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POPS: Mitigation of DNS Cache Poisoning Attacks

Yehuda Afek, Harel Berger, Anat Bremler Barr

Usenix-Security Aug 14, 2025 Seattle USA

N - DNS Cache Poisoning is still kicking…

DNS Cache Poisoning Remains Pervasive — and Highly Dangerous

CVE-2008-1447
CVE-2008-1454
CVE-2008-1146
CVE-2007-2926
CVE-2002-2211
CVE-2002-2212
CVE-2002-2213

…oning bugs hits Symantec

cold

The financial sector has emerged …
the impact of DNS attacks.

GlobalData. | GlobalData Thematic Intelligence | November 6, 2023

[TuDoor Attack: Systematically Exploring and Exploiting Logic Vulnerabilities in DNS Response Pre-processing with Malformed Packets
SP-**2024** Xiang Li; Wei Xu; Baojun Liu; Mingming Zhang; Zhou Li; Jia Zhang]

PoPS

New Fast & Efficient

Detection & Mitigation

of ***all*** Statistical DNS Poisoning attacks

with 0 FN and negligible FP

PoPS

__all__ Statistical DNS Poisoning attacks

1st statistical

1. Standard Statistical attacks

2nd Fragment

2. Fragmentation attacks

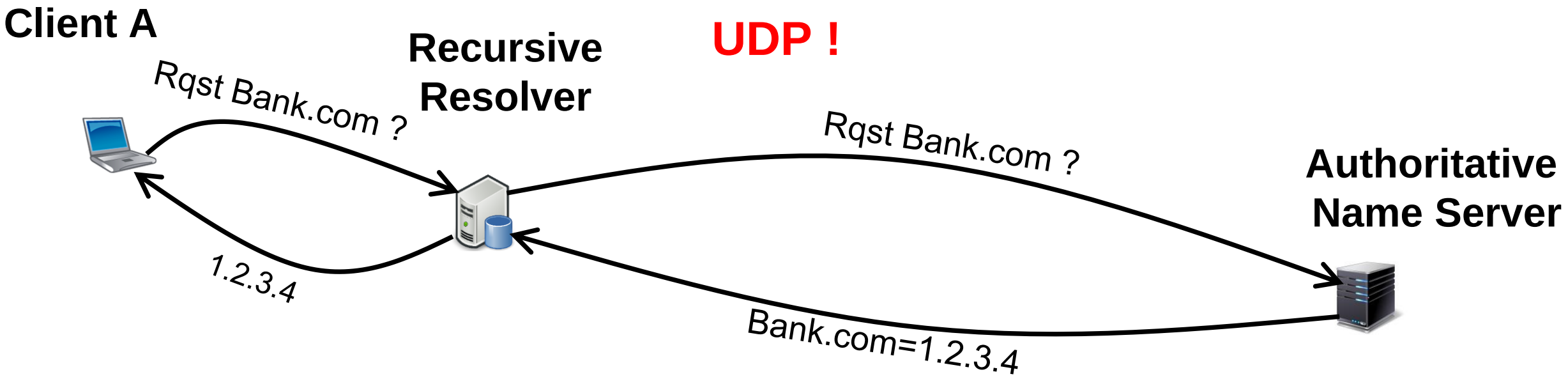
3rd Out-of-Bailiwick

3. Out-of-Bailiwick attacks

We do not detect|mitigate Session hijacking attacks:

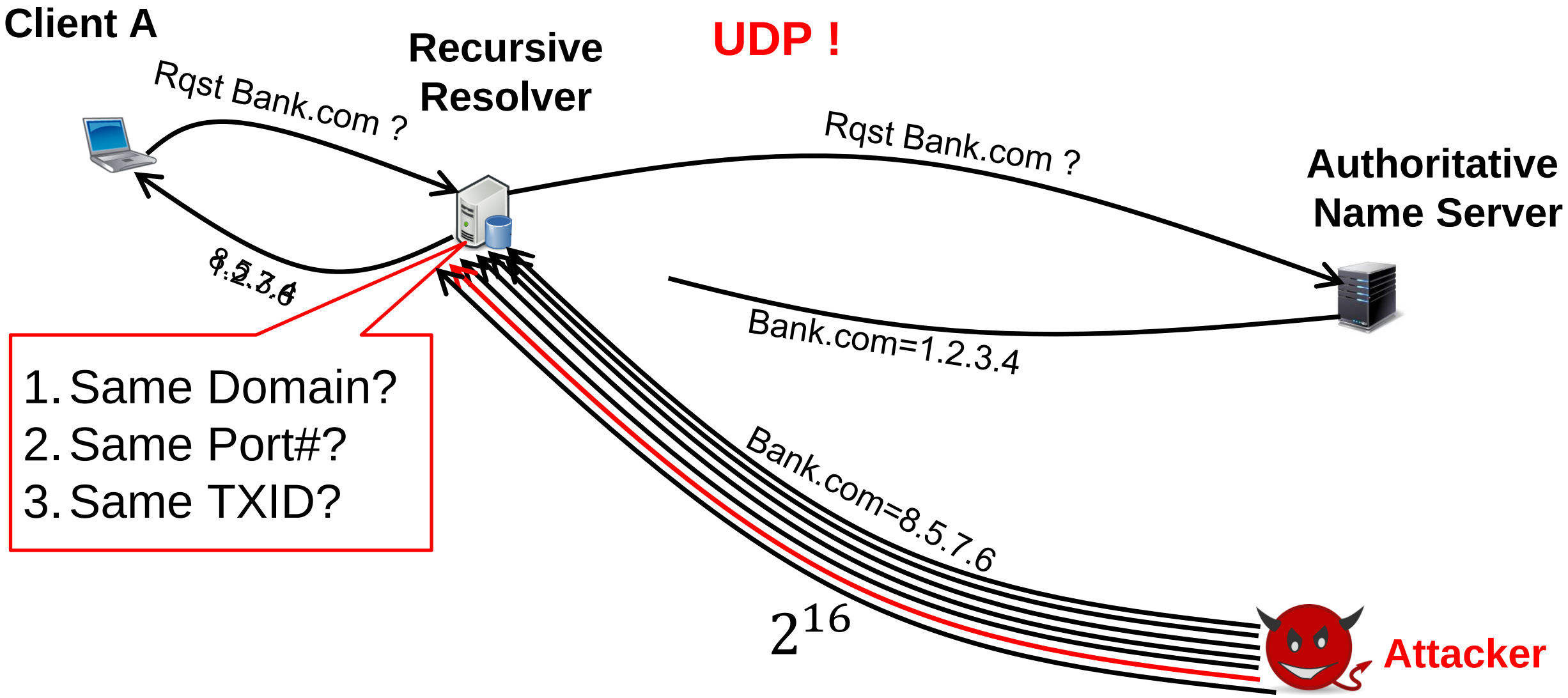
1. MITM poisoning attacks
2. BGP hijacking attacks

High level DNS request



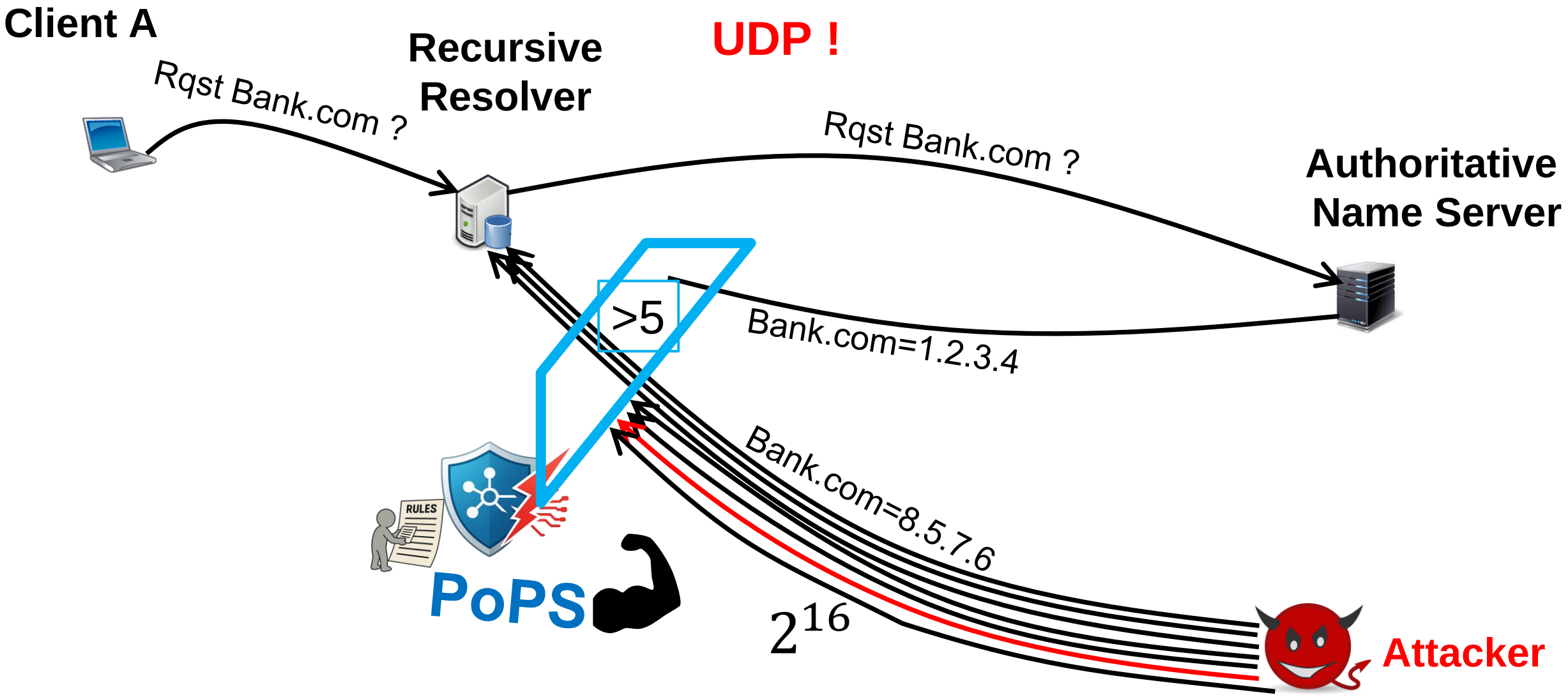
1st statistical

Statistical **Poisoning Attack**



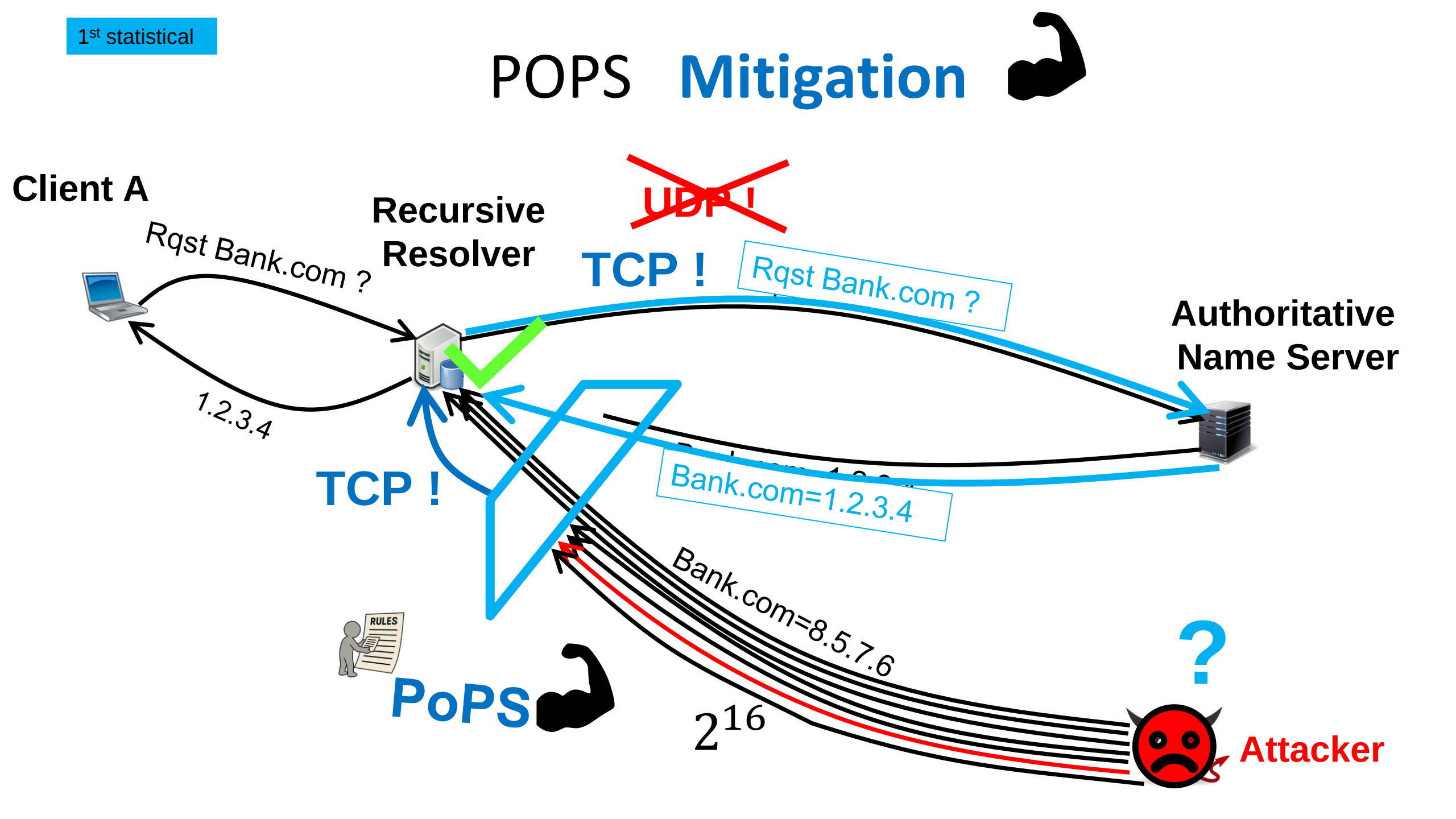
1st statistical

POPS Detection



1st statistical

POPS Mitigation



1st statistical

PoPS

Statistical attacks

- Detection: **minimize false negatives (FN)** **&** **negligible false positive, 0.0076% (FP)**
- Mitigation: **zero FN** * **&** **zero FP**

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- All together: **zero FN** **&** **negligible FP (0.0076%)**

In conclusion:

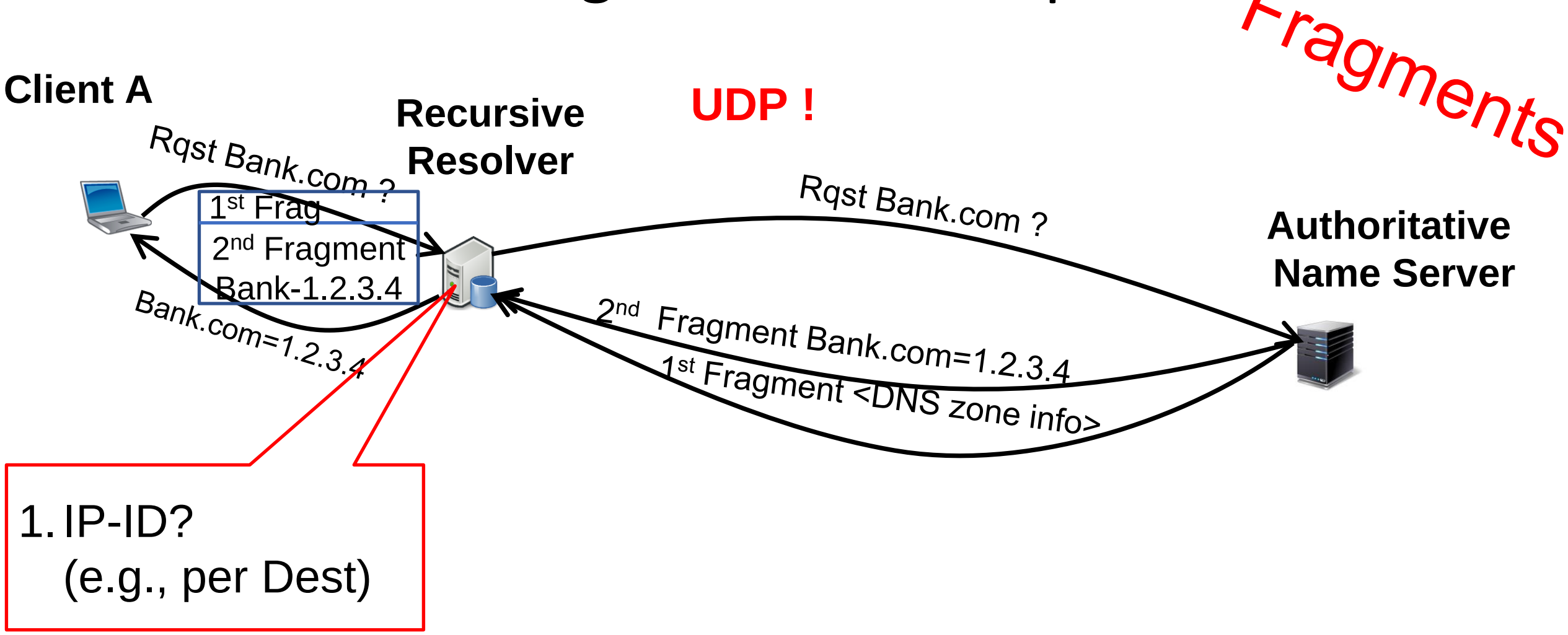
➔ Blocks 99.993% of attacks with **zero** false negatives!

➔ **Fast & efficient**

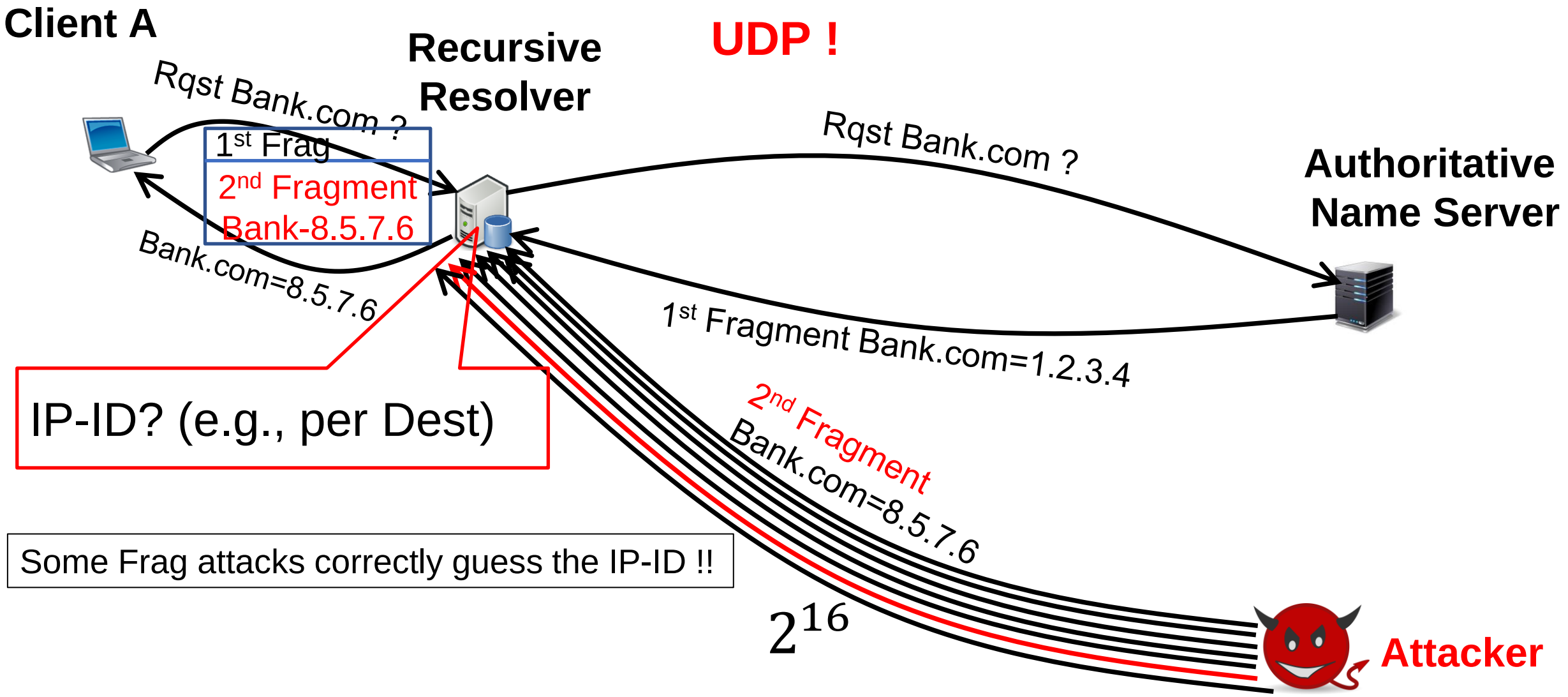
*Assuming resolvers respond \w TCP on TC bit
(all large ones. > 97% [Moura et.al. 21] [Bhowmick et.al.23])

2nd Fragmentation

DNS Fragmentation Response



Fragmentation Poisoning Attack

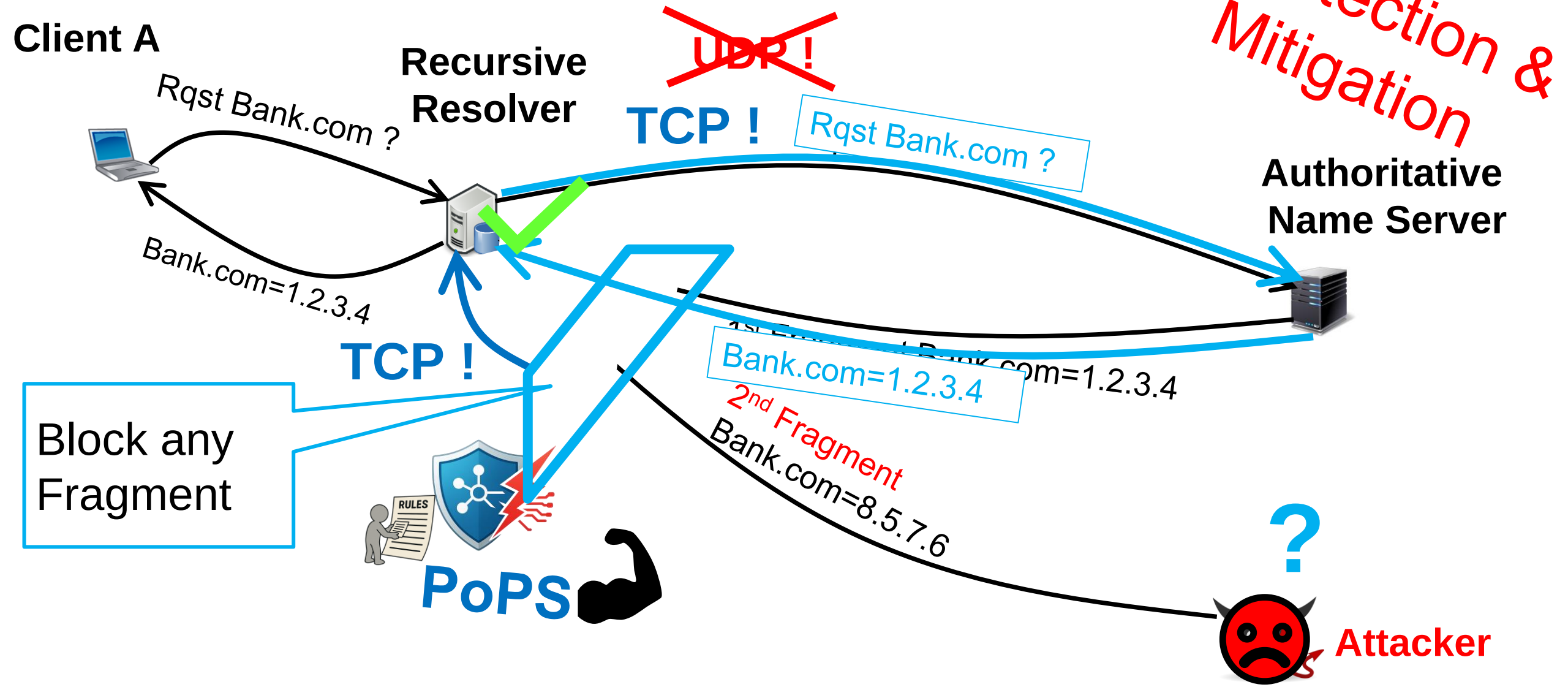


Some Frag attacks correctly guess the IP-ID !!

2nd Fragmentation

Fragmentation Poisoning Attack

Detection & Mitigation



2nd Fragmentation

PoPS

Fragmentation attack

- Detection: **100% false negatives (FN)** **&** **0% false positive**
- Mitigation: **zero FN** * **&** **zero FP**

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- All together: **zero FN** **&** **zero FP**

In conclusion:

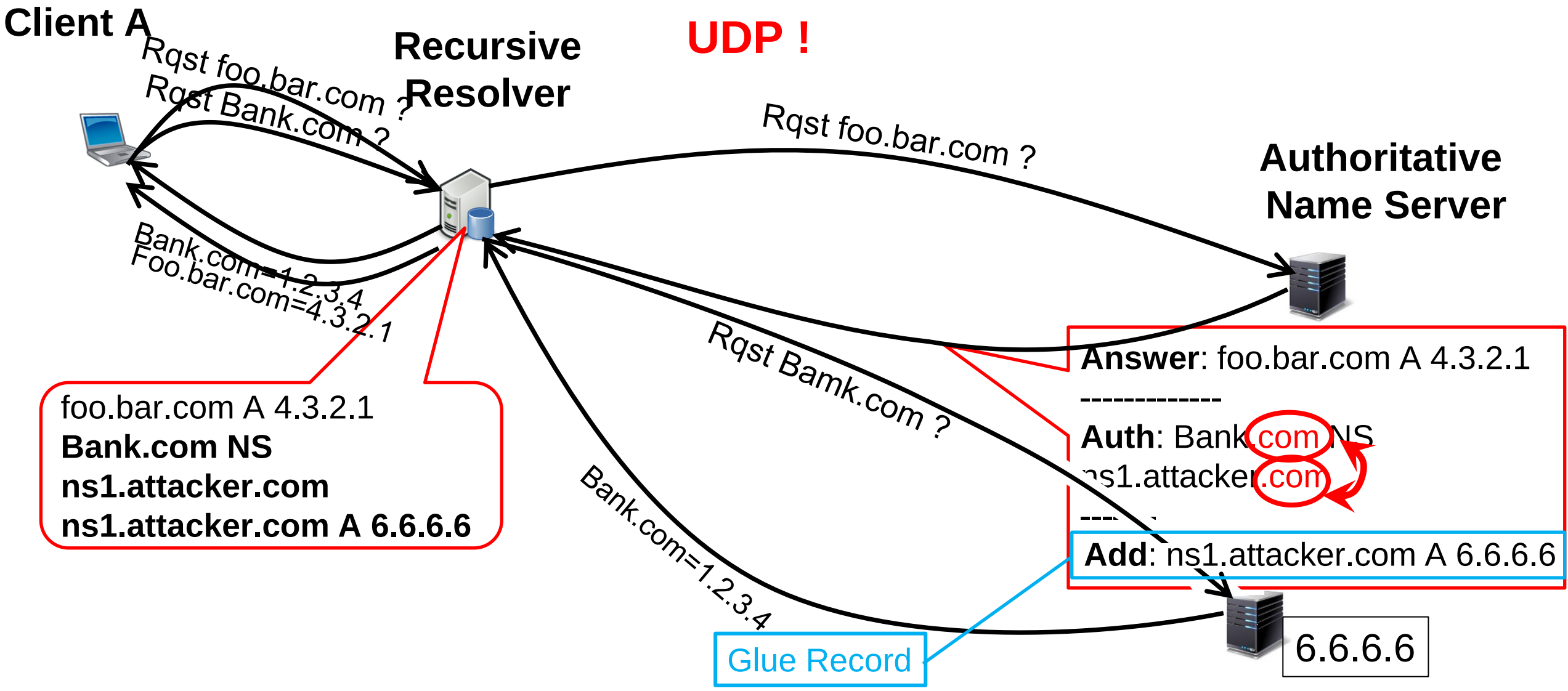
➔ Blocks 100% of fragmentation attacks with **zero** false negatives!

➔ **Fast & efficient**

*Assuming resolvers respond \w TCP on TC bit
(all large ones. > 97% [Moura et.al. 21] [Bhowmick et.al.23])

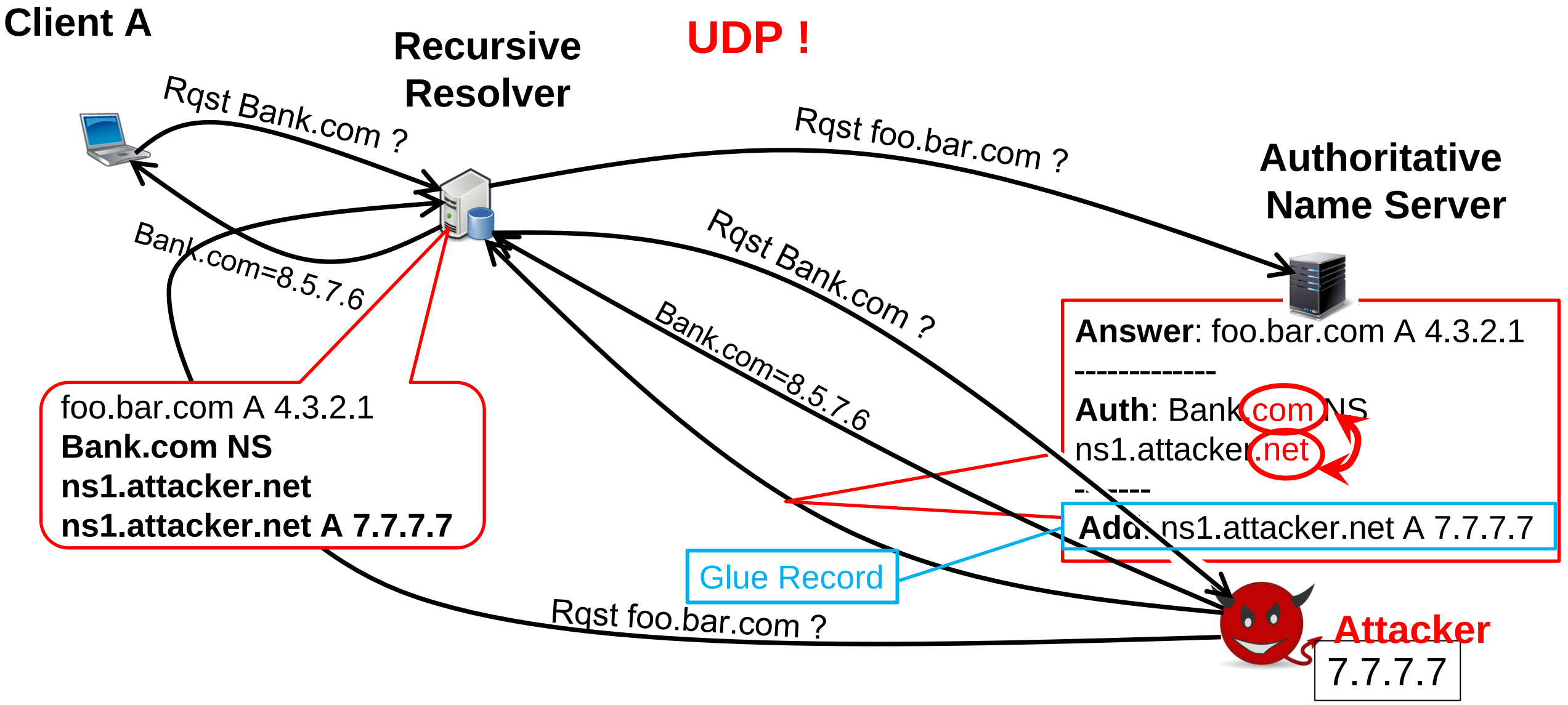
3rd Out-of-Bailiwick

In--Bailiwick DNS response



3rd Out-of-Bailiwick

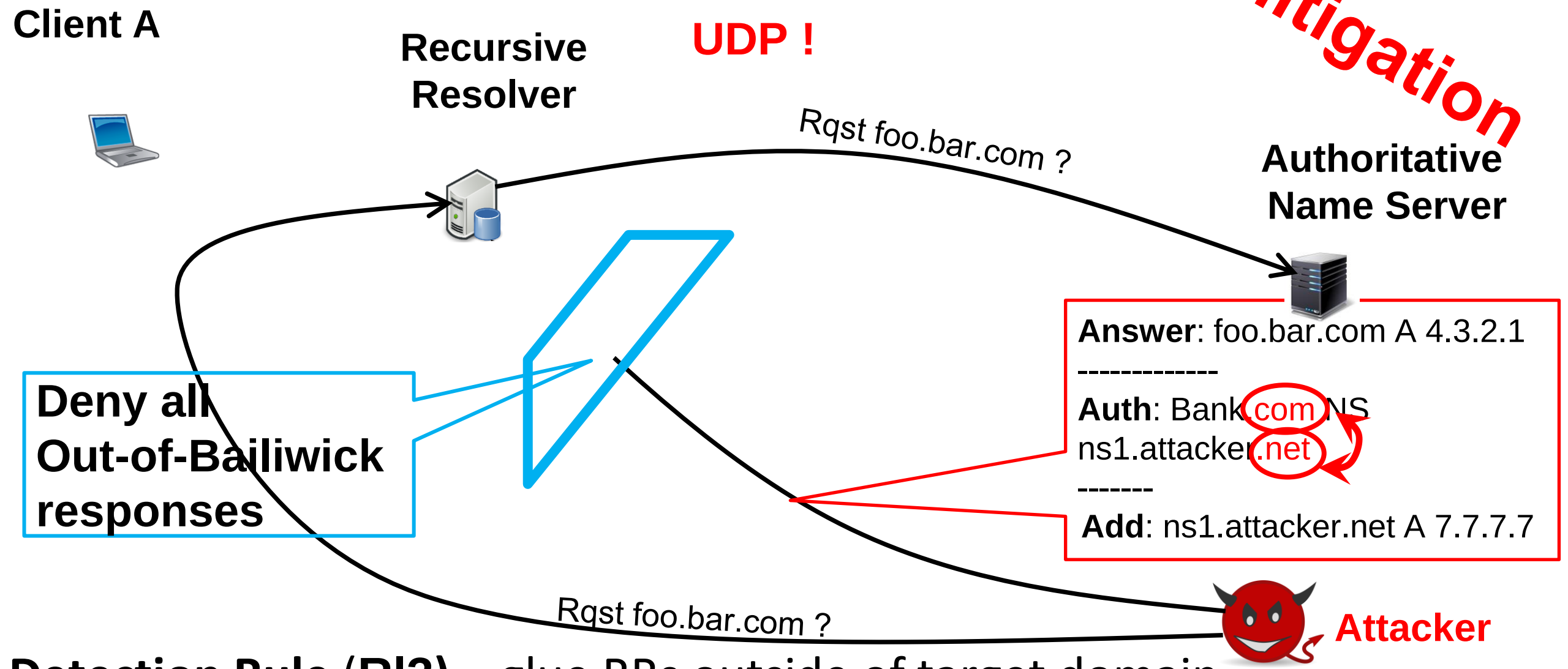
Out-of-Bailiwick Poisoning Attack



3rd Out-of-Bailiwick

Out-of-Bailiwick Poisoning Attack

Mitigation



Detection Rule (RI3) – glue RRs outside of target domain

PoPS 3 Detection rules

1st statistical

Rℓ1 >5 Catches attack after 5 packets!

- Using CMS, Minimum Memory (~4Kbit)

2nd Fragment

Rℓ2 - Fragmentation Attacks – any fragment.

3rd Out-of-Bailiwick

Rℓ3 - Out of Bailiwick Attacks – any out-of-bailiwick

= glue RRs outside the target domain

Detection Module vs. Attacks

Paper	Type	#Pkts	POPS
Schuba et al. [12] 1993	-	1	-
V. Sacramento [41] 2002	S	2^{16}	Rℓ1
Klein, Amit [42] 2007	S	>100	Rℓ1
Kaminsky, Dan [13] 2008	S	$200 \cdot q$	Rℓ1
Herzberg et al. [18] 2012	S	2^{16}	Rℓ1
Herzberg et al. [18] 2012	S_{Frag}	2^{16}	Rℓ2
Herzberg et al. [43] 2013	B_{Frag}	1	Rℓ2
Herzberg et al. [44] 2013	S_{Frag}	$\sim 2^{11}$	Rℓ2
Herzberg et al. [45] 2013	S, S_{Frag}	2^{16}	Rℓ1
Zheng et al. [46] 2020	B_{Frag}	1	Rℓ2
Man et al. [47] 2020	S	2^{16}	Rℓ1
Dai et al. [48] 2021	S_{Frag}	64	Rℓ1
Klein et al. [49] 2021	S	2^{16}	Rℓ1
Jeitner et al. [50] 2022	S	2^{16}	Rℓ1
Jeitner et al. [50] 2022	S	2^{16}	Rℓ1
Li et al. [17] 2023	S_{OoB}	2^{16}	Rℓ3
Heftring et al. [51] 2023	S_{Frag}	2^{16}	Rℓ2
Li et al. [22] 2024	S	2^{16}	Rℓ1

Mitigated CVEs

CVE	Type	Vendor	POPS
2023-30464 [88]	S	CoreDNS	Rℓ1
2023-28457 [89]	S	Microsoft DNS, Technitium	Rℓ1
2021-43105 [90]	B_{OOB}	Technitium	Rℓ3
2021-3448 [91]	S	dnsmasq	Rℓ1
2020-25684 [92, 93]	S	dnsmasq,Cisco, OpenWRT	Rℓ1
2017-12132 [94]	S_{Frag}	-	Rℓ2
2008-3217 [95]	S	PowerDNS	Rℓ1
2008-1447 [96]	S	BIND, Microsoft DNS	Rℓ1
2008-1454 [97]	B_{OOB}	Microsoft DNS	Rℓ3
2008-1146 [98]	S	OpenBSD's BIND	Rℓ1
2007-2926 [99]	S	ISC BIND	Rℓ1
2002-2211 [100]	S	BIND	Rℓ1
2002-2212 [101]	S	Fujitsu UXP/V	Rℓ1
2002-2213 [102]	S	Infoblox DNS	Rℓ1

Comparison to Suricata/Snort

Suricata & Snort

- Passive IDSs
- Cannot aggregate by domain name

POPS detection:

- 2x – 5x faster than Suricata/Snort
- 5%–10% of packets analyzed by Suricata/Snort
- Suricata/Snort 10×–20× more False Negatives than PoPS

Conclusions POPS:

- Simple Detection of DNS cache poisoning attacks (3 rules).
- Mitigation - TC Flag →TCP, Data Erasure ~0 FN, 0 FP.
- POPS mitigation works with any detection method various combinations are considered.

Thank you for listening!

For more information
https://deepness-lab.org

Open Source code:
https://zenodo.org/records/15688589