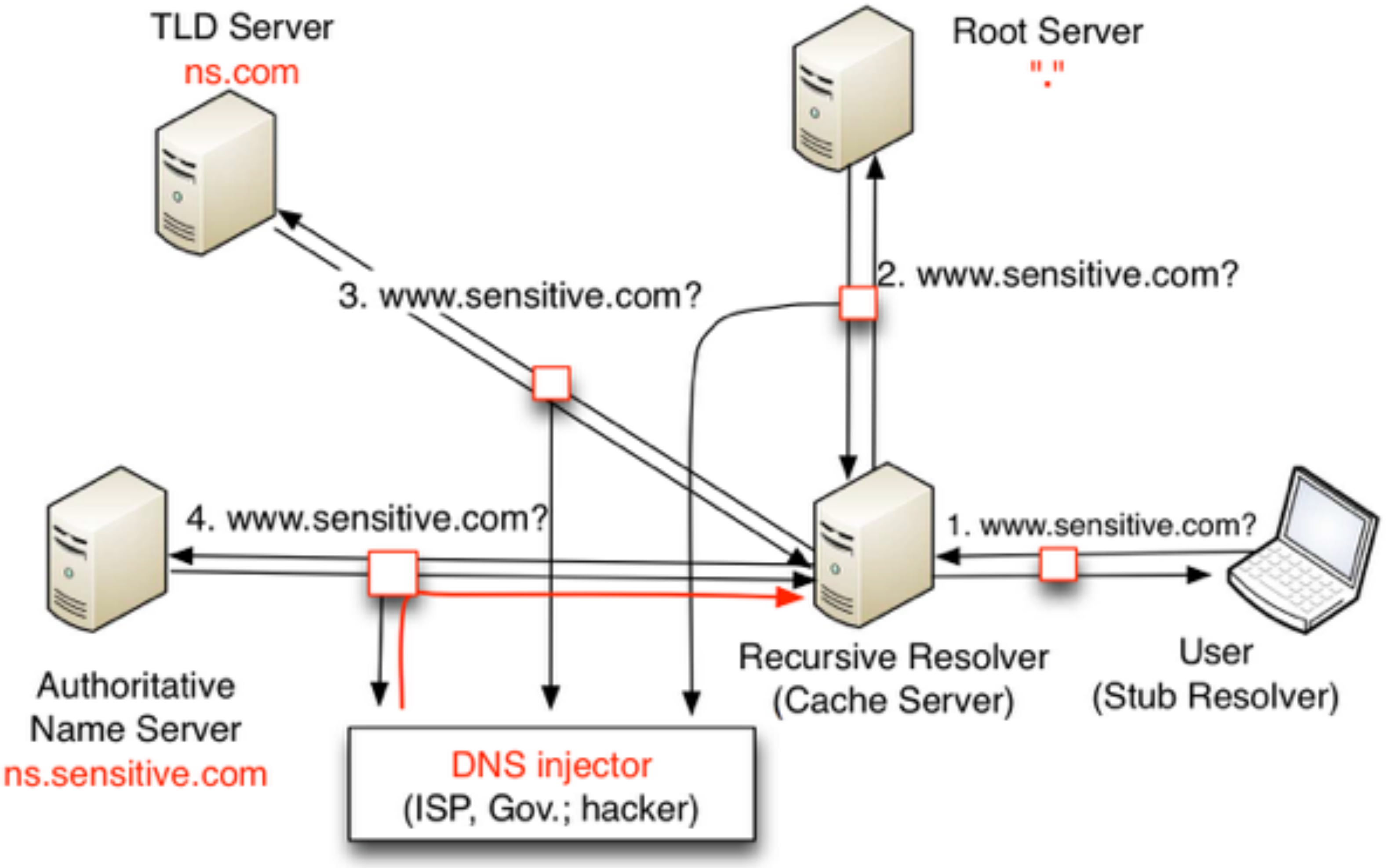
- Note that DNS queries always contain full domain name queried for, regardless of server to which query addressed

- Injector configured with domain names for which to block correct resolution

  - For these domain names, injector replies to query with incorrect (“lemon”) IP address

  - Injector doesn’t prevent DNS query from reaching real target DNS server; but injector’s reply reaches querier first

DNS Injection
Works at All Query Stages



- Queries to root, TLD server, authoritative server all liable to injection if Internet path incorporates DNS injector

Questions

- How does collateral damage occur?
- Which ISPs practice DNS injection?
- Which domain names and resolvers (resolver locations) are affected by collateral damage?

Causes of Collateral Damage

- Iterative queries create multiple opportunities for collateral damage:
  - Caching name server to root DNS server
  - Caching name server to TLD DNS server
  - Caching name server to authoritative DNS server
- Censored transit: DNS injector may target all DNS queries on link; caching name server's route to target server may transit censored AS!
- Redundant, anycasted DNS servers
  - 13 anycasted root servers, 13 anycasted global TLD servers
  - Path to any of these 26 IPs may pass through censored network

Experiment:
Finding Paths Affected by Injection

- Randomly select one IP address in each /24 of IP address space; verify doesn't respond to DNS queries

- Probe the resulting 14 million IP addresses with a DNS query for a likely censored DNS name (e.g., `facebook.com`, `twitter.com`, `youtube.com`, etc.)

- Launch probes from server in AS 40676 in US

- If response received, must be from injector: record domain name as blacklisted; record target IP address as poisoned; remember IP address in response ("lemon IP")

Many Paths Affected by DNS Injection

Region	IP Count	%age
CN	388206	99.8
CA	363	0.09
US	127	0.03
HK	111	0.03
IN	94	0.02

AS	Region	IP Count	%age
4134	CN	140232	36.05
4837	CN	88573	22.77
4538	CN	35217	9.05
9394	CN	24880	6.40
4812	CN	14913	3.83

- 388,988 IP addresses poisoned in 16 regions (CN, CA, US, HK, IN, AP, KR, JP, TW, DE, PK, AU, SG, ZA, SE, FI)

- 6 domain names blacklisted (www.facebook.com, twitter.com, www.youtube.com, www.appspot.com, www.xxx.com, www.urltrends.com)

- 28 distinct IPs in list of lemon IPs

Experiment: Locating Injecting ISPs

- Generate DNS query for blacklisted name sent to known poisoned target IP

- Send queries with successively increasing IP header TTL field values

  - Observe IP addresses in "ICMP time exceeded" replies to learn locations of routers on path

  - Observe DNS replies—they are from injectors

- Result: learn ASes where injectors located

Injector Locations

- 3120 router IPs associated with DNS injectors
- All these IPs in 39 ASes in China
- Implication: poisoned IP addresses not in China caused by DNS queries transiting China (or by errors in geolocating those IP addresses)

Experiment: Assessing Effect of Injection on Real Resolvers

- Send queries for blacklisted names to 43,842 non-censored open recursive resolvers in 173 countries

- If reply gives a lemon IP address, conclude queries handled by that open resolver censored

- Injectors tend to censor queries in which any part of domain name string is blacklisted

- So can force tests of path from open resolver to root and TLD servers with queries like:

  - `www.facebook.com.{random string}`

  - `www.facebook.{random string}.com`

Incidence of Collateral Damage Censorship

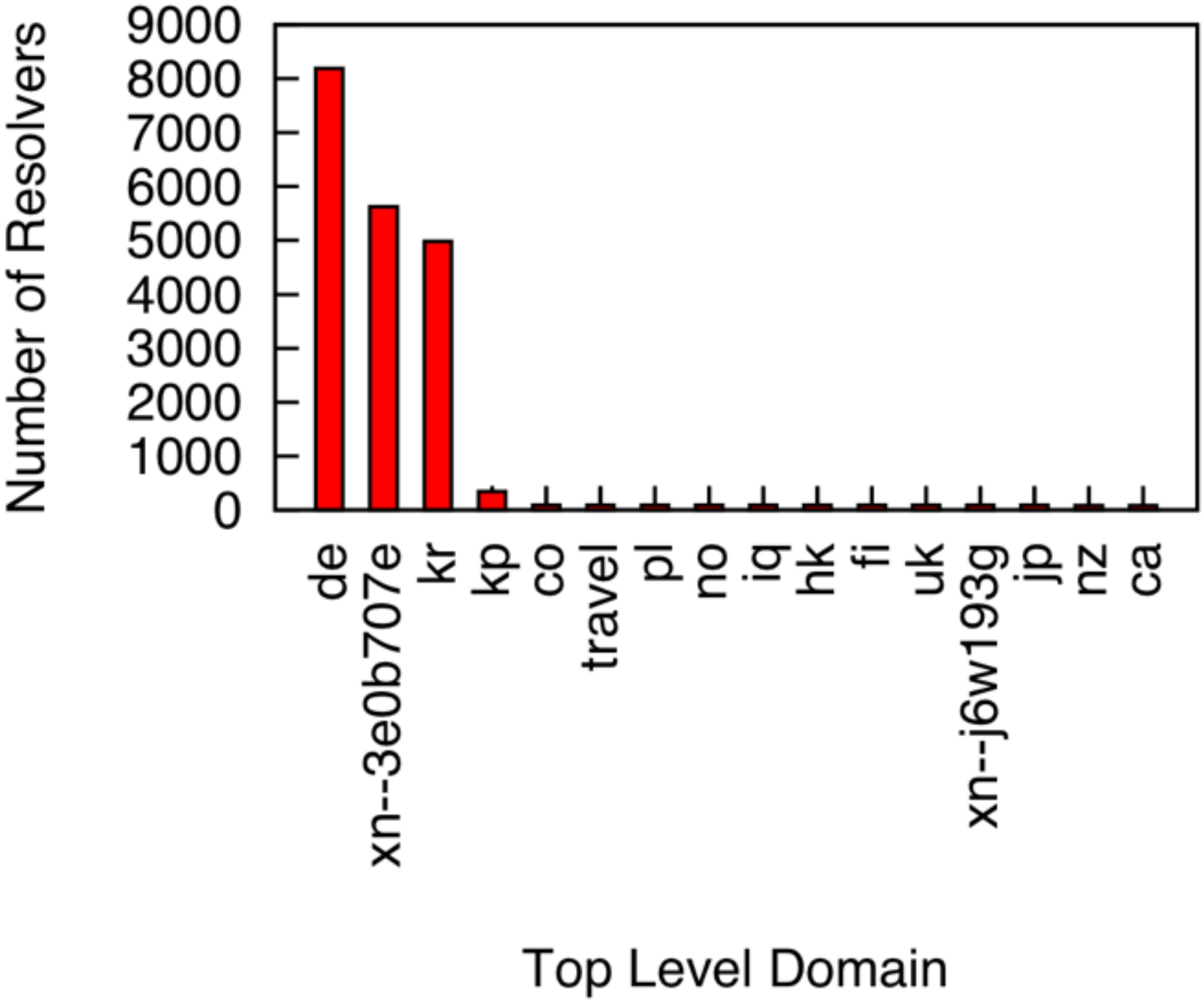
- DNS queries to root almost never censored; implication: DNS queries to root seldom transit ASes in China

- TLDs suffer substantial collateral damage; among all 312 TLDs:

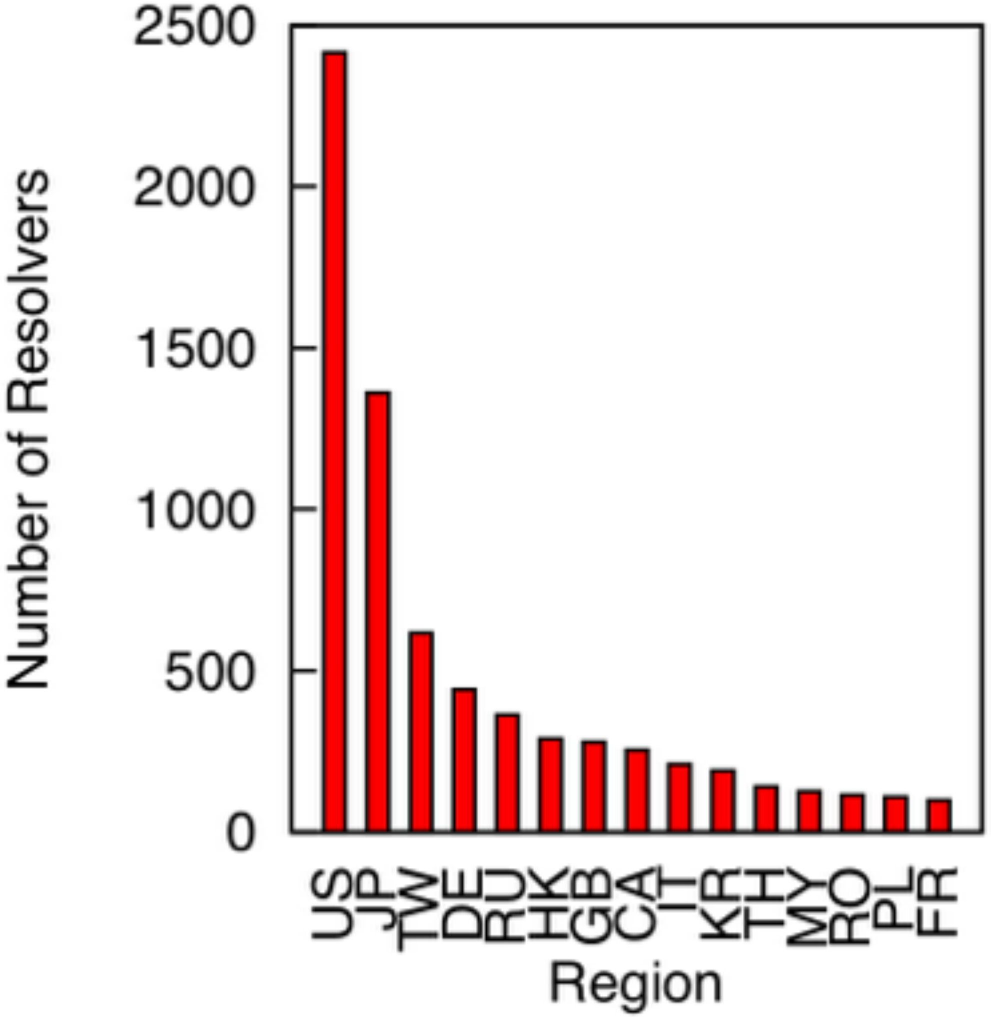
  - 99.53% of resolvers (43,322) censored for TLDs in China

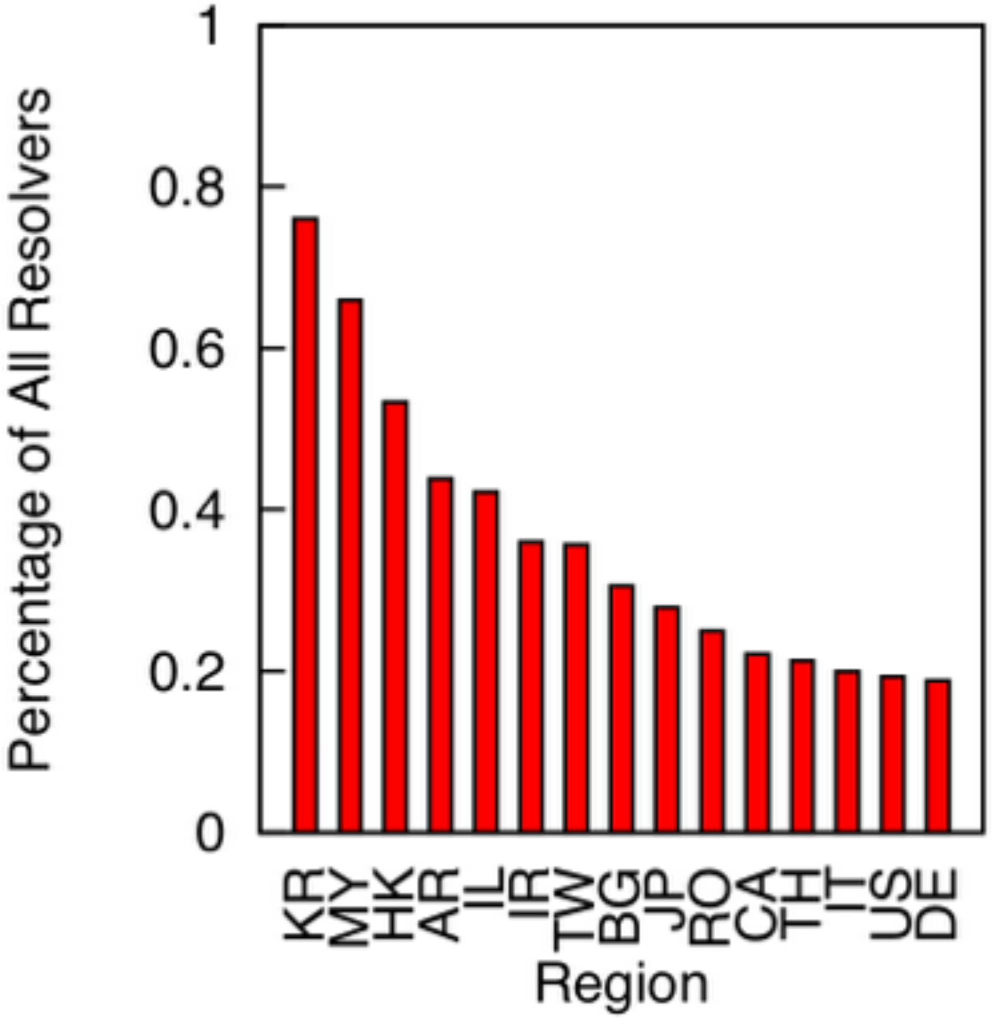
  - 26.4% of resolvers (11,573) censored for one or more of 16 other TLDs

TLD Servers on Censored Paths from Open Resolvers



TLD .de in Detail





- Left: number of censored resolvers in various countries when looking up names in .de

- Right: percentage of censored resolvers in various countries when looking up names in .de

Summary

- Evidence of collateral damage of censorship: even when resolver and target nameserver outside censored network, users can be censored

- DNS injectors in 39 ASes located in China

- 26.41% of open recursive resolvers around the world could be affected by collateral censorship damage

- Primary mechanism of collateral damage: paths between resolvers and TLD servers