UNIVERSITÄT DUISBURG ESSEN

The Impact of DNSSEC

on the Internet Landscape

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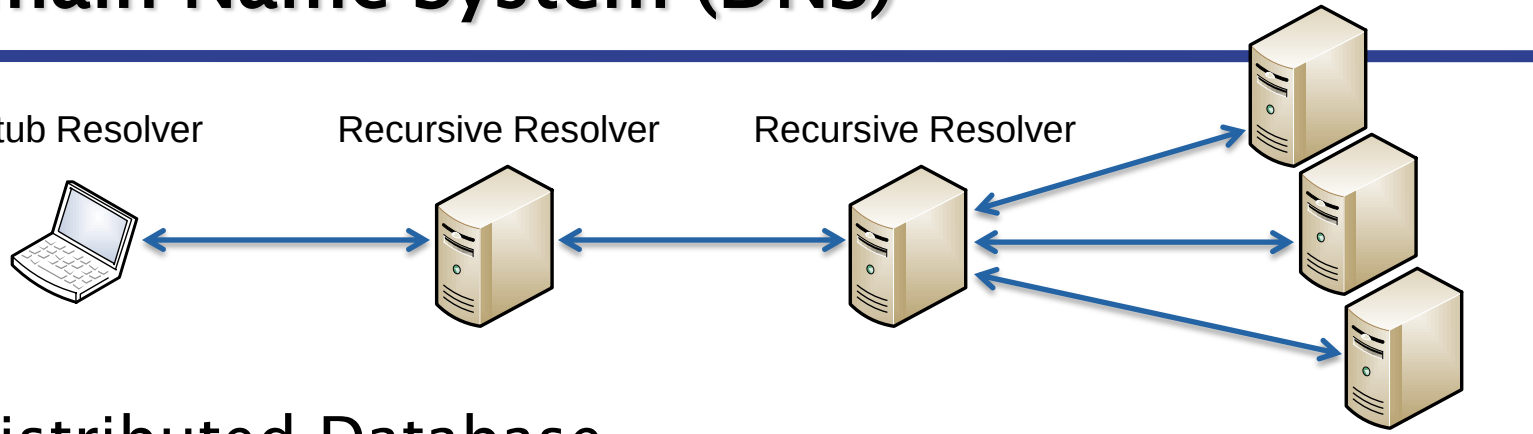
Outline

- Domain Name System
  - Security problems
  - Attacks in practice
- DNS Security Extensions (DNSSEC)
  - Protection and new problems
  - Adoption in practice

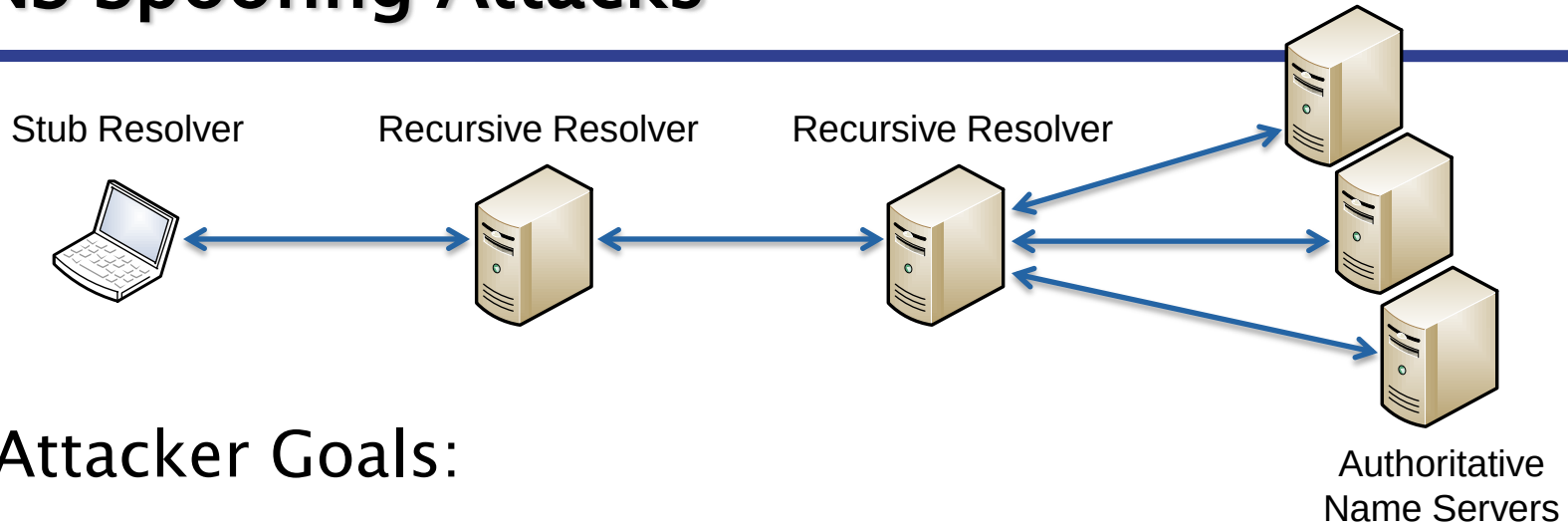
Domain Name System

Domain Name System (DNS)



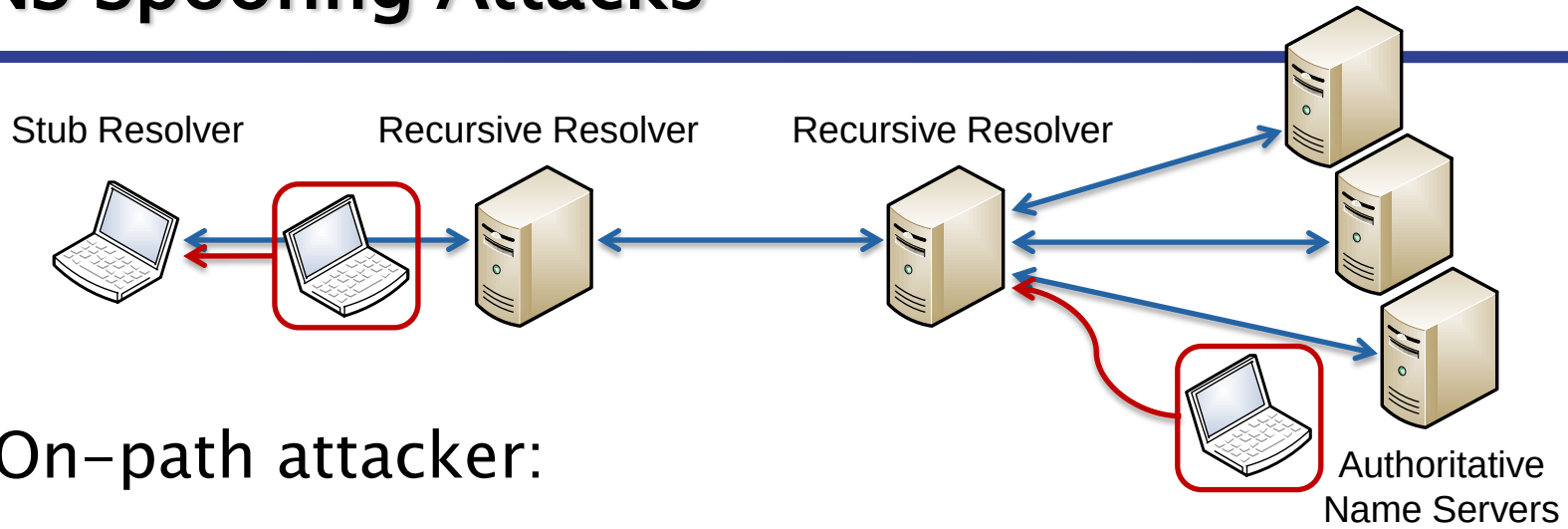
- Distributed Database
- Hierarchical Namespace
- Resolve domain names to data (e.g. IP address)
  - Data sets: resource records

DNS Spoofing Attacks



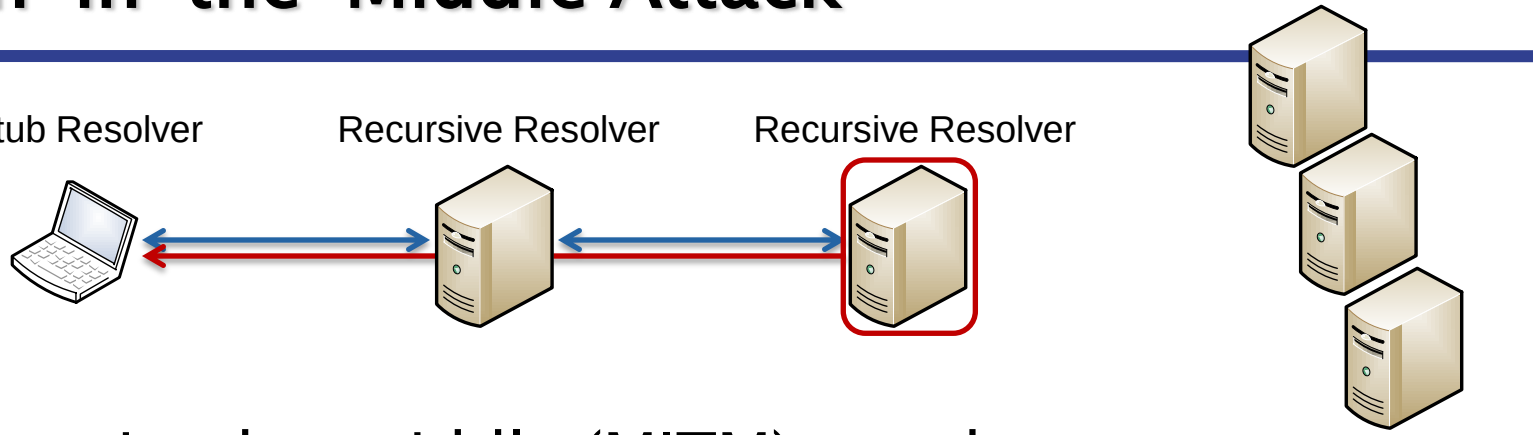
- Attacker Goals:
  - Divert application to another server
  - Deny service

DNS Spoofing Attacks



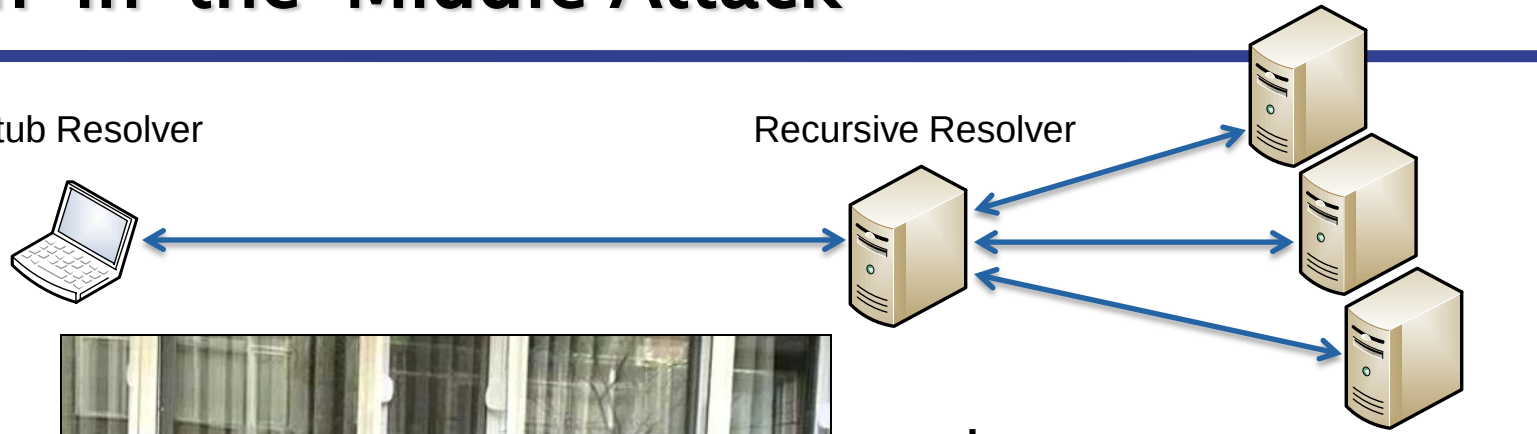
- On-path attacker:
  - Sees query, spoofs response (e.g. public WiFi)
- Off-path attacker:
  - Predicts query, spoofs response (anywhere in the Internet)

Man-in-the-Middle Attack



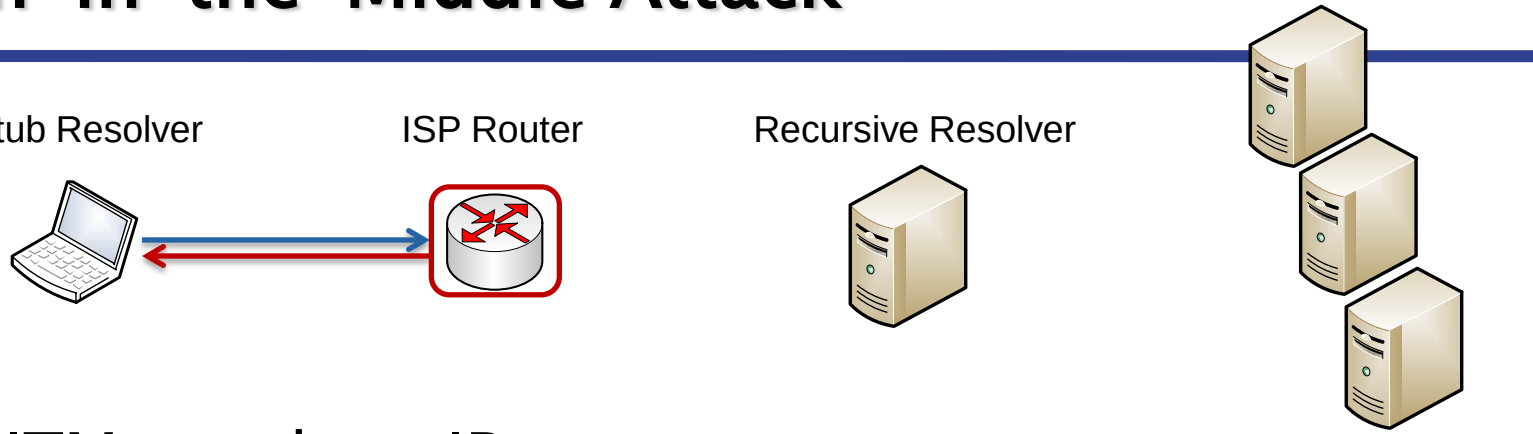
- Man-in-the-middle (MITM) attacker:
  - Sees query, spoofs response
- Filtering of resolver users

Man-in-the-Middle Attack



- Mar ttacker:
  - S
- Filte

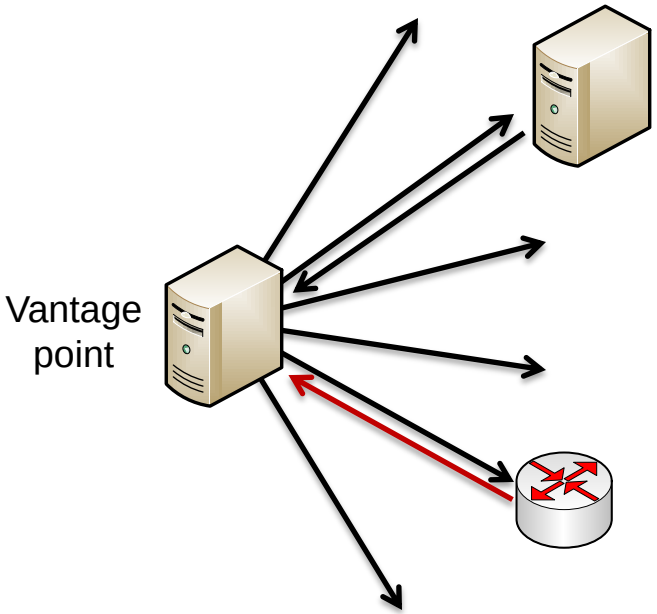
Man-in-the-Middle Attack

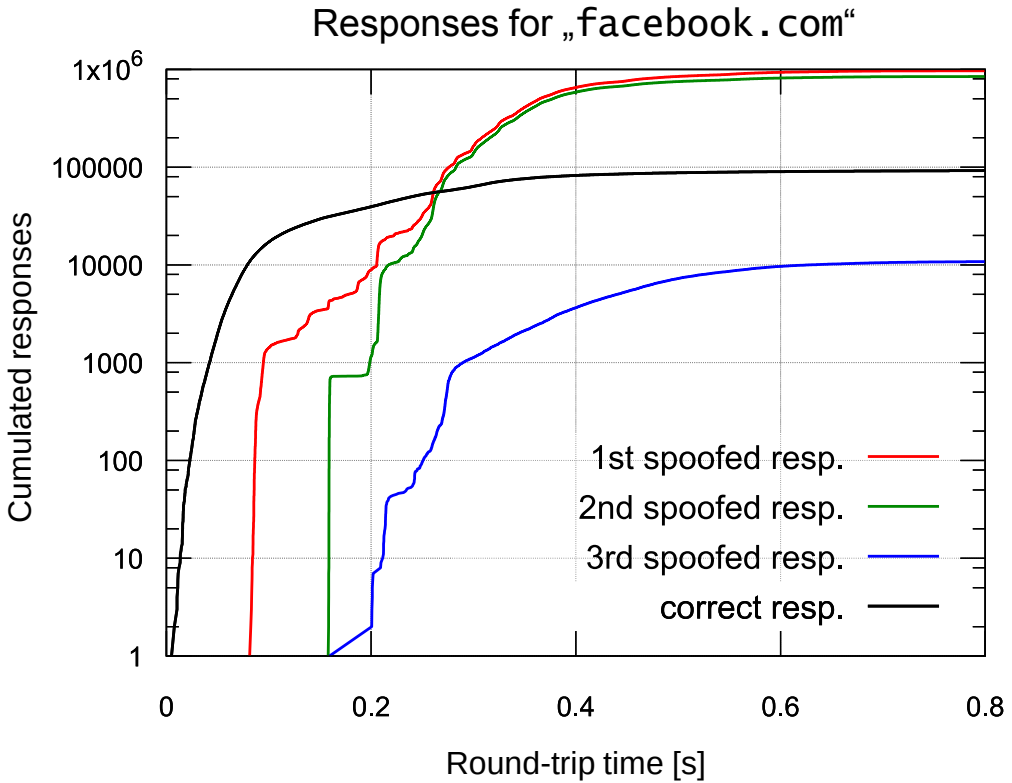


- MITM attack on IP router:
  - Deep Packet Inspection of DNS traffic
  - Router sees query, spoofs response
- Effective filtering of all DNS queries in network

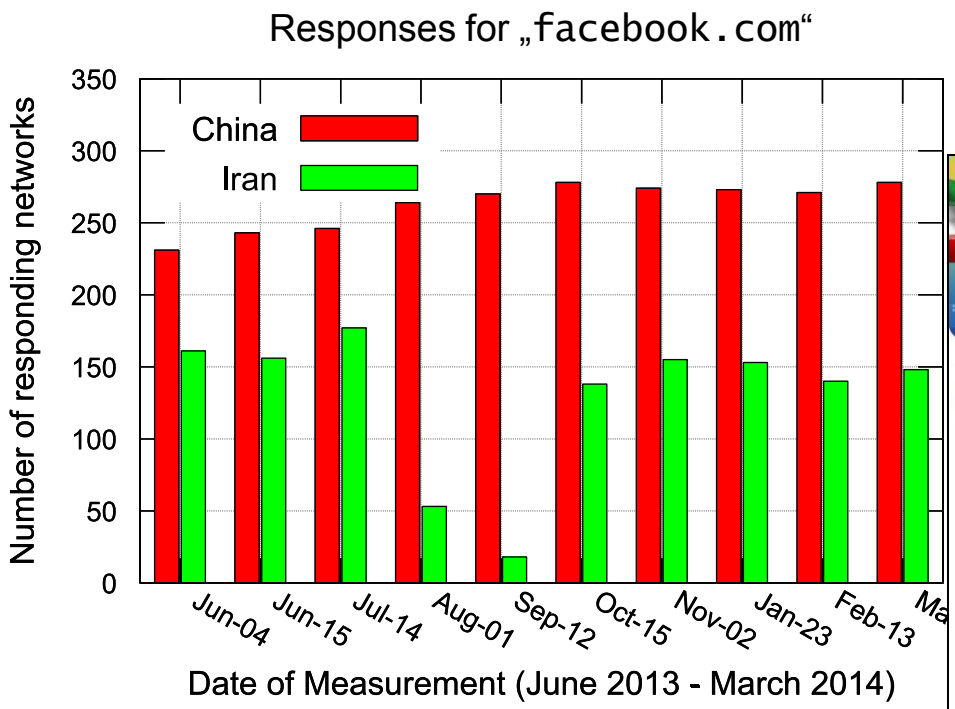
Probing for DNS Injectors

Published in:
IEEE Access, 2014



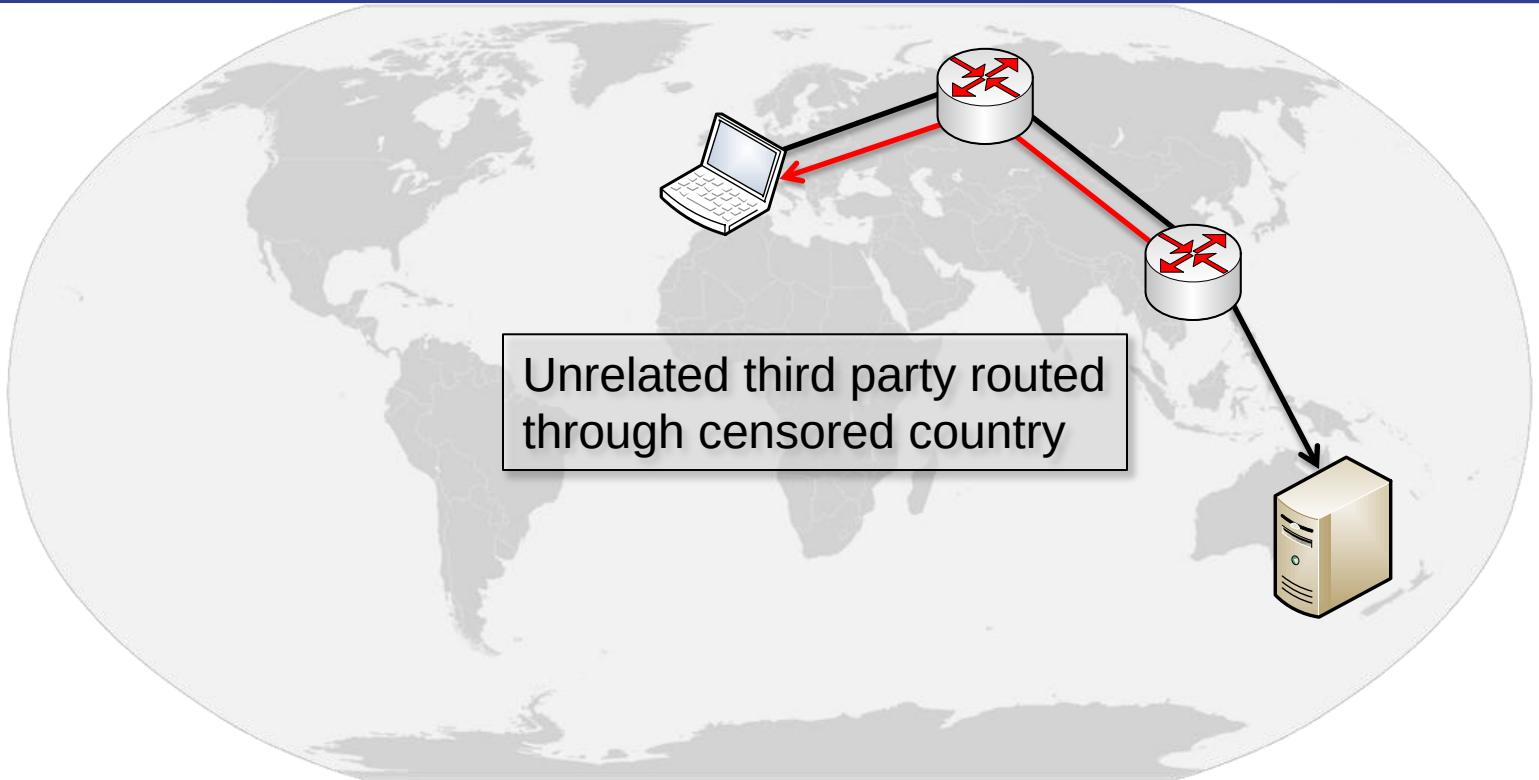


DNS Injection over Time



Impact Assessment on Third Parties

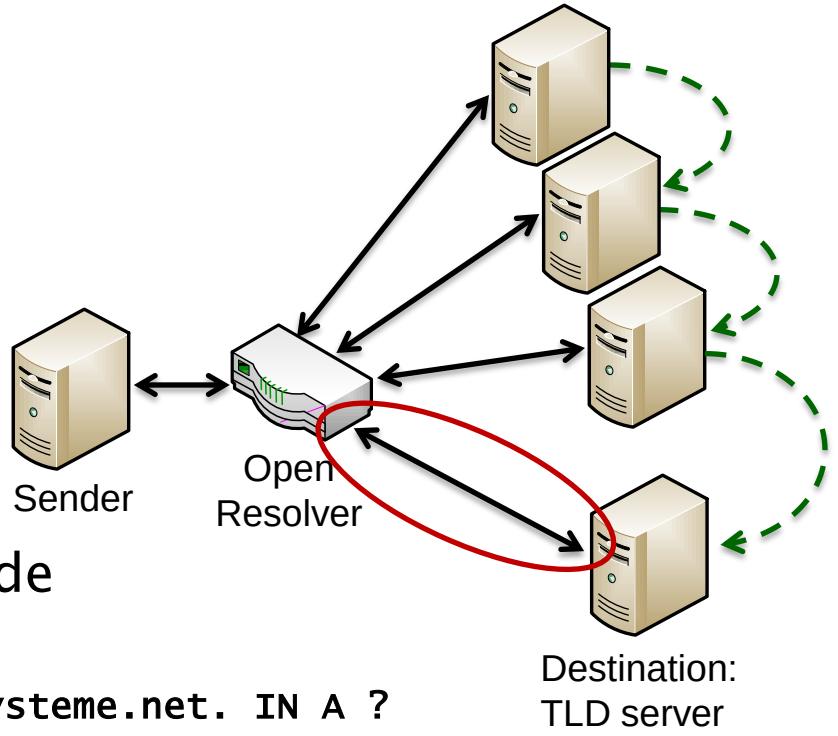
Published in:
IEEE Access, 2014



Open Resolver Measurement

Published in:
IEEE Access, 2014

- Worldwide impact of Chinese DNS injection
- Top-level domains
  - 1144 name servers
- Multiple vantage points
  - 255k open resolvers worldwide

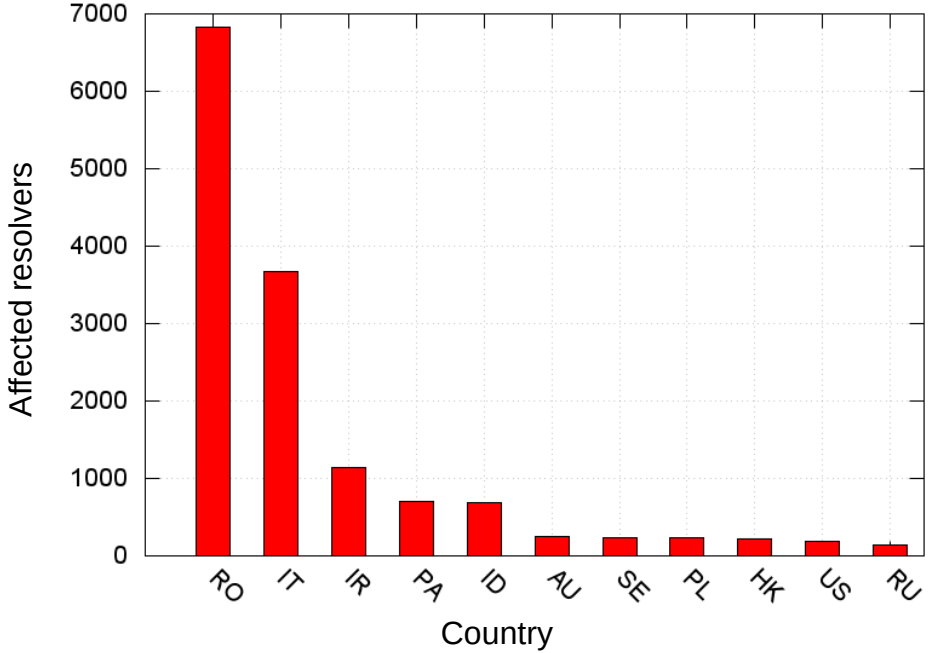


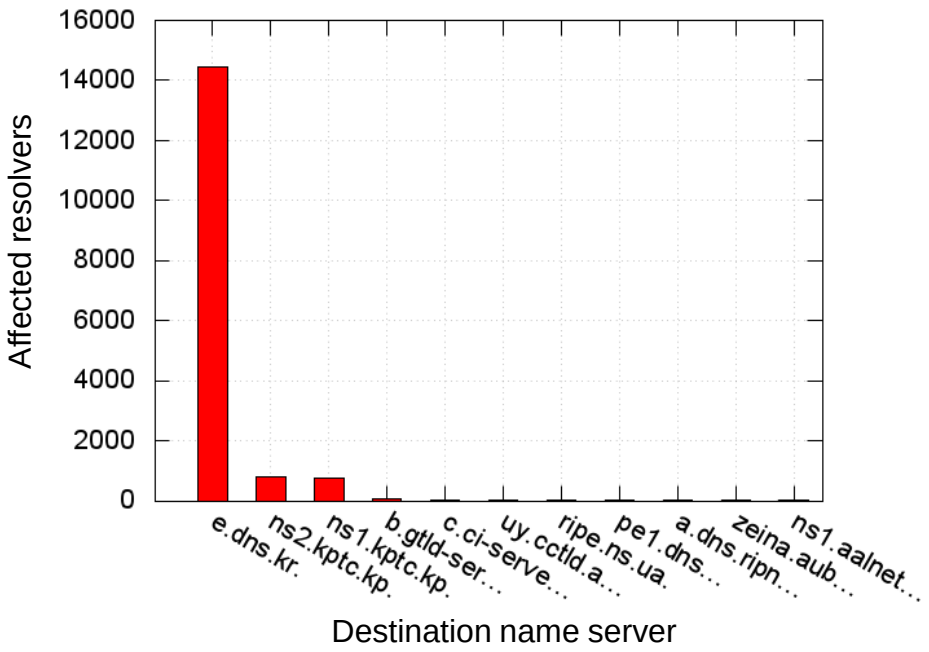
`www.minghui.org.s1.verteiltesysteme.net. IN A ?`

Open Resolver Results

Published in:
IEEE Access, 2014

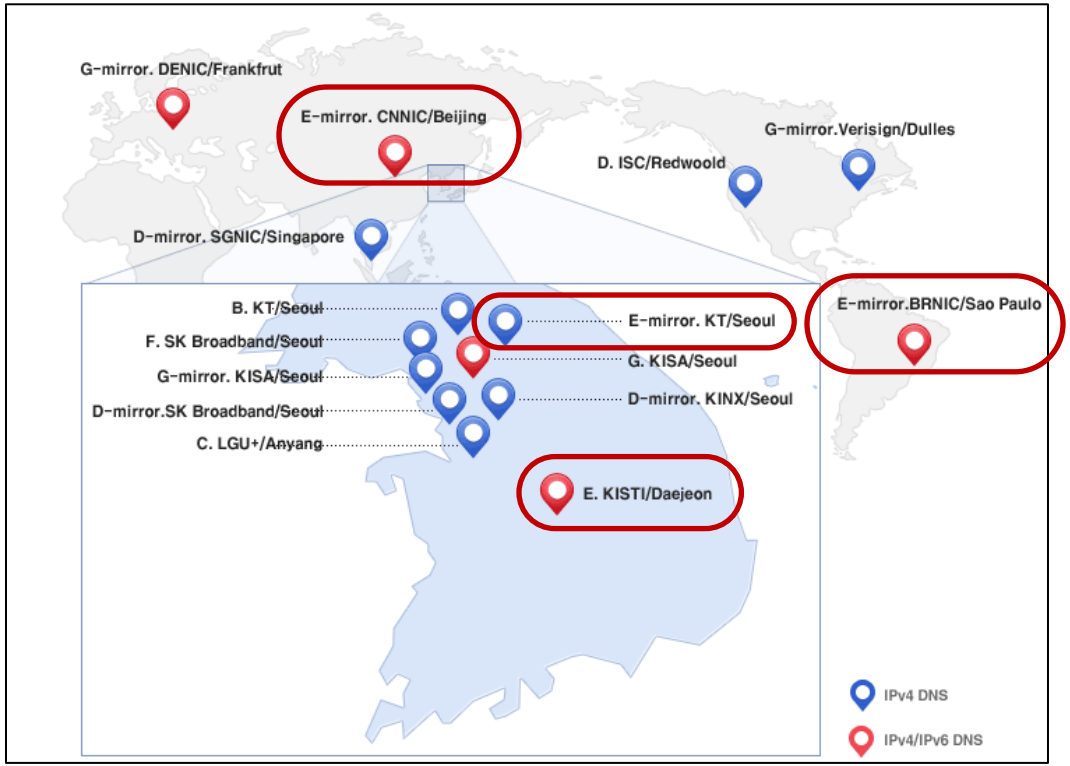
- 15k resolvers (6%) affected by Chinese DNS injection
- 14k affected when contacting „e.dns.kr“





.kr Top-Level Domain Servers

Published in:
IEEE Access, 2014



Impact Assessment on Third Parties

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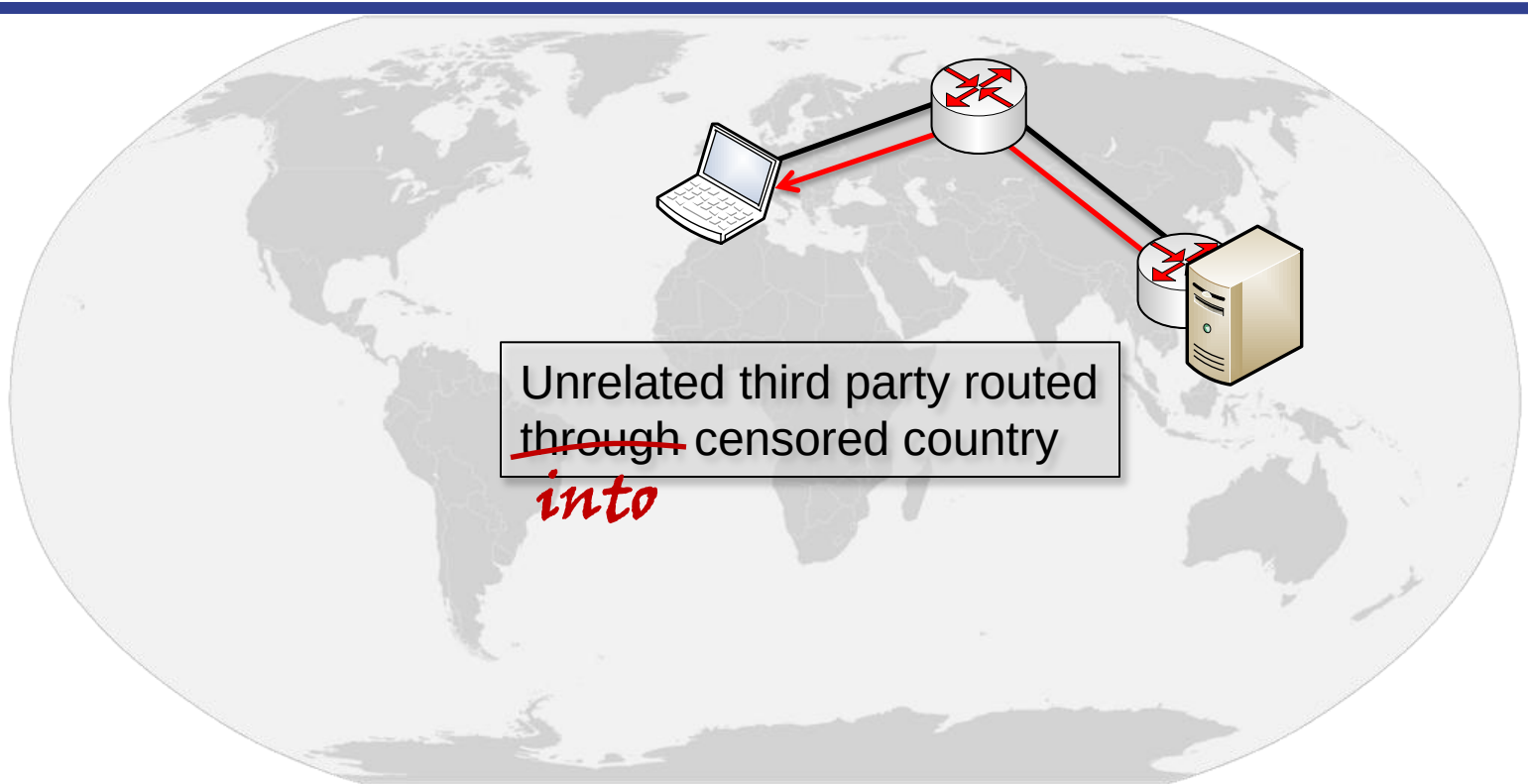
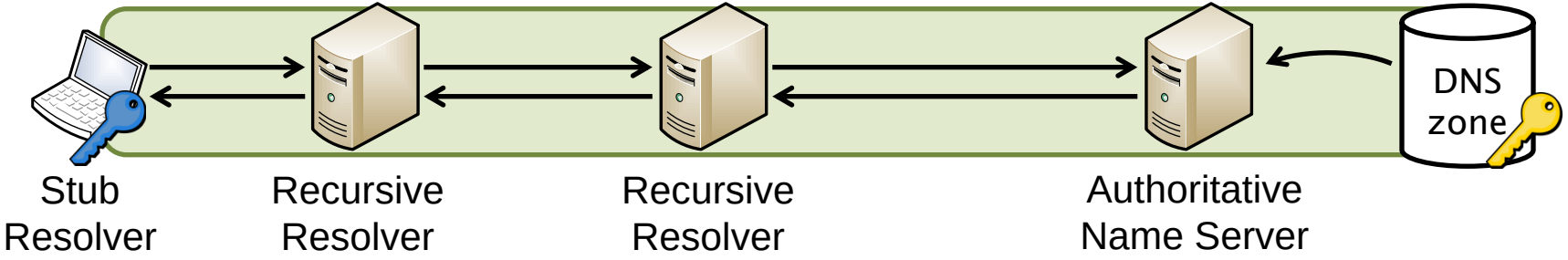


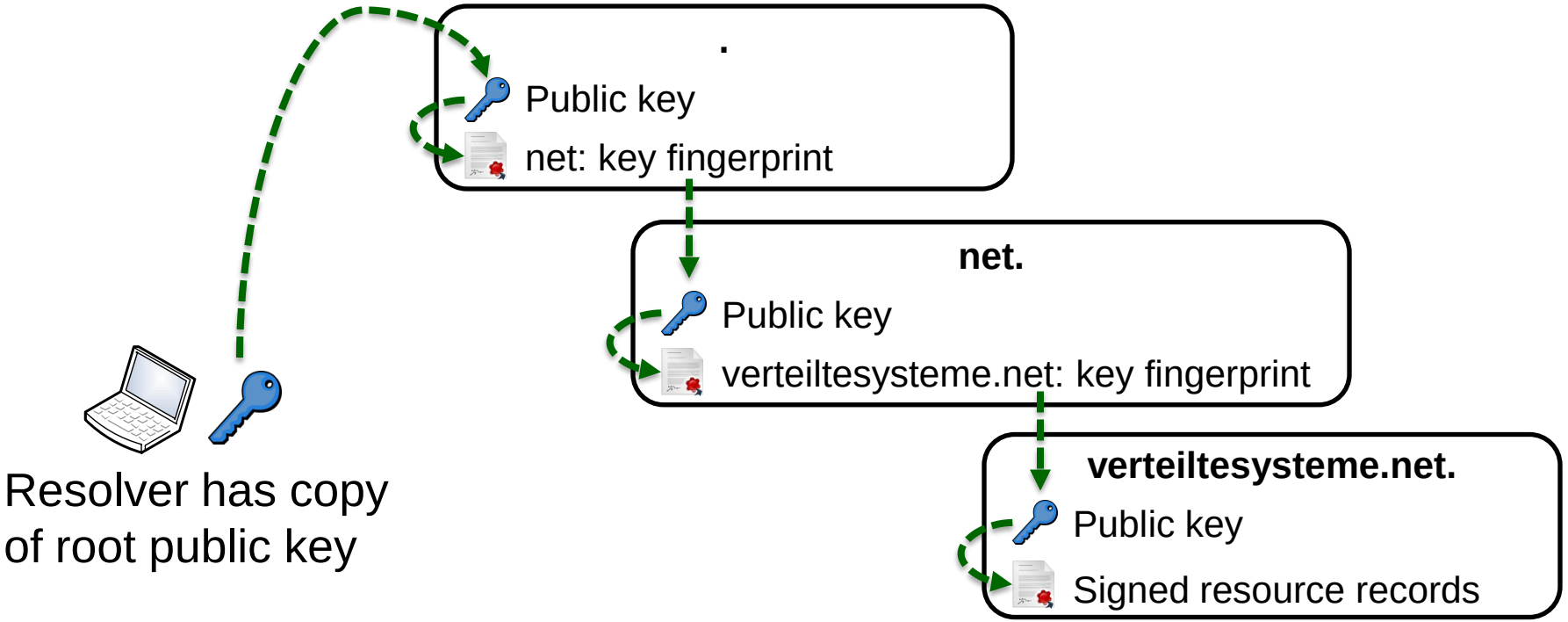
DNSSEC

Concept

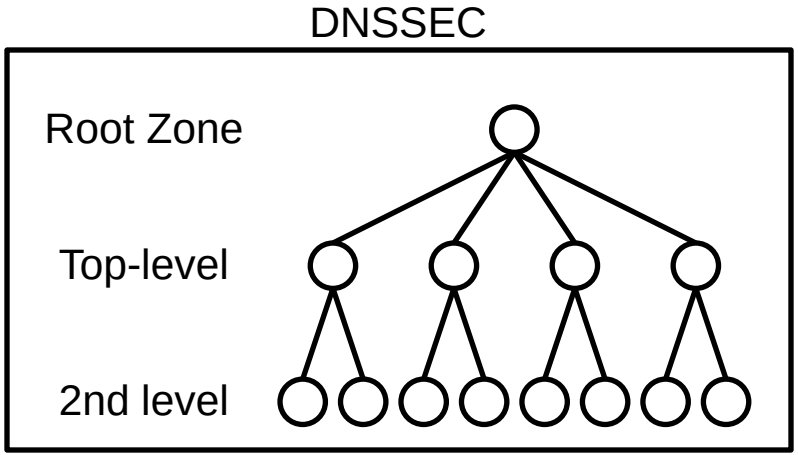


- Security goals: data integrity and authenticity
- Signatures pre-generated over DNS data sets
- End-to-end security between validator and signer

Public Key Distribution

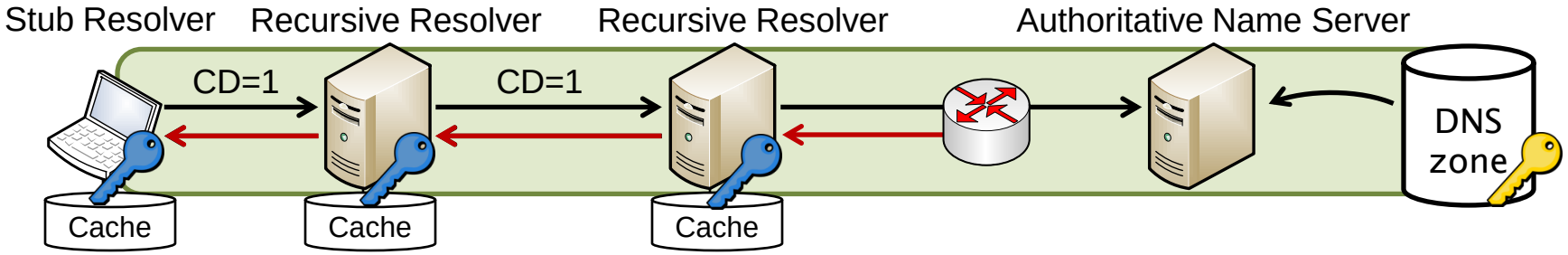


Trust Model



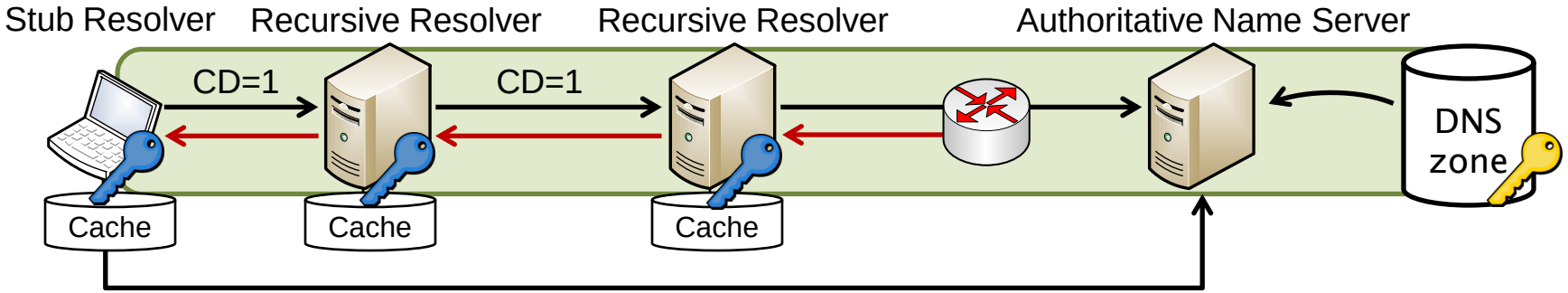
- Authority limited to subnamespace
- Powerful root authority

Cache Lock-in



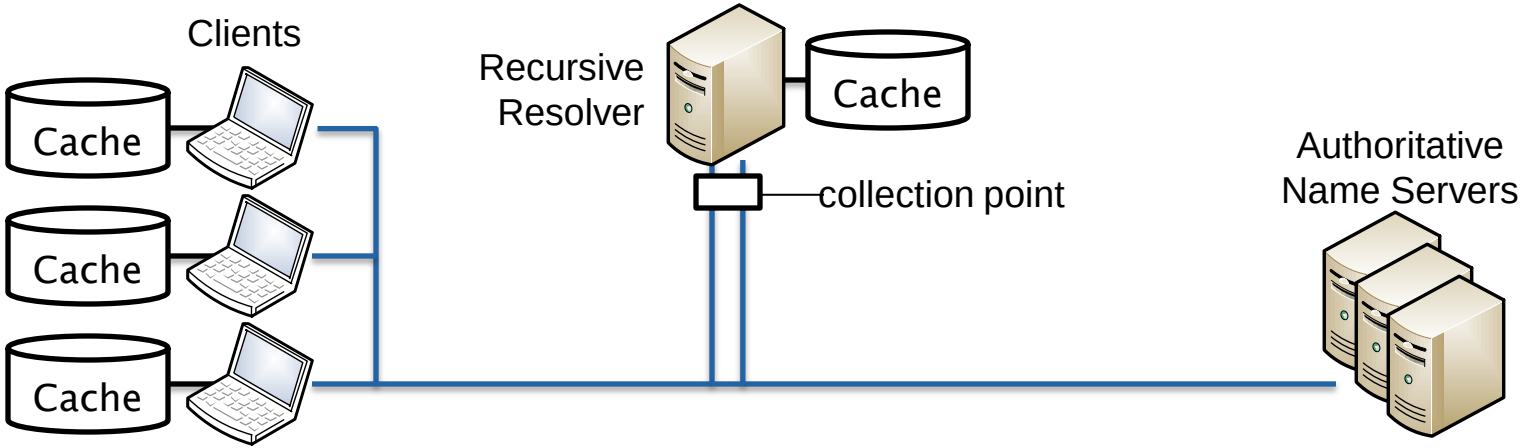
- End-to-end security: validation on end host
  - Independent of validation failures on intermediate resolvers
- Request response without DNSSEC validation
  - Problem: cache lock-in

Cache Lock-in



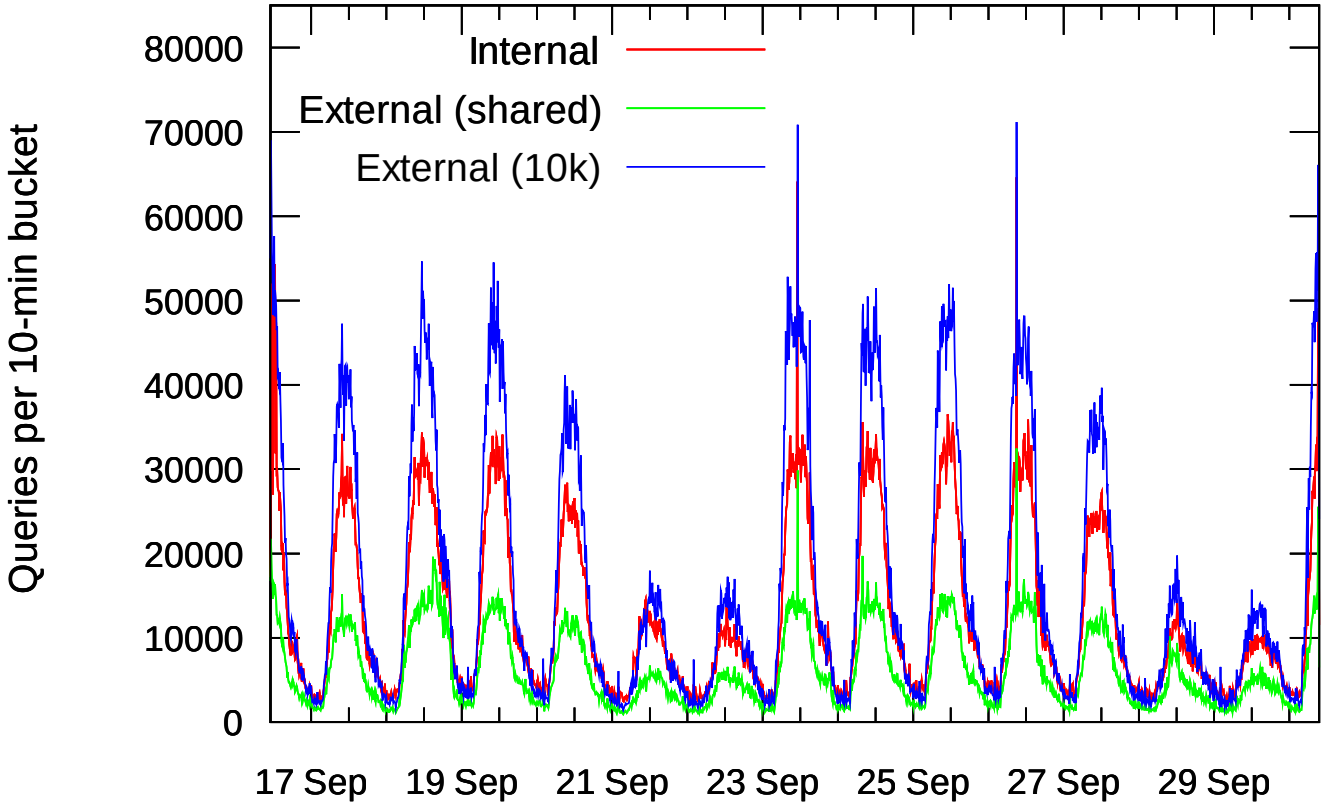
- Omit intermediate resolvers
- Effectiveness of intermediate caching?

Trace-driven Simulation of Cache Effectiveness



- Cache models:
  - Shared cache in front of 10k clients
  - 10k independent caches

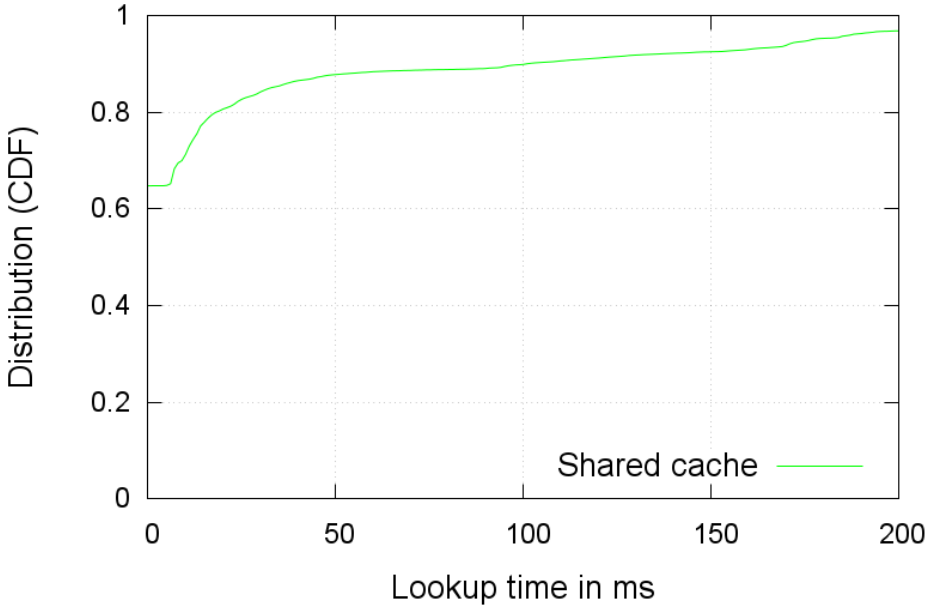
Bandwidth Overhead

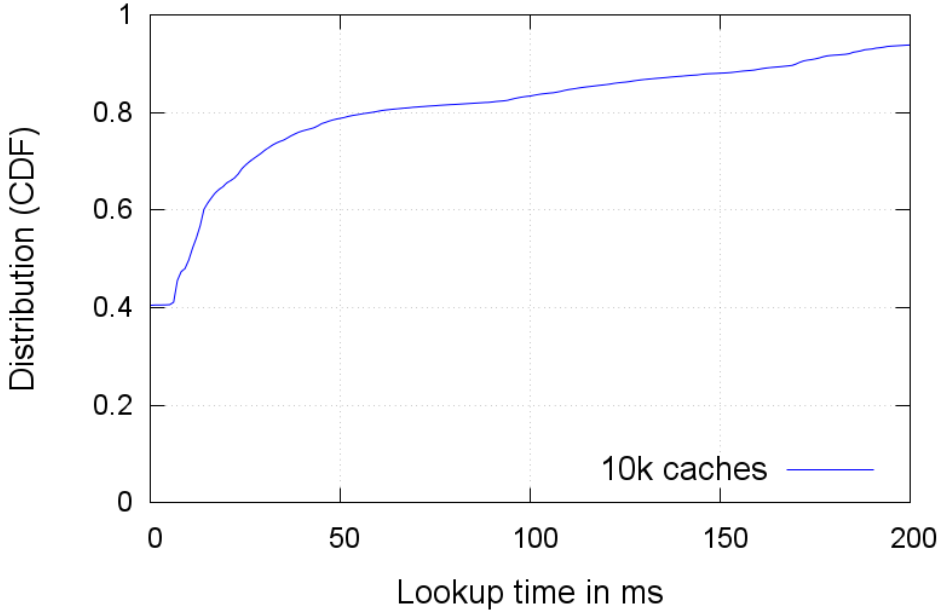


External traffic:

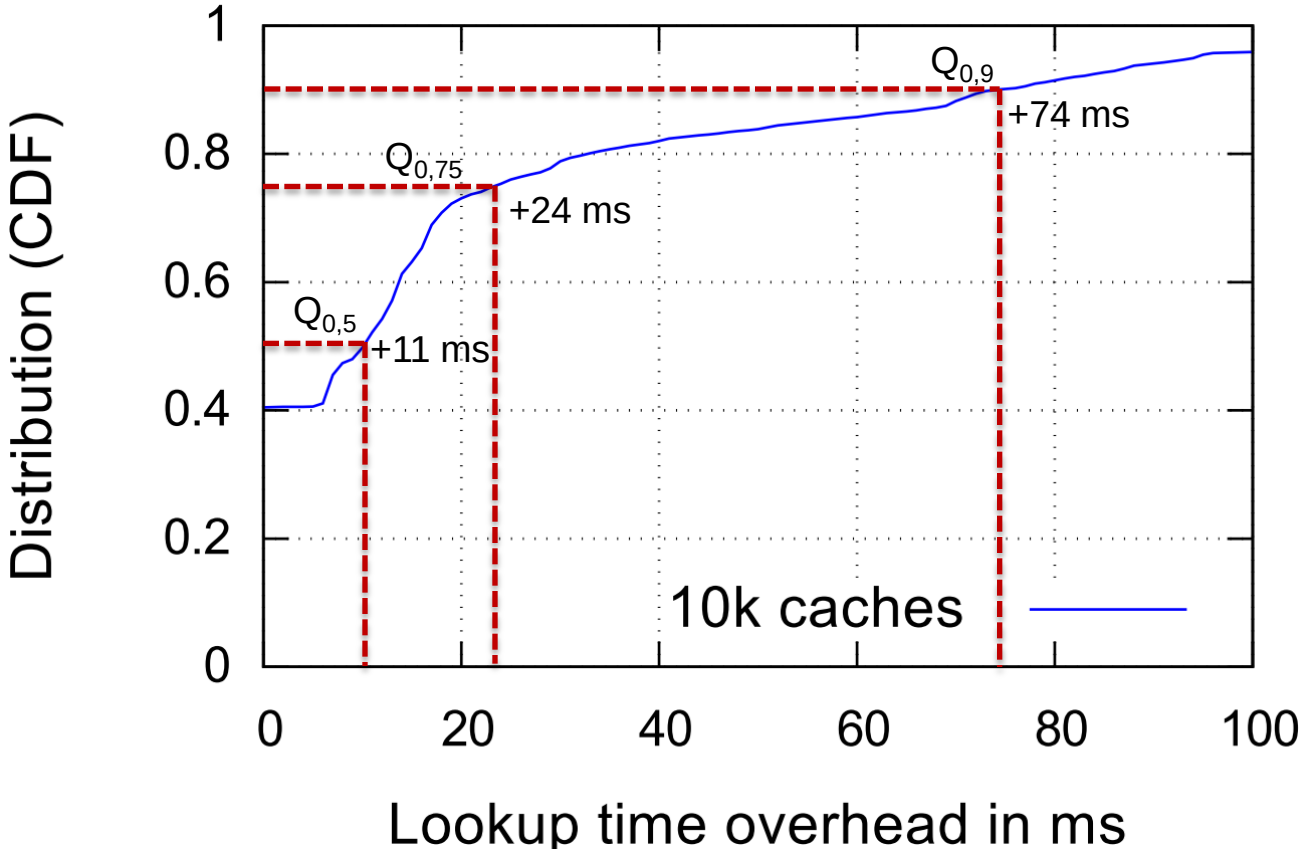
- Shared cache: 2.44 GBytes
- 10k caches: 7.55 GBytes

Latency Overhead





Latency Overhead



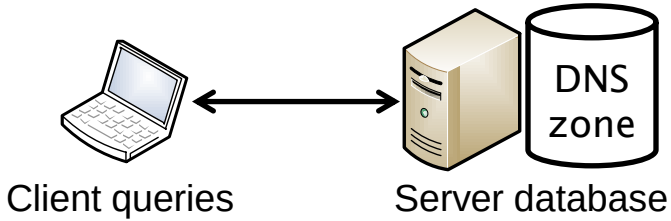
⇒ **Utilize intermediate DNS caches**

⇒ **Fall back to autonomous resolution on failure**

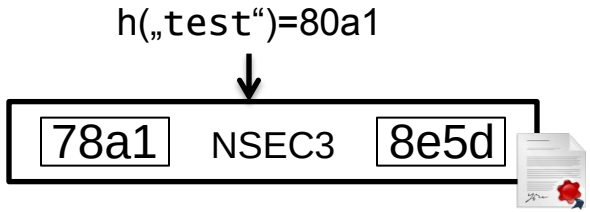
Privacy and Confidentiality

Published in:
IEEE NCA, 2014

- Client: no privacy improvement
  - Cleartext DNSSEC messages



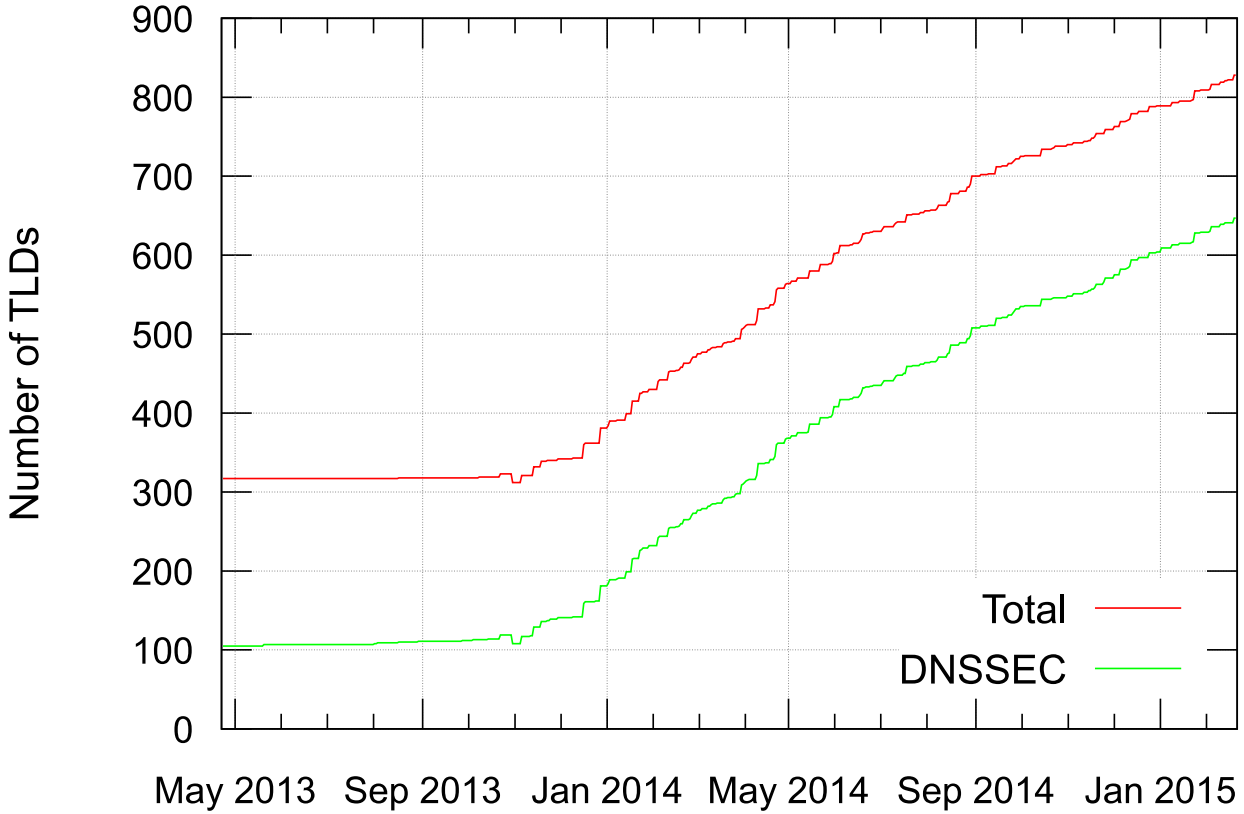
- Server: discloses hash values of zone contents
  - Server proves non-existence
  - Hashing supposed to hide names



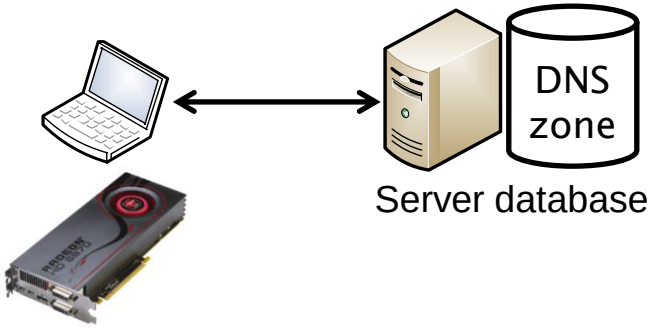
- Break NSEC3 hash values with GPU-based attacks
  - One GPU reveals 65% `.com` hash values in 5 days

ADOPTION OF DNSSEC

Signed Top-Level Domains



Signed Second-Level Domains



TLD	Domains		
1. nl	2,279,702	8. no	119,759
2. br	566,694	9. be	92,385
3. cz	448,984	10. net	81,391
4. com	426,182	11. org	46,382
5. se	349,514	12. ovh	29,372
6. eu	320,311	13. nu	21,126
7. fr	205,662	14. de	20,004

Total: 5,146,705 signed domains

Algorithms and Key Sizes

Survey of
3.4M domains

Algorithm	Domains
RSA/MD5	0
DSA/SHA-1	2,176
RSA/SHA-1	1,547,782
RSA/SHA-256	1,869,157
RSA/SHA-512	1,100
GOST R 34.10-2001	30
ECDSA P-256/SHA-256	29
ECDSA P-384/SHA-384	19

>99% use RSA

RSA Key Size	Domains
512	13,674
768	25
1024	3,152,420
1032	535
1152	108
1280	185,825
1304	105
1536	106
2048	59,907
2560	1
3072	3
4096	5,135

Shortest RSA key per domain

Result	Domains
No DNSKEY (dangling DS)	17,751
No trusted DNSKEY (dangling DS)	1,066
No RRSIG for trusted DNSKEY	238
Signature expired	2,138
Signature verify failure	5
Validation failure	**21,198**
Validation success	**3,416,700**

0,6% domains fail validation

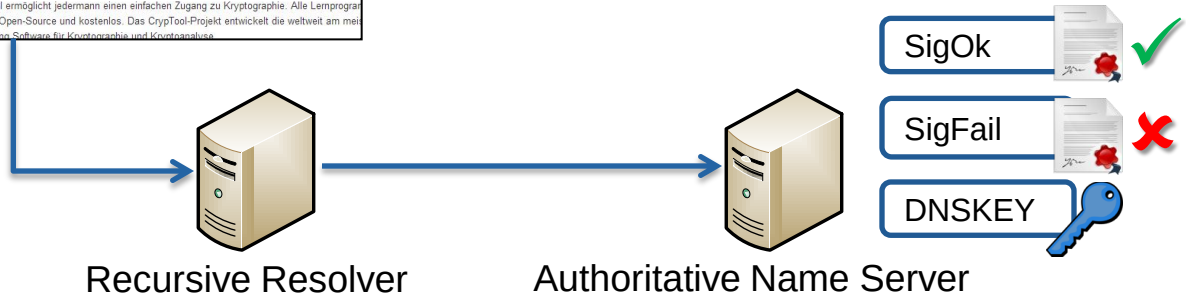
Measuring Validating Clients

Published in:
LNCS PAM, 2013

`https://SigOk.verteiltesysteme.net/a.png`

`https://SigFail.verteiltesysteme.net/b.png`

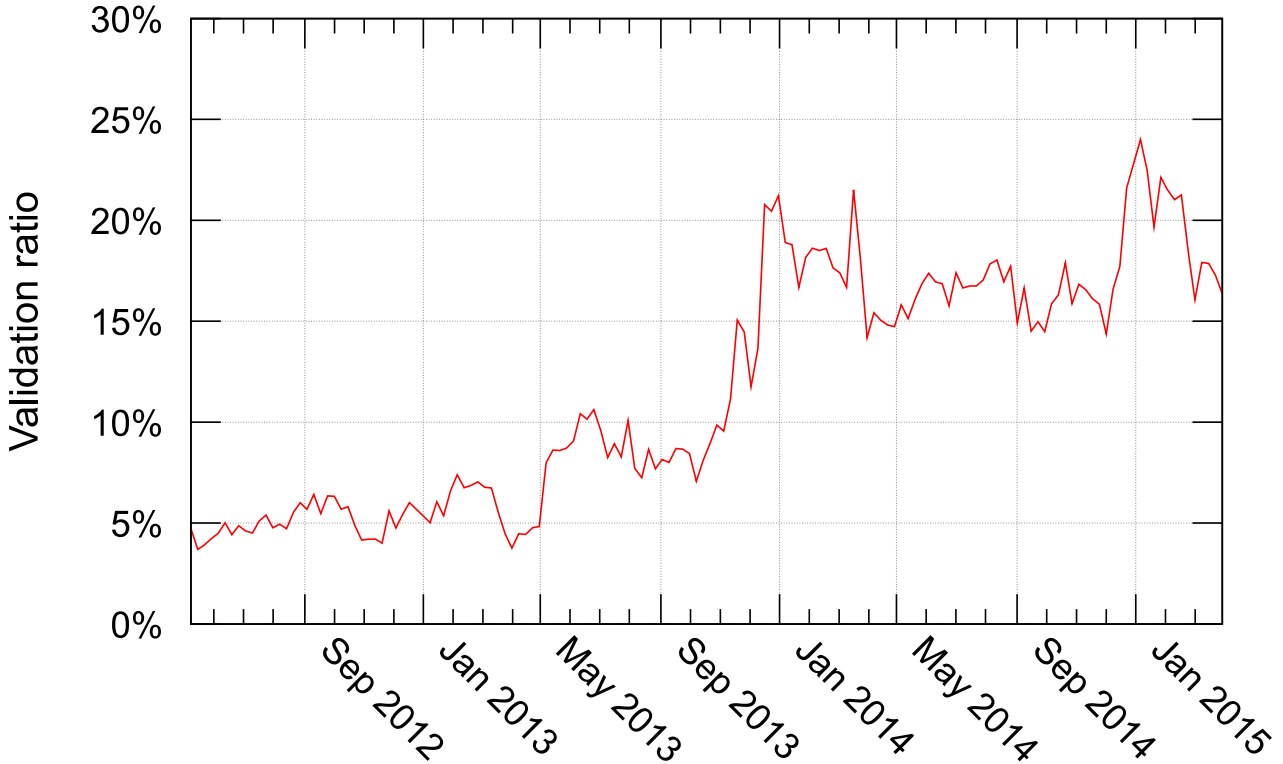
Invisible 1px images



DNSSEC Validation

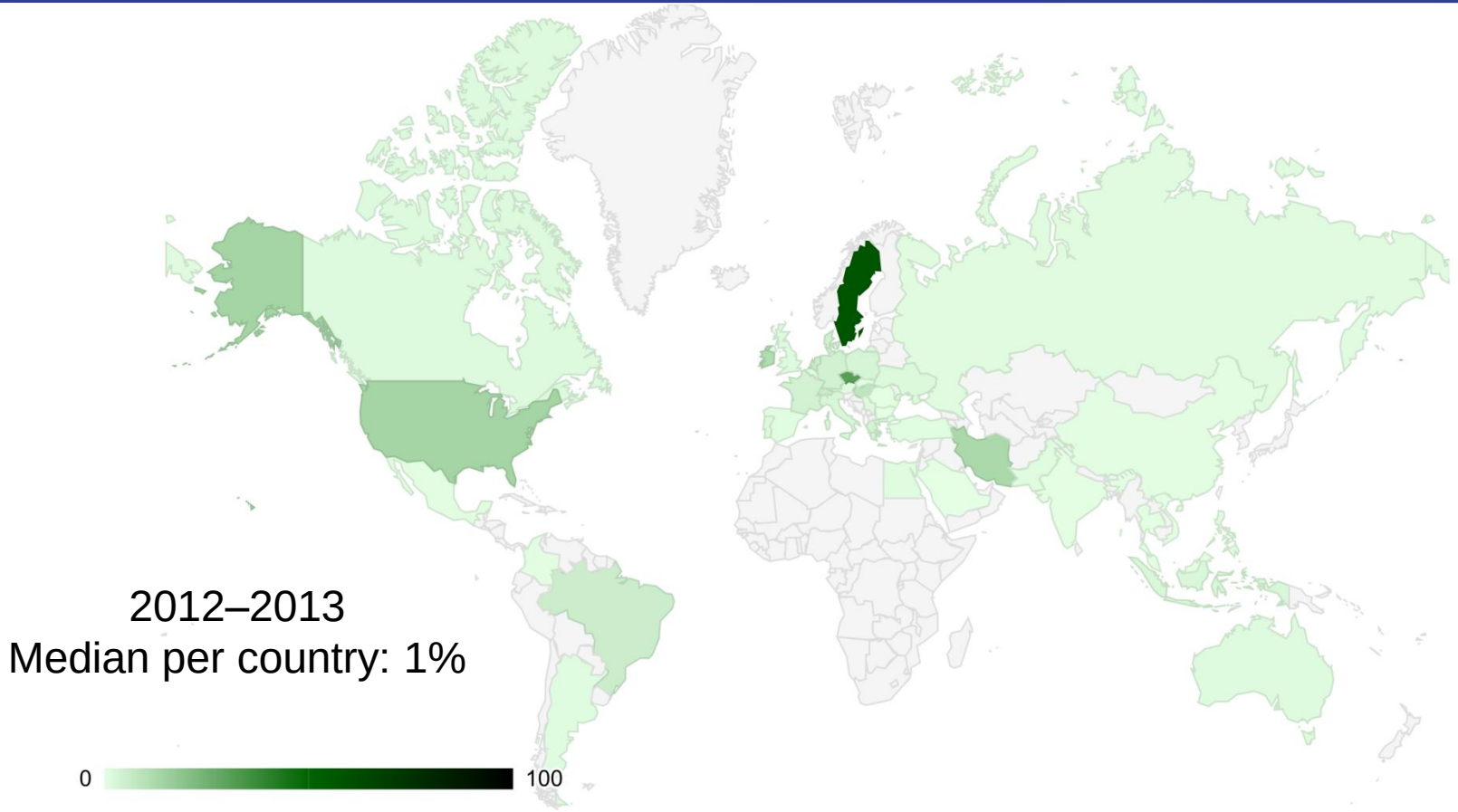
Published in:
LNCS PAM, 2013

- 841k test results from 557k distinct IP addresses

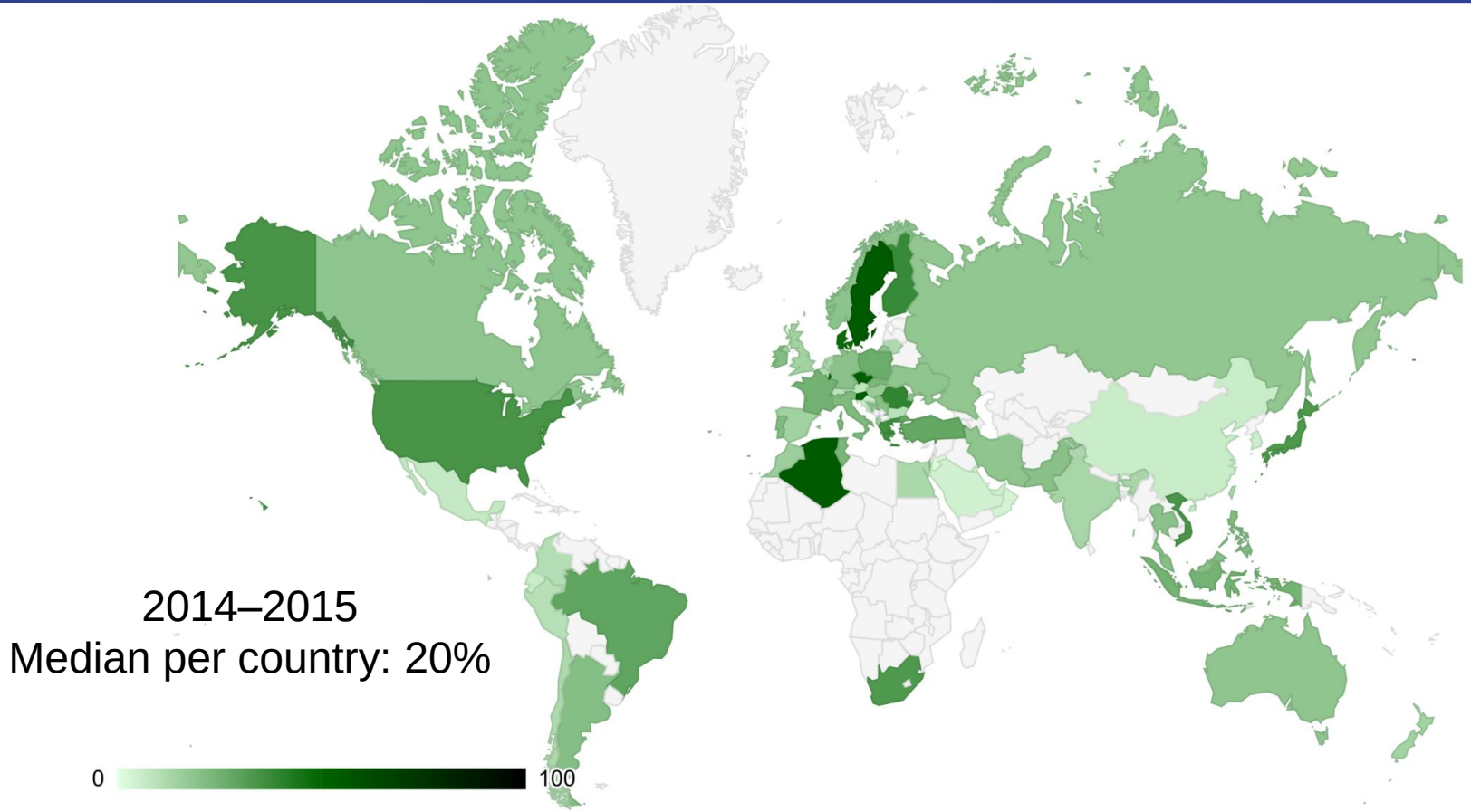


DNSSEC Validation per Country

Published in:
LNCS PAM, 2013



DNSSEC Validation per Country



Conclusions (1/2)

- DNS spoofing used for Internet filtering
  - 6% resolvers worldwide affected by Chinese DNS injection
  - Evidence of router-based DNS injection in Iran
  - Political changes in DNS filtering observable from outside
- DNS caching causes lock-in on bogus data
  - Trace-driven simulation shows moderate benefit of caching
  - Suggestion: omit DNS caches on DNSSEC validation failure

Conclusions (2/2)

- DNSSEC secures data integrity and authenticity
  - Hashing is ineffective for protecting the DNS database
- First-time survey of all DNSSEC signed domains
  - 5M signed domains: >99% use RSA, 0.6% are broken
- 3-year measurement of validating clients
  - Worldwide increase of DNSSEC adoption
  - Varies by country (median 20%)

Referenced Publications

- M. Wander, T. Weis:
  Measuring Occurrence of DNSSEC Validation,
  Passive and Active Measurement (PAM), LNCS Springer, 2013.
- M. Wander, C. Boelmann, L. Schwittmann, T. Weis:
  Measurement of Globally Visible DNS Injection,
  IEEE Access, 2014.
- M. Wander, L. Schwittmann, C. Boelmann, T. Weis:
  GPU-based NSEC3 Hash Breaking,
  IEEE NCA, 2014. Awarded **best student paper**.