Who Is Answering My Queries?
Understanding and Characterizing Hidden Interception of the DNS Resolution Path

Baojun Liu, Chaoyi Lu, Haixin Duan,
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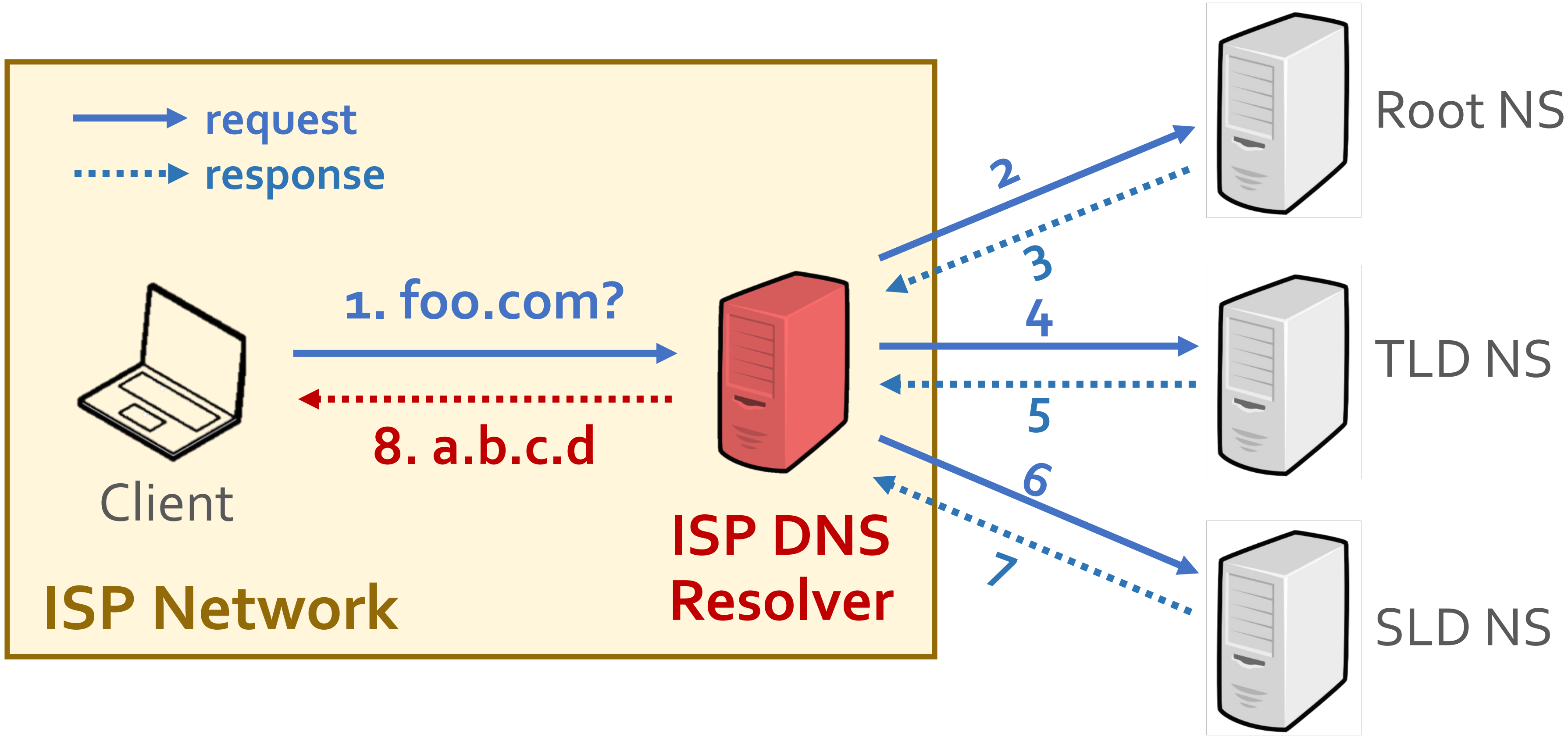
DNS Resolution

- ISP DNS Resolver
  - Might have security problems [Dagon, NDSS'08] [Weaver, SATIN'11] [Weaver, FOCI'11] [Kuhrer, IMC'15] [Chung, IMC'16] …



DNS Resolution

- Public DNS Resolver
  - Performance (e.g., load balancing)
  - Security (e.g., DNSSEC support)
  - DNS extension (e.g., EDNS Client Subnet)

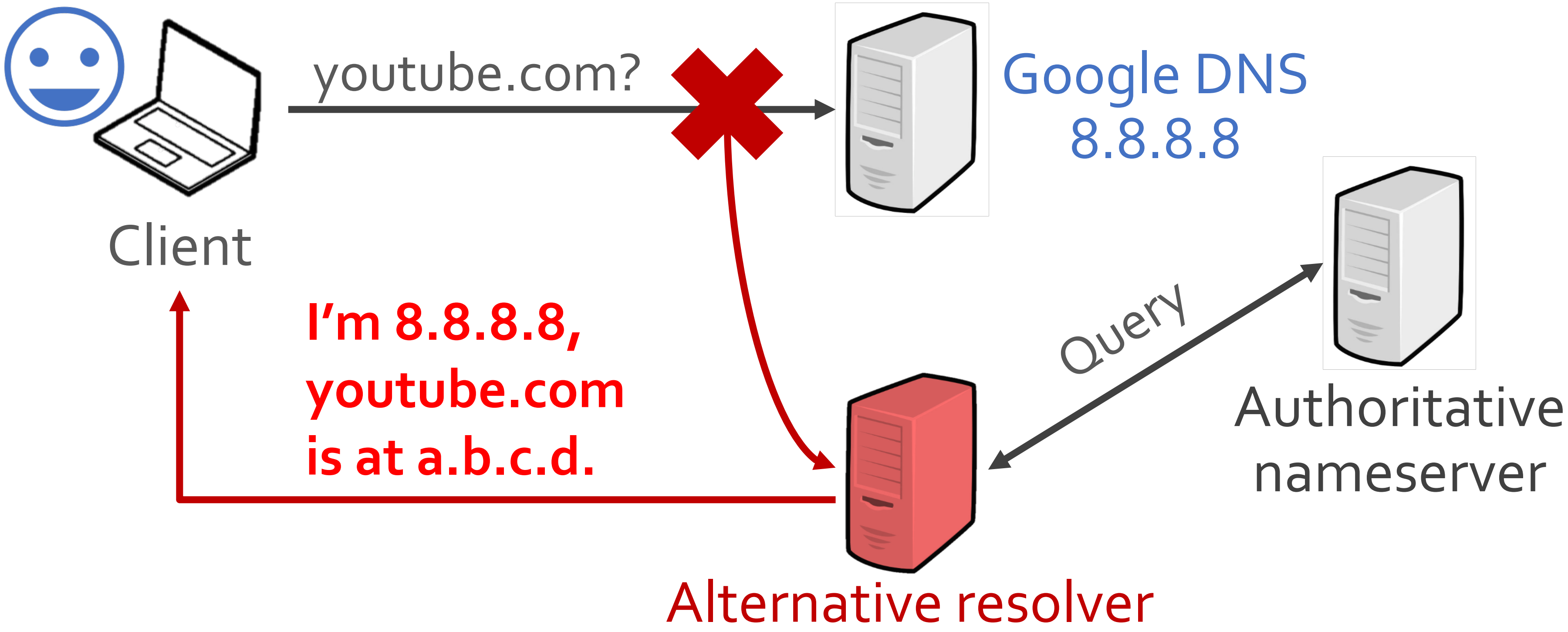
Google Public DNS

OpenDNS

CLOUDFLARE 1.1.1.1 DNS

DNS Interception

- Who is answering my queries?



Spoof the IP address and **intercept** queries.

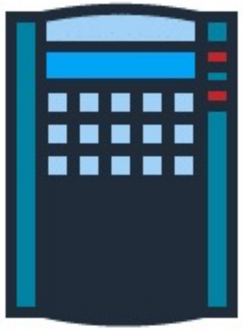
Potential Interceptors

Internet Service Provider
(ISP)

Censorship / firewall

Anti-virus software / malware
(E.g., Avast anti-virus)

Enterprise proxy
(E.g., Cisco Umbrella intelligent proxy)



Q1:

*How to **globally measure** the hidden DNS interception?*

Q2:

*What are the **characteristics** of the hidden DNS interception?*

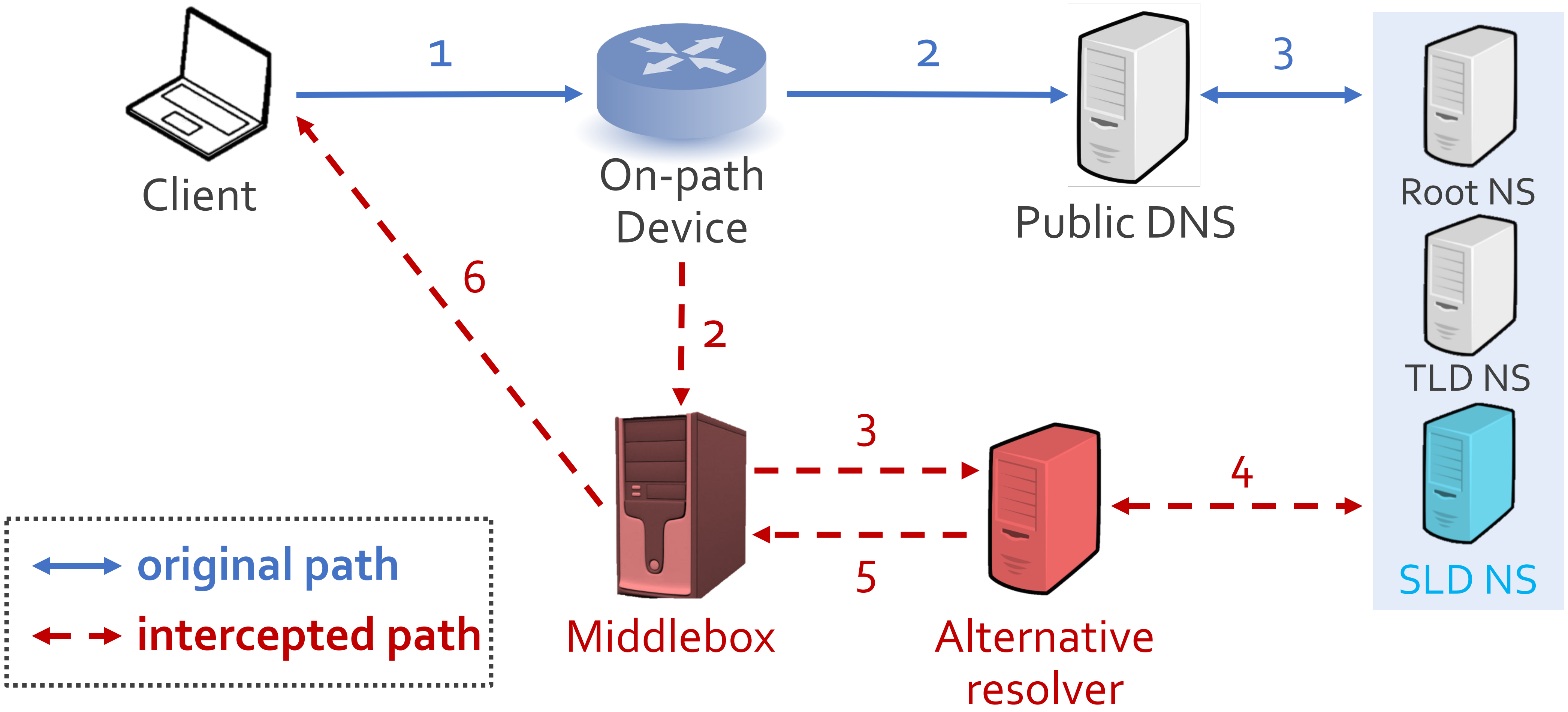
Motivation

Threat Model

Methodology

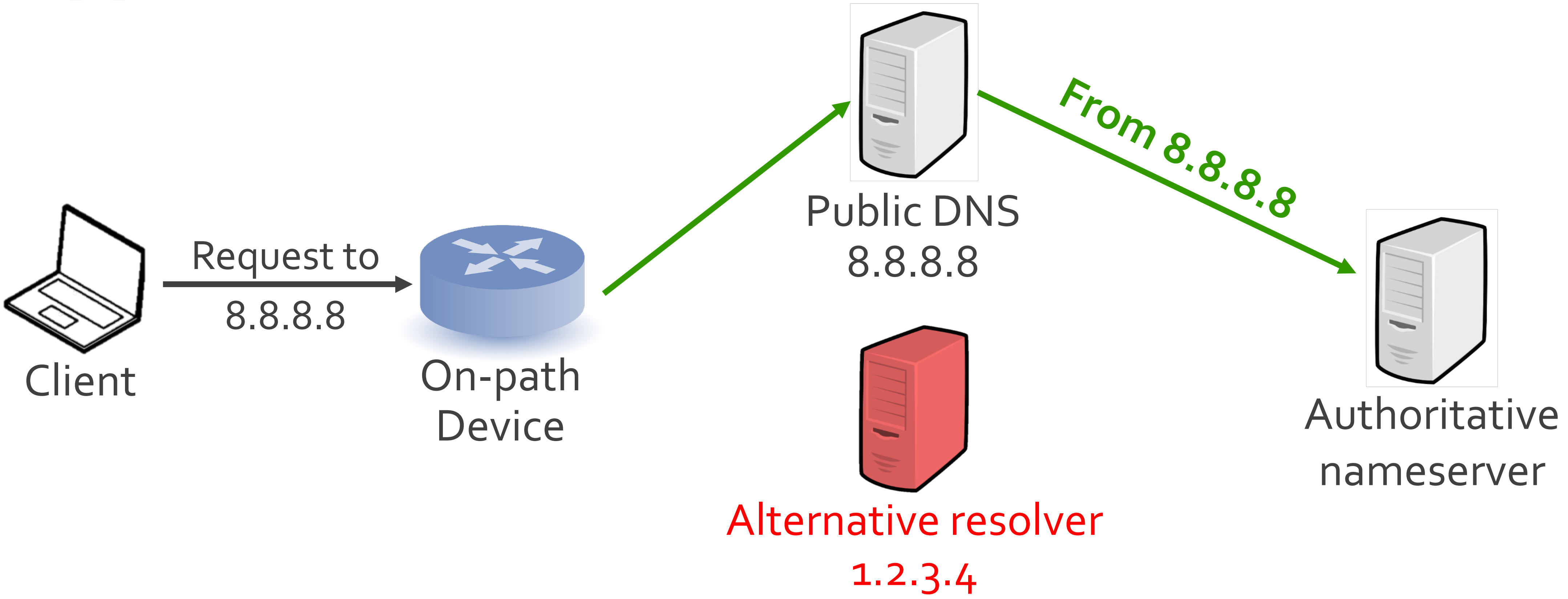
Analysis

Threat Model



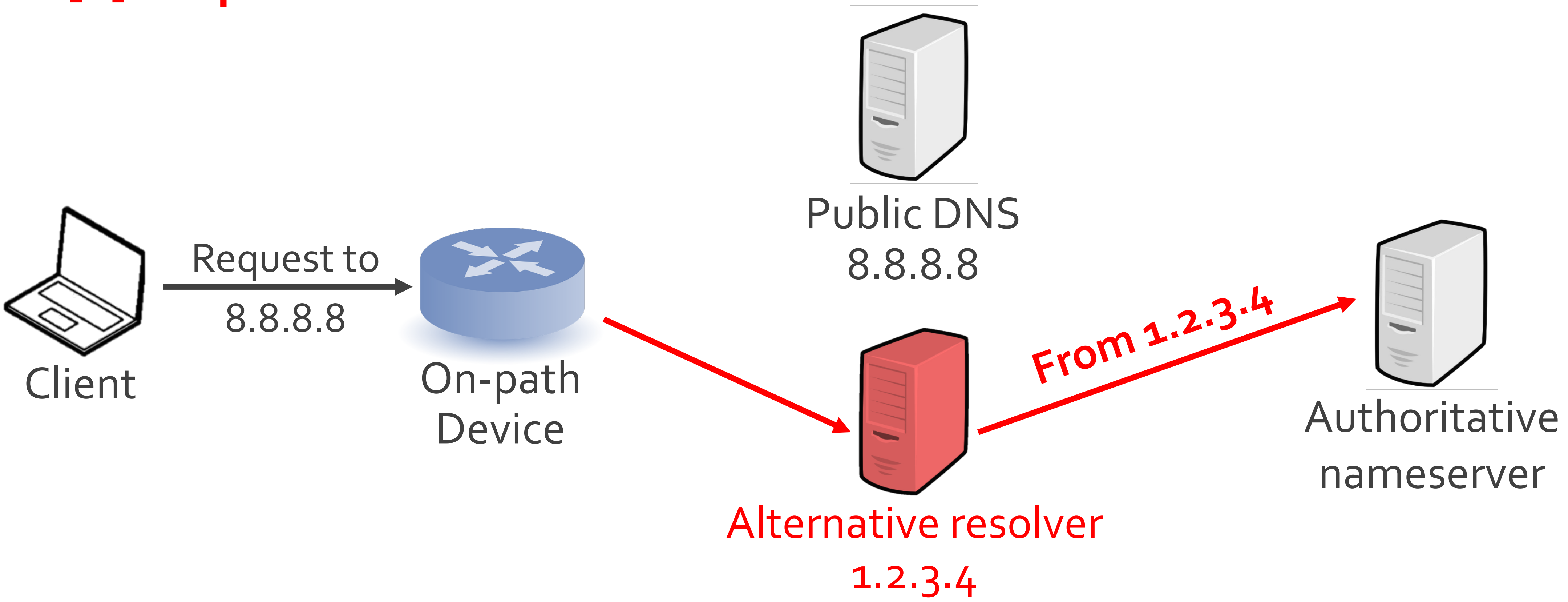
Threat Model

- Taxonomy (request only)
  - **[1] Normal resolution**



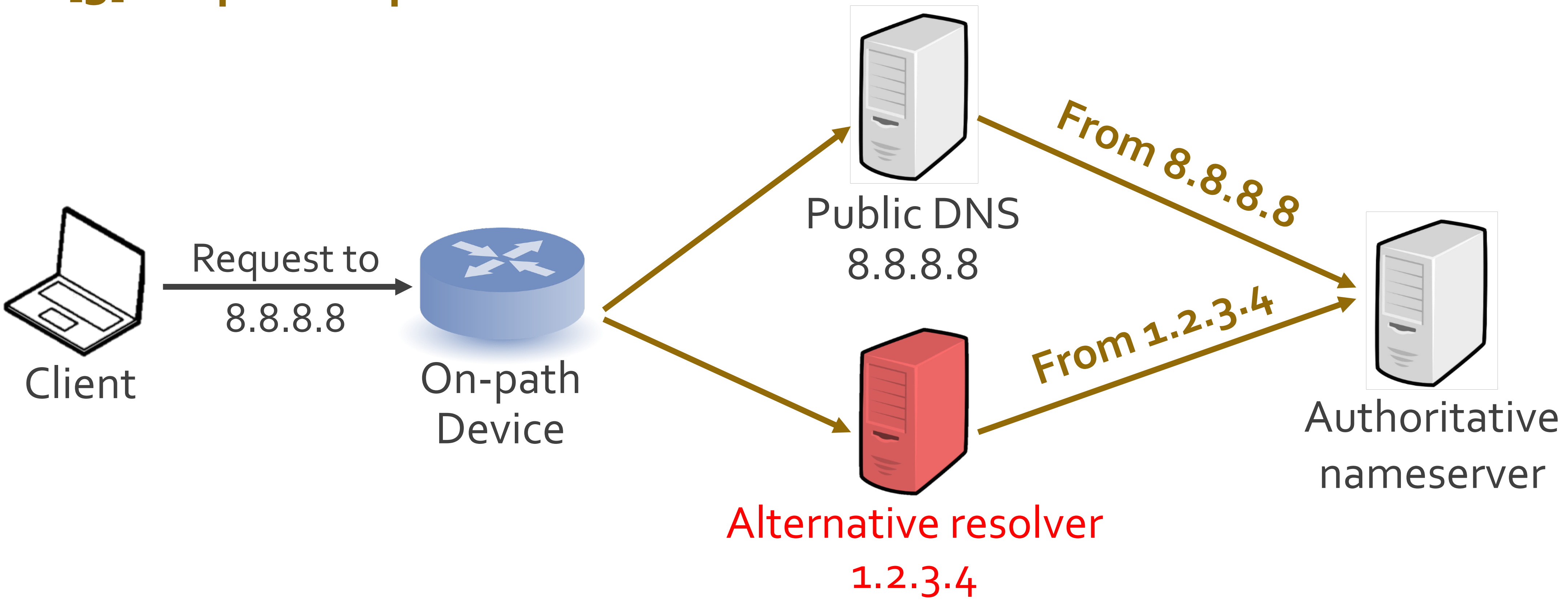
Threat Model

- Taxonomy (request only)
  - **[2] Request redirection**



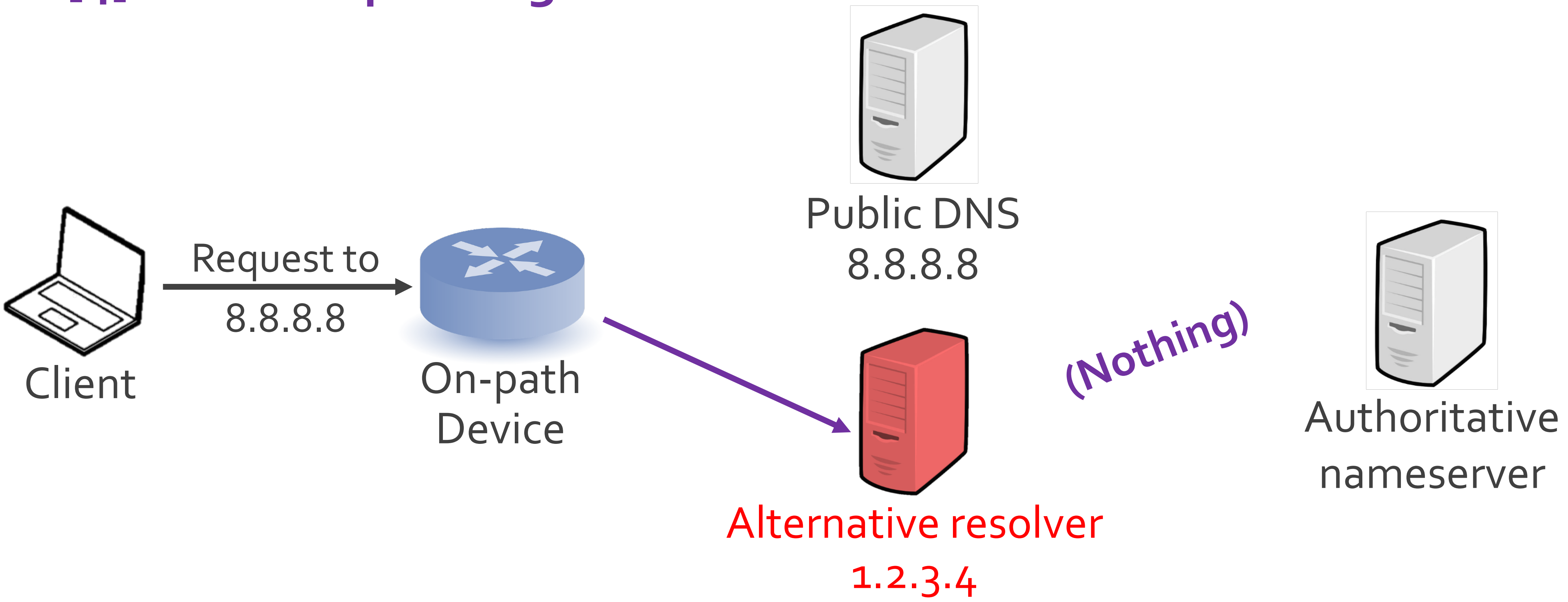
Threat Model

- Taxonomy (request only)
  - [3] Request replication



Threat Model

- Taxonomy (request only)
  - [4] Direct responding



Motivation

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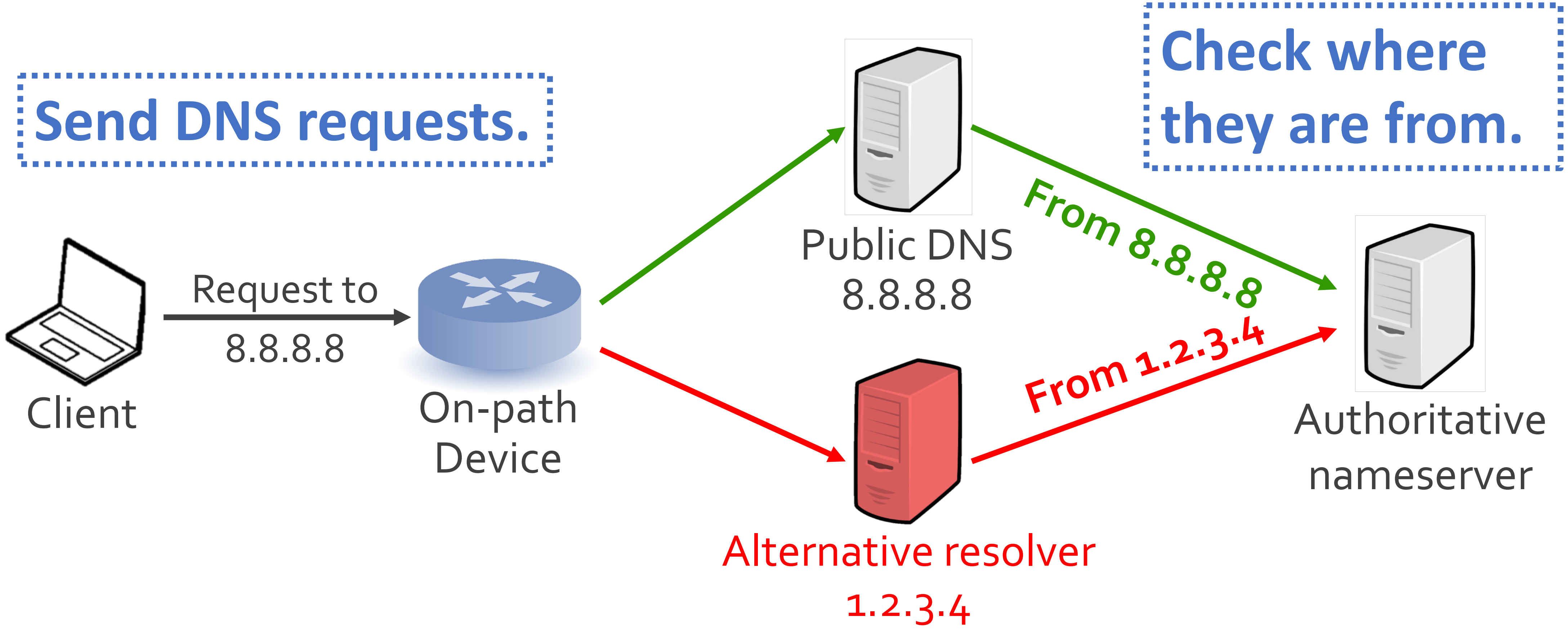
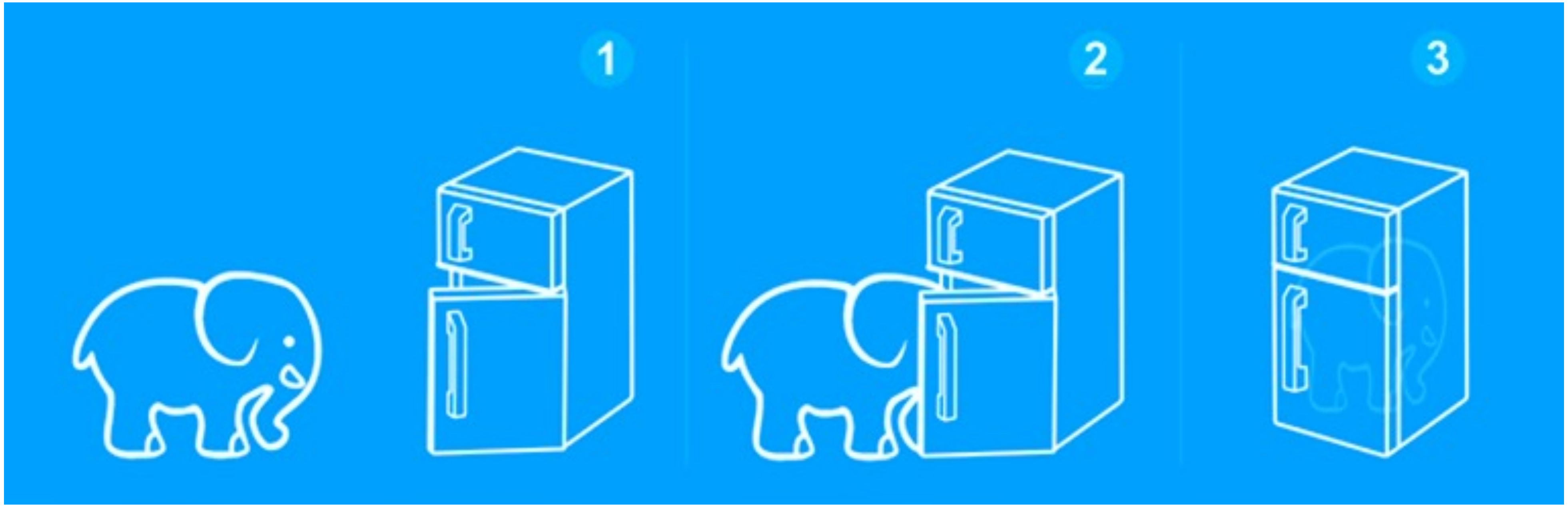
How to Detect?

- At a glance



How to Detect?



[1] Open the refrigerator
[2] Put in the elephant
[3] Close the door

→

[1] Collect vantage points
[2] Send DNS requests
[3] Collect requests on NS

* Pic source: cdc.tencent.com

Collect vantage points

Diversify DNS requests

Identify egress IP

Vantage Points

- Requirements
  - Ethical
  - Large-scale and geo-diverse
  - **Directly send DNS packets to specified IP**

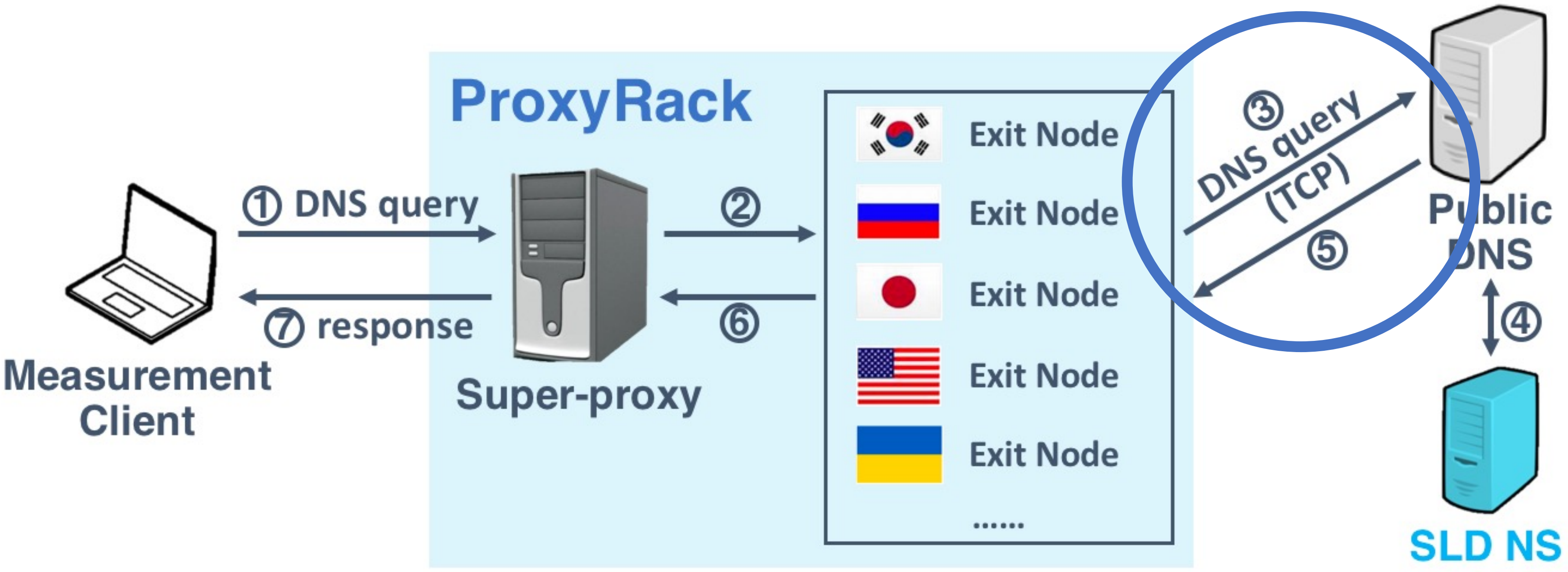
Measurement frameworks

- Advertisement Networks
  - Flash applet [Huang, W2SP'11] [Chen, CCS'16]
  - JavaScript [Burnett, Sigcomm'15]
- HTTP Proxy Networks
  - Luminati [Chung, IMC'16] [Tyson, WWW'17], [Chung, Security'17]
- Internet Scanners
  - Open DNS resolver [Kuhrer, IMC'15] [Pearce, Security'17]
  - Scanners [Zakir, Security'13] [Pearce, SP'17]

Cannot be used in this study.

Vantage Points

- Phase I: Global Analysis
  - ProxyRack: SOCKS5 residential proxy networks
  - Limitation: **TCP** traffic only



Vantage Points

- Phase I: Global Analysis
  - ProxyRack: SOCKS5 residential proxy networks
  - Limitation: **TCP** traffic only
- Phase II: China-wide Analysis
  - A **network debugger module** of security software
  - Similar to ***Netalyzr*** [Kreibich, IMC' 10]
  - Capability: **TCP and UDP; Socket level**

Vantage Points

- Ethics considerations

Global (ProxyRack)	Pay for access
	Abide by ToS
	Only query our domain
China-wide (network debugging tool)	One-time consent
	Restrict traffic amount
	Only query our domain

Collect vantage points

Diversify DNS requests

Identify egress IP

DNS Requests

- Requirements
  - **Diverse**: triggering interception behaviors
  - **Controlled**: allowing fine-grained analysis

Public DNS	*Google, OpenDNS, Dynamic DNS, EDU DNS*
Protocol	*TCP, UDP*
QTYPE	*A, AAAA, CNAME, MX, NS*
QNAME (TLD)	*com, net, org, club*
QNAME	UUID.[Google].OurDomain. [TLD]

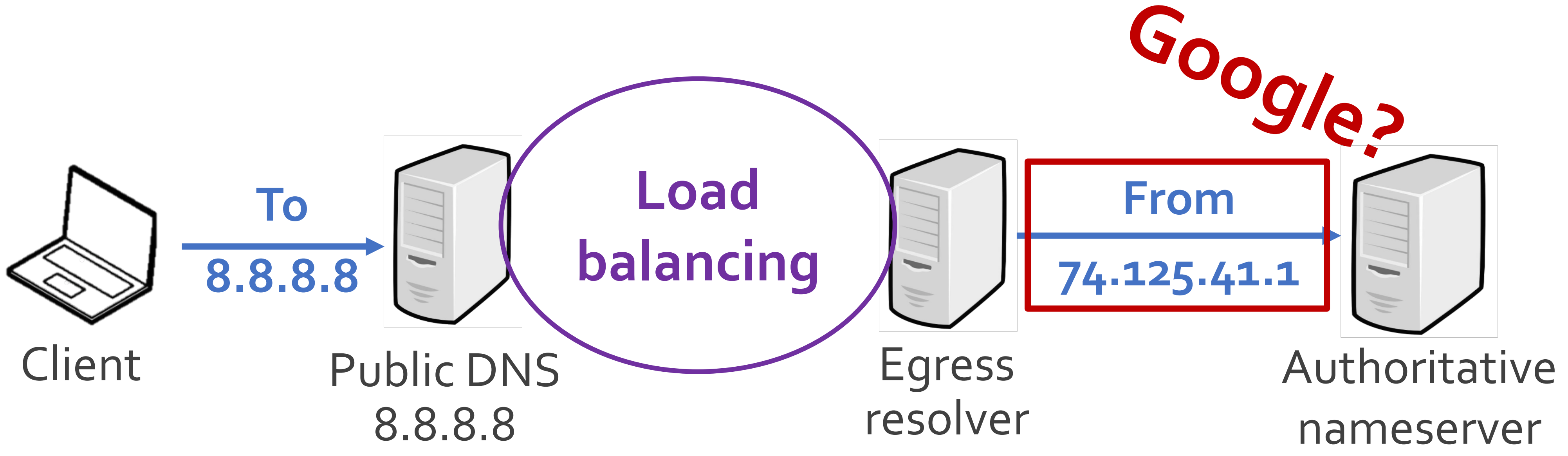
Collect vantage points

Diversify DNS requests

Identify egress IP

Egress IP

- Ownership of resolver IP
  - Is a request from public DNS?



Egress IP

- Ownership of resolver IP
  - Is a request from public DNS?
- Solution
  - **PTR & SOA records** of reverse lookups

```
$ dig -x 74.125.41.1

;; AUTHORITY SECTION:
125.74.in-addr.arpa.60    IN    SOA  ns1.google.com.
dns-admin.google.com. 207217296 900 900 1800 60
```

Collected Dataset

- DNS requests from vantage points
  - **A wide range of requests** collected

Phase	# Request	# IP	# Country	# AS
ProxyRack	1.6 M	36K	173	2,691
Debugging tool	4.6 M	112K	87	356

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Q1: Interception Characteristics

Q2: DNS Lookup Performance

Q3: Response Manipulation

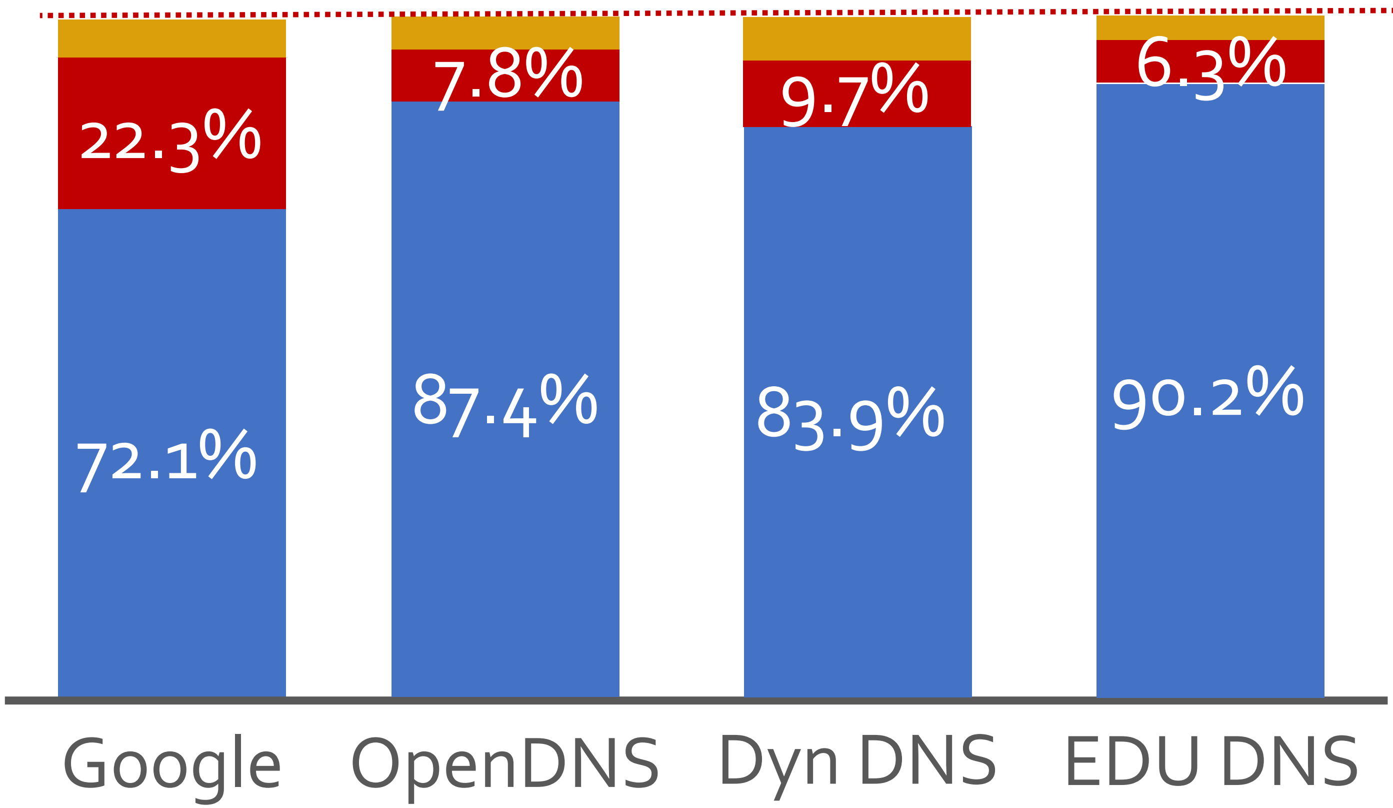
Q4: Security Threats

Q5: Interception Motivations

Q6: Solutions

Interception Characteristics

- Magnitude (% of total requests)
  - Normal resolution   Request redirection   Request replication

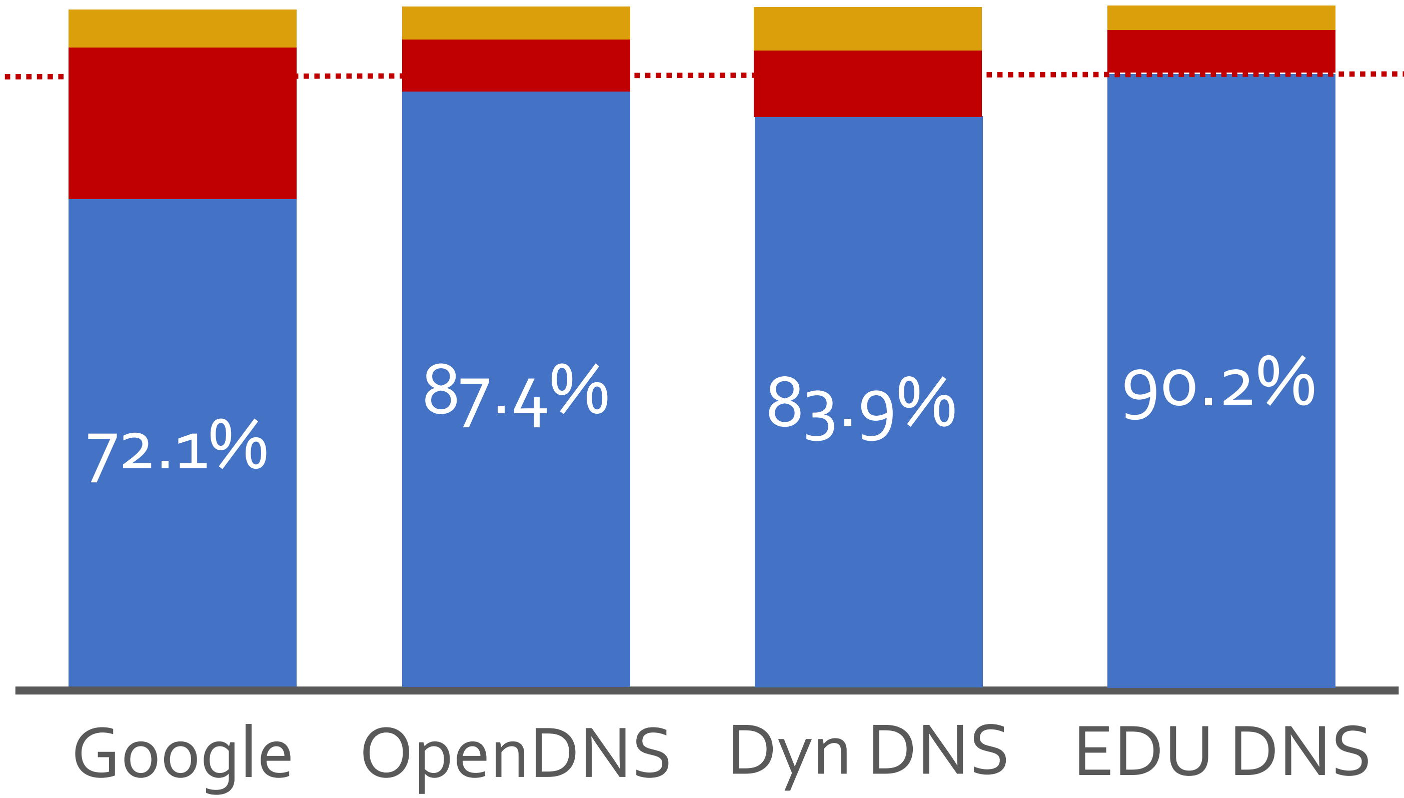


Direct responding is rare.

Request redirection > Request replication

Interception Characteristics

- Magnitude (% of total requests)
  - **Normal resolution** **Request redirection** **Request replication**



Requests to **popular public DNS services** are more likely to be intercepted.

Interception Characteristics

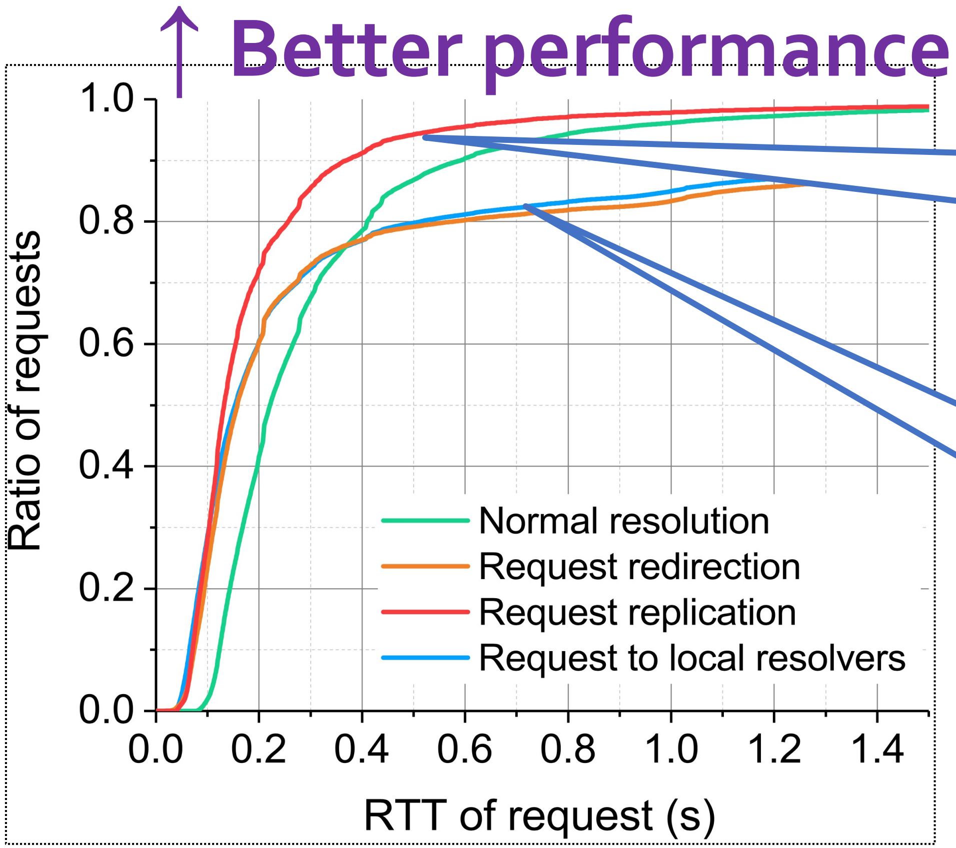
- ASes (% of total requests)
  - Sorted by # of total requests

AS	Organization	Redirection	Replication	Alternative Resolver
AS4134	China Telecom	5.19%	0.2%	116.9.94.* (AS4134)
AS4837	China Unicom	4.59%	0.51%	202.99.96.* (AS4837)
AS9808	China Mobile	**32.49%**	**8.85%**	112.25.12.* (AS9808)
AS56040	China Mobile	**45.09%**	0.04%	120.196.165.* (AS56040)

Interception strategies can be **complex**, and **vary** among ASes.

DNS Lookup Performance

- RTT of requests
  - Which requests complete faster?

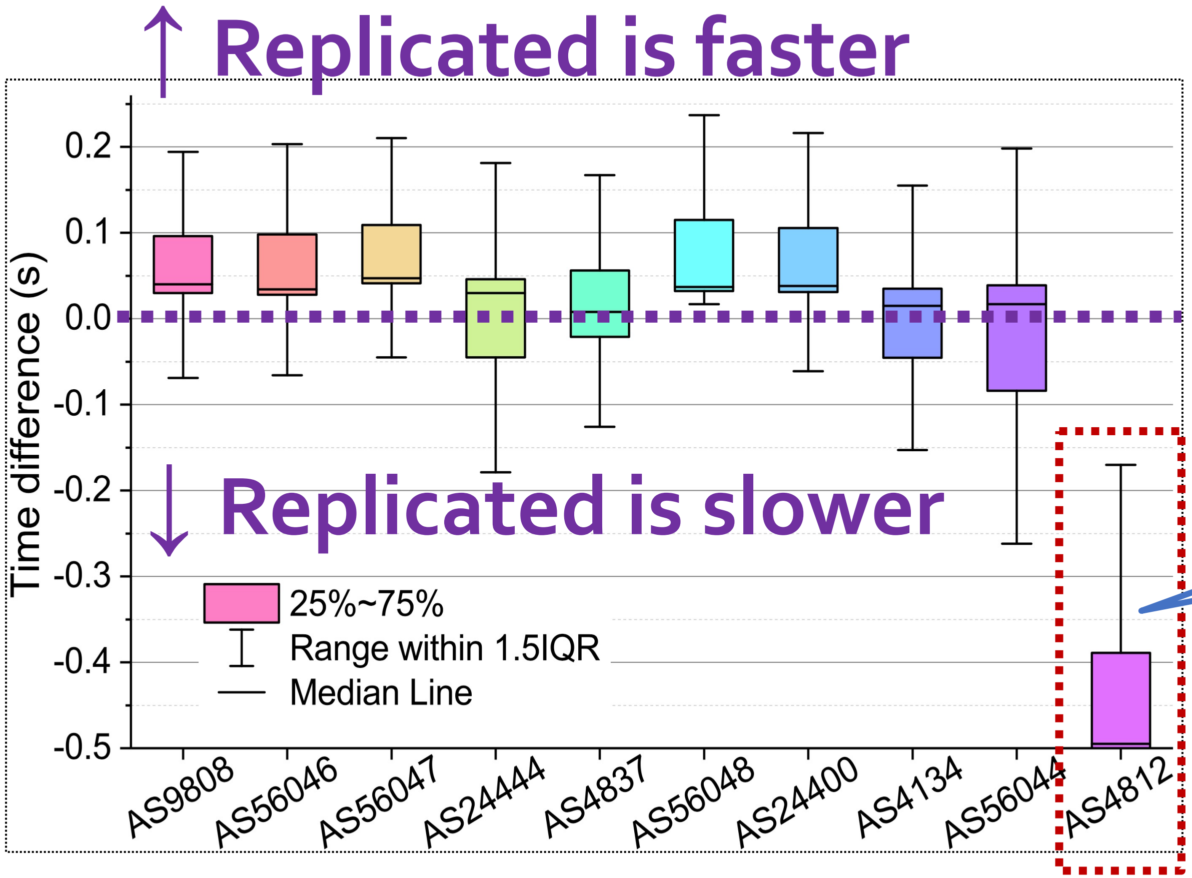


Request replication vs. Normal resolution:
Better.

Request redirection vs. Request to local resolver:
Very similar.

DNS Lookup Performance

- Arrival time of replicated requests
  - Which requests reach NS faster?



In AS4812, **ALL** replicated requests arrive **slower than** their original counterparts.

Response Manipulation

- DNS record values
  - Which responses are tampered?

Classification	#	Response Example	Client AS
Gateway	54	192.168.32.1	AS4134, CN, China Telecom
Monetization	10	39.130.151.30	AS9808, CN, GD Mobile
Misconfiguration	26	::218.207.212.91	AS9808, CN, GD Mobile
Others	54	fe80::1	AS4837, CN, China Unicom

Response Manipulation

- Example: traffic monetization

China Mobile Group of Yunnan: **advertisements of an APP**.

Security Threats

- Ethics & privacy
  - Users may **not be aware** of the interception behavior
- Alternative resolvers' security
  - An analysis on **205 open alternative resolvers**

Only 43% resolvers support DNSSEC

BIND

Berkeley Internet Domain Name

ALL BIND versions should be deprecated before 2009

Interception Motivations

- Vendors
  - Routers
  - Software platforms
- Motivations
  - Improving DNS security ?
  - Improving DNS lookup performance ?
  - Reducing traffic financial settlement

Solutions

- Encrypted DNS
  - **Resolver authentication (RFC8310)**
  - DNS-over-TLS (RFC7858)
  - DNS-over-DTLS (RFC8094, experimental)
  - DNS-over-HTTPS
- Online checking tool
  - Which resolver are you really using?
  - http://whatismydnsresolver.com/

Conclusions

- Understanding
  - A measurement platform to systematically study DNS interception
- Findings
  - DNS interception exists in 259 ASes we inspected globally
  - Up to 28% requests from China to Google are intercepted
  - Brings security concerns
- Motivations
  - Reducing traffic financial settlement
- Mitigation
  - Online checking tool

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