CSE227 – Graduate Computer Security

DNS

UC San Diego

Housekeeping

General course things to know

- Midpoint check-in document is due **TOMORROW at 11:59pm PT**
  - Introduction (frame the problem)
  - Related work section (should include ~5 – 10 relevant papers)
  - Research plan, current status, what's left to do
  - Submission is on Gradescope from *Canvas*
- Optional meetings with meet available next week on 20th

Today's lecture

Learning Objectives

- Learn what the domain name system is, how it works in practice, and how it really really works in practice
- Discuss the Kaminsky cache poisoning attack, how it works, and why it's still possible today

Preliminaries

What is DNS?

What is DNS?

Domain Name System: Our mechanisms for converting human-readable names to IP addresses.

Why do we have DNS?

Why do we have DNS?

Numbers are hard! Names are easier.

What’s easier to remember? 75.2.44.127, or **ucsd.edu**?

A brief history lesson

DNS back in the day

- There was a single file, called *hosts.txt*, that was run by the Stanford Research Institute for ARPANET membership
- SRI kept the main copy
    - Single place to update records (had to go through someone)
    - People would periodically download hosts.txt, that's how everyone knew what was happen
- <u>What are some problems with this approach?</u>

DNS Intuition

DNS Today

- Rather than centralize everything, we can *decentralize* everything
  - Build a “chain” of knowledge that starts with roots and goes down to the leaves
  - Every step of the way is a “pointer” to the next step, until you get to a final answer
- We can *recursively resolve* names to get to our final answer!
  - And you thought you’d never use recursion…

DNS Hierarchical Namespace

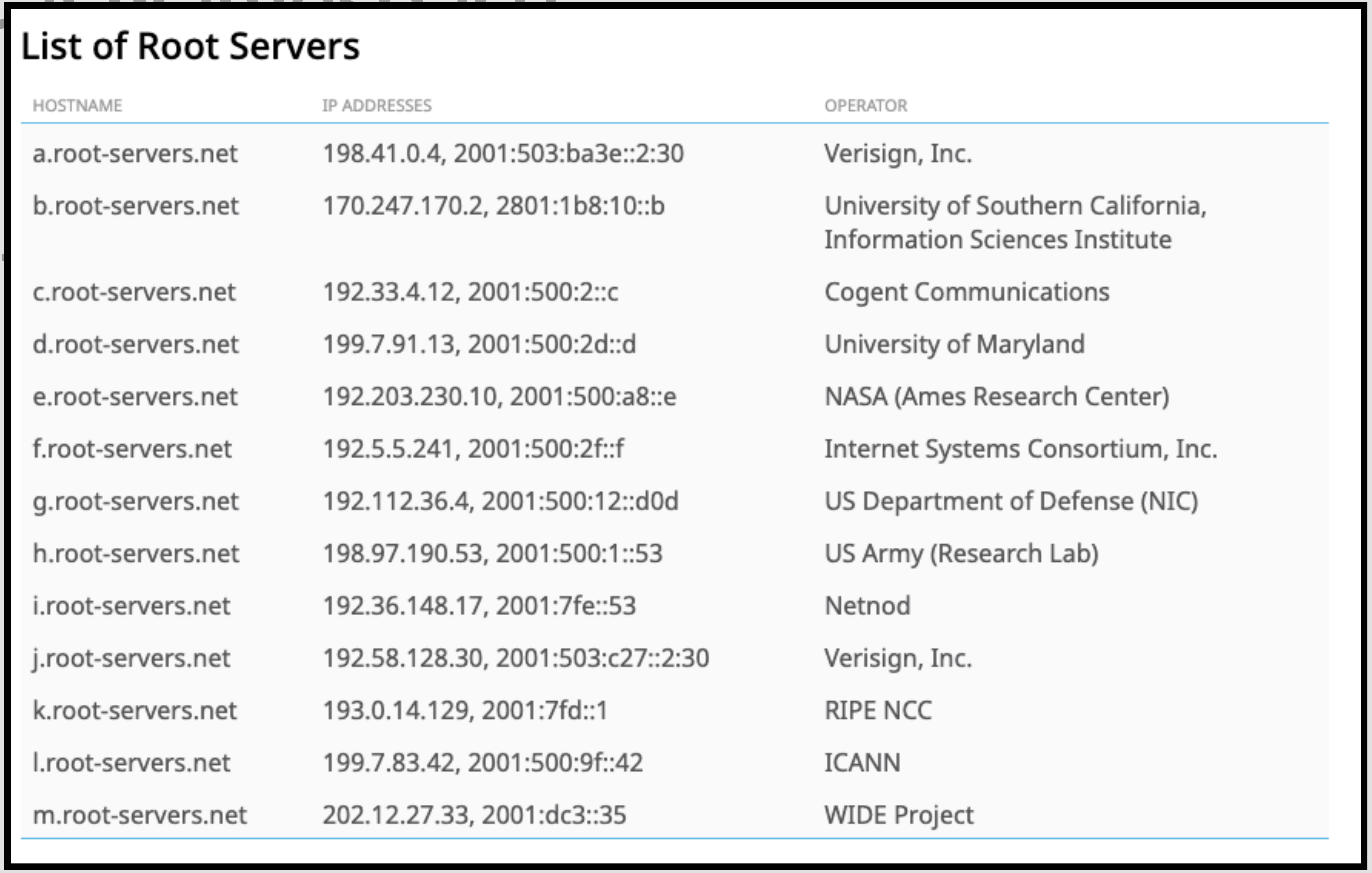
DNS Root *13 root servers*

ICANN

iana
Internet Assigned Numbers Authority

DNS Hierarchical Namespace

DNS Root



List of Root Servers

HOSTNAME	IP ADDRESSES	OPERATOR
a.root-servers.net	198.41.0.4, 2001:503:ba3e::2:30	Verisign, Inc.
b.root-servers.net	170.247.170.2, 2801:1b8:10::b	University of Southern California, Information Sciences Institute
c.root-servers.net	192.33.4.12, 2001:500:2::c	Cogent Communications
d.root-servers.net	199.7.91.13, 2001:500:2d::d	University of Maryland
e.root-servers.net	192.203.230.10, 2001:500:a8::e	NASA (Ames Research Center)
f.root-servers.net	192.5.5.241, 2001:500:2f::f	Internet Systems Consortium, Inc.
g.root-servers.net	192.112.36.4, 2001:500:12::d0d	US Department of Defense (NIC)
h.root-servers.net	198.97.190.53, 2001:500:1::53	US Army (Research Lab)
i.root-servers.net	192.36.148.17, 2001:7fe::53	Netnod
j.root-servers.net	192.58.128.30, 2001:503:c27::2:30	Verisign, Inc.
k.root-servers.net	193.0.14.129, 2001:7fd::1	RIPE NCC
l.root-servers.net	199.7.83.42, 2001:500:9f::42	ICANN
m.root-servers.net	202.12.27.33, 2001:dc3::35	WIDE Project

DNS Hierarchical Namespace

DNS Root	*13 root servers*	ICANN	iana Internet Assigned Numbers Authority
TLD	**.edu, .com,** etc.,	EDUCAUSE	VERISIGN™

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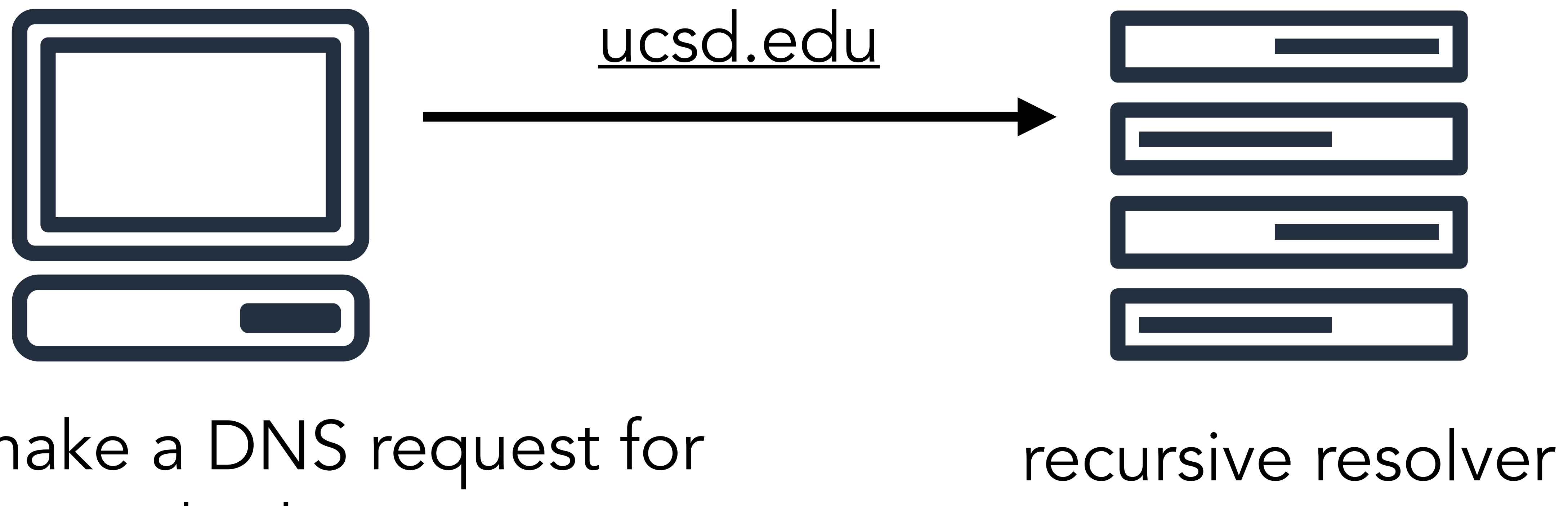
TLD	**.edu, .com,** etc.,	EDUCAUSE, VERISIGN™
Authoritative	**ucsd.edu**	UC San Diego
Authoritative	**deepak.ucsd.edu**	

Life of a DNS query

I want to make a DNS request for
ucsd.edu

Who do I talk to first?

Life of a DNS query



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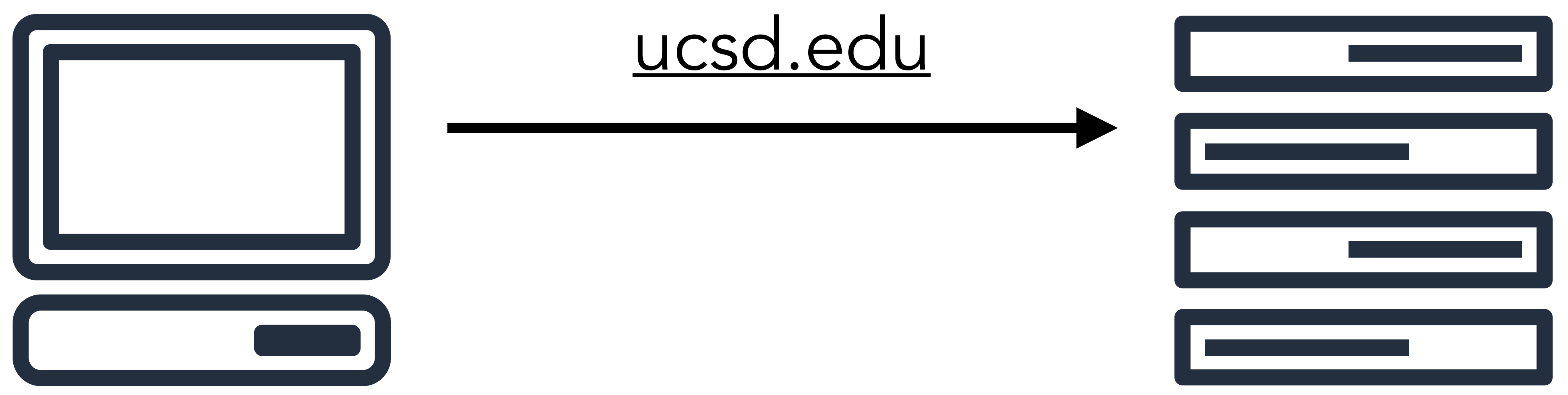
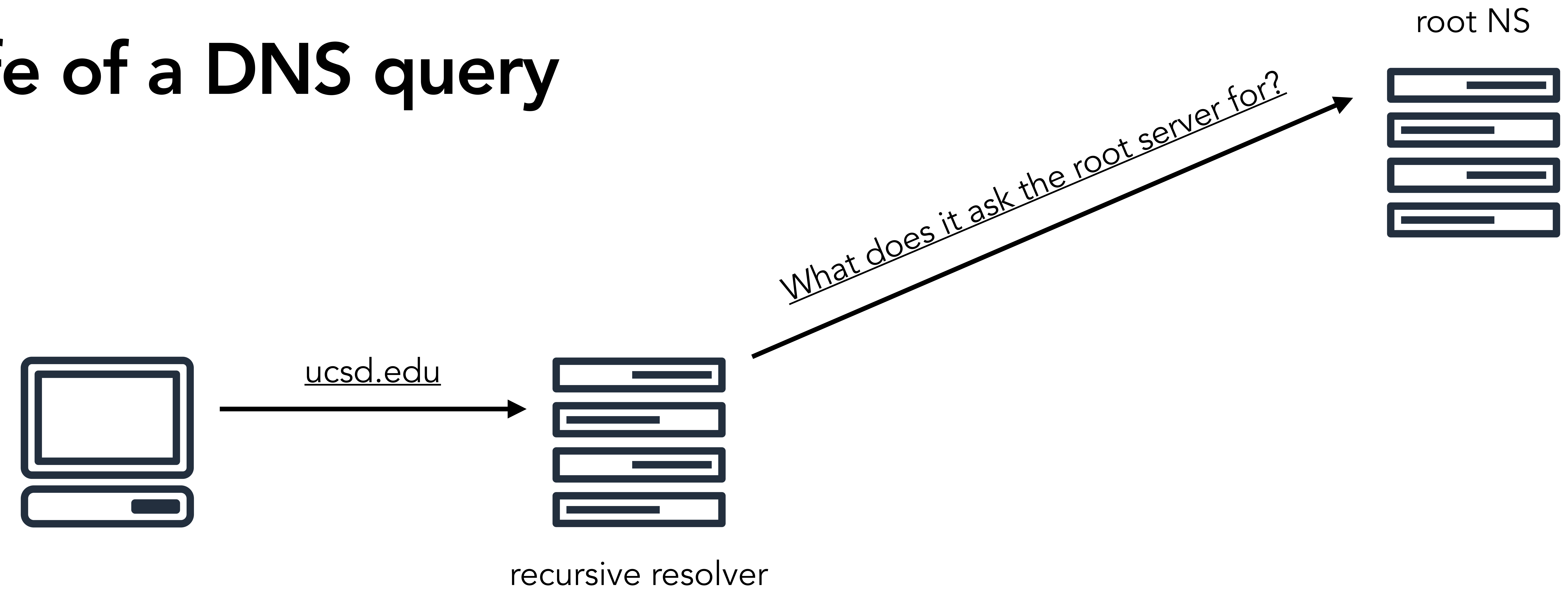


recursive resolver

The resolver has never heard of ucsd.edu.

Where does it go next?

Life of a DNS query



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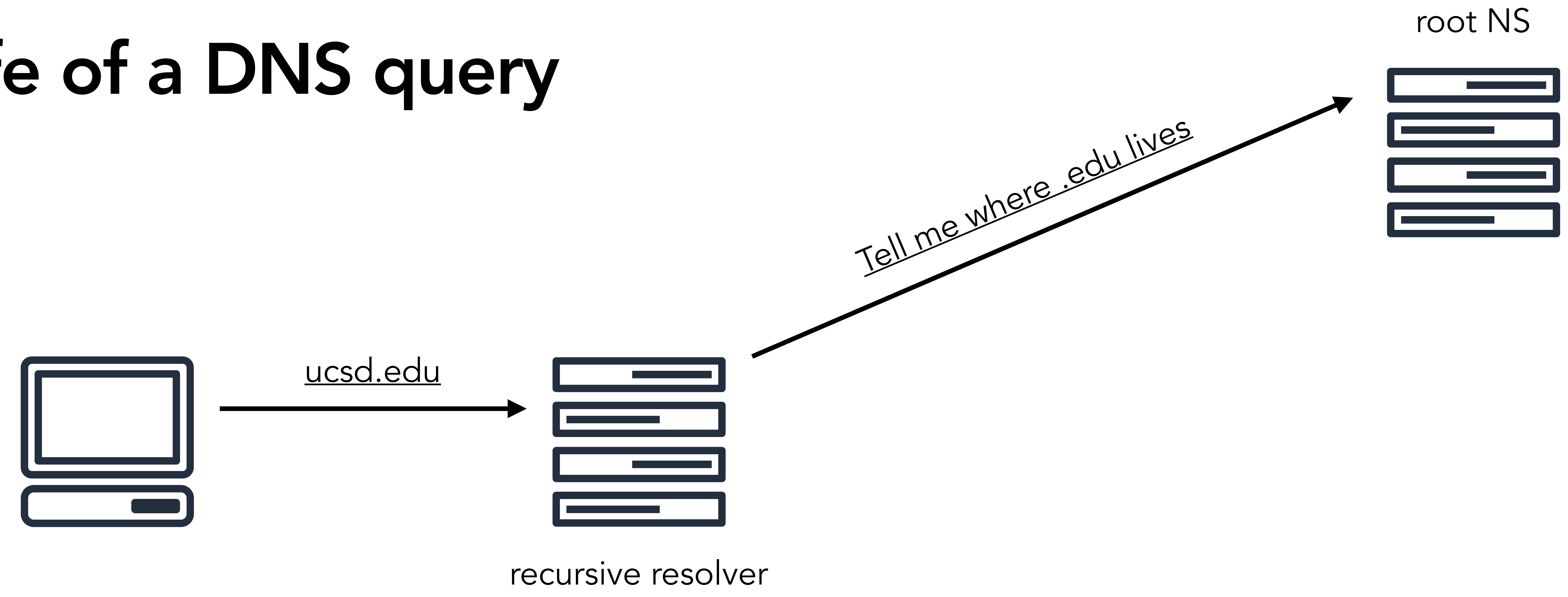

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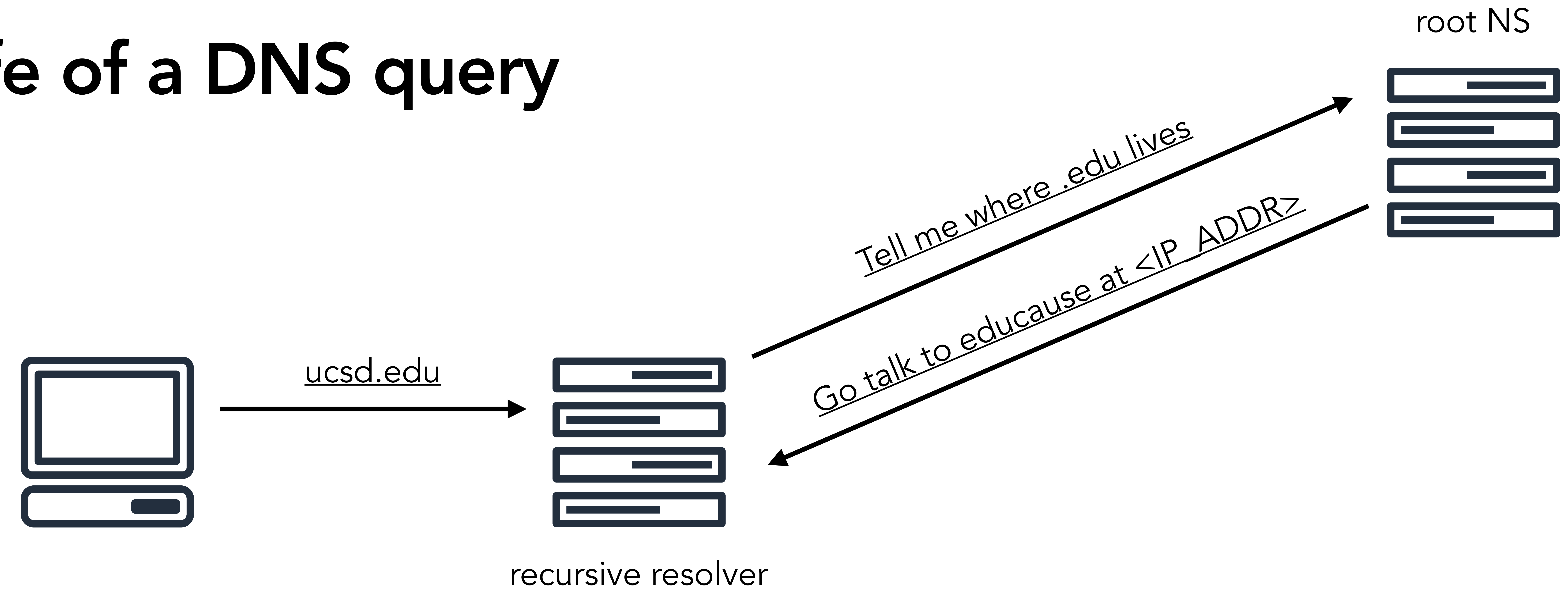

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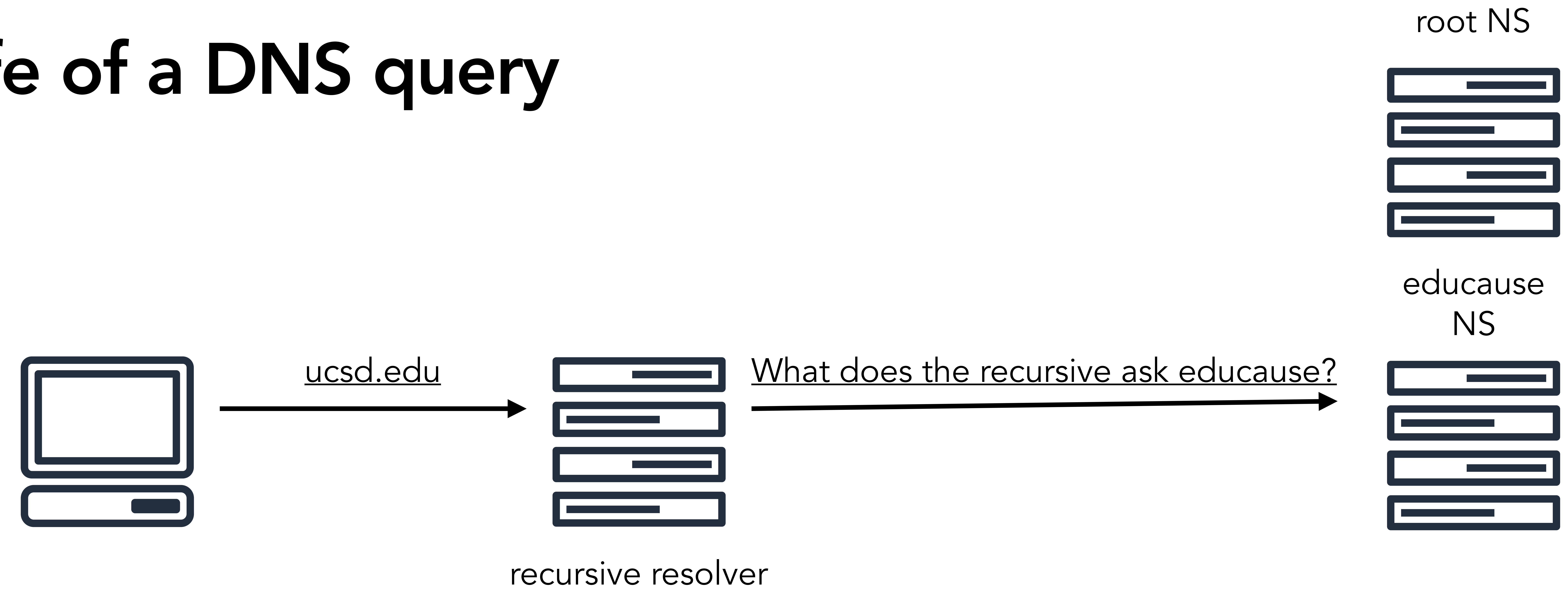

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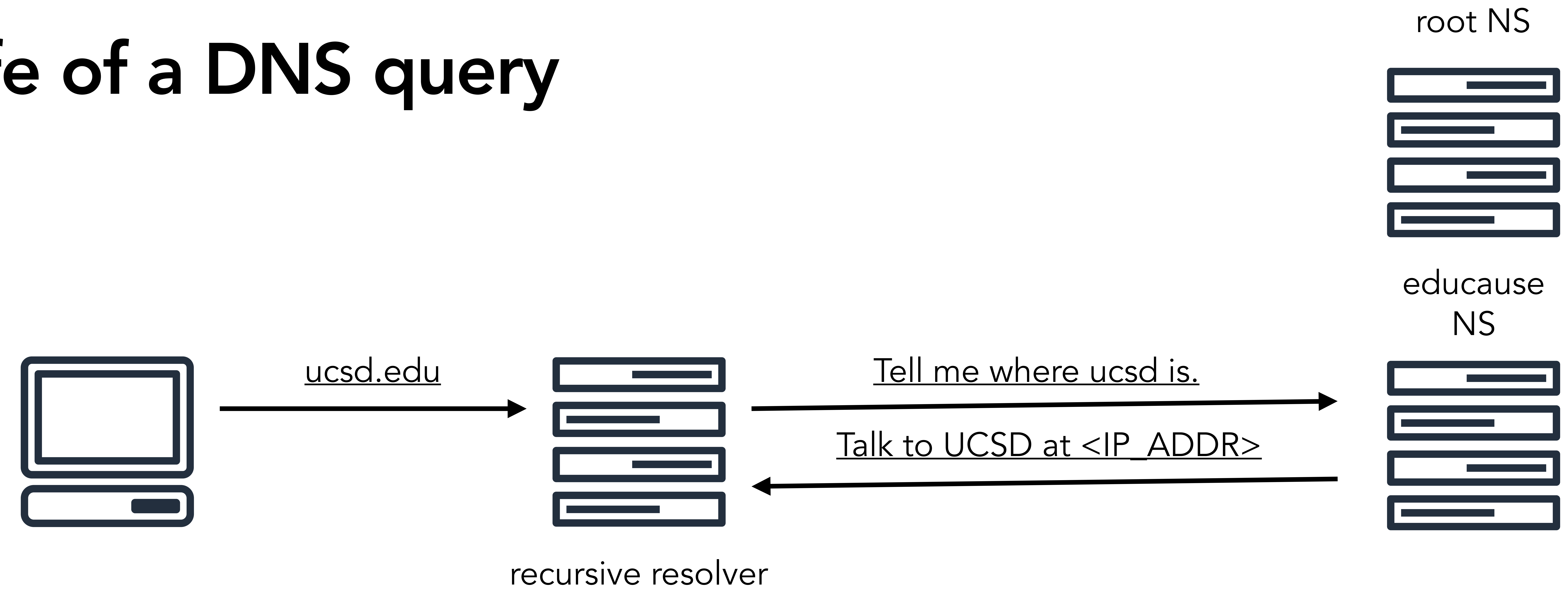

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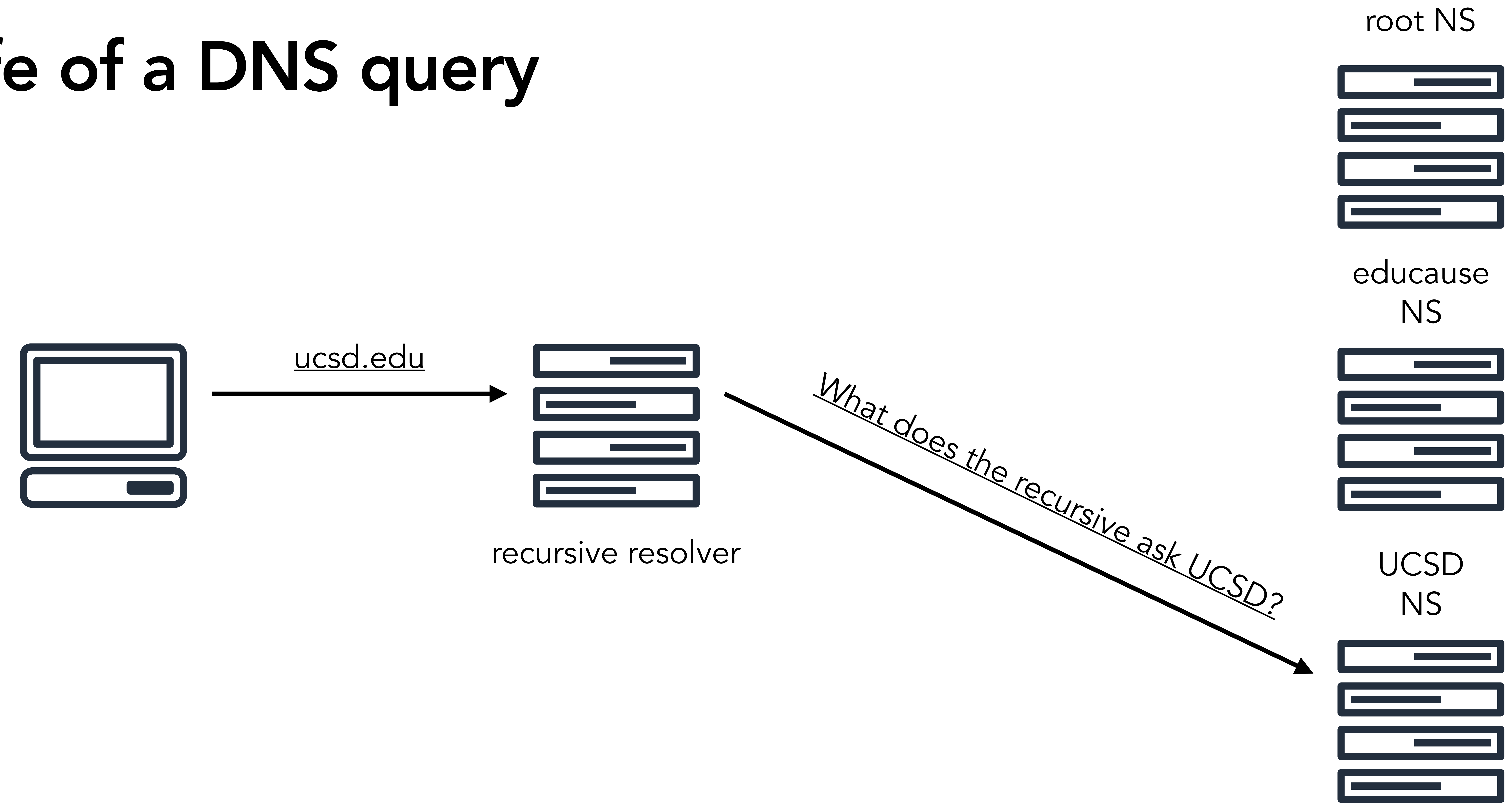

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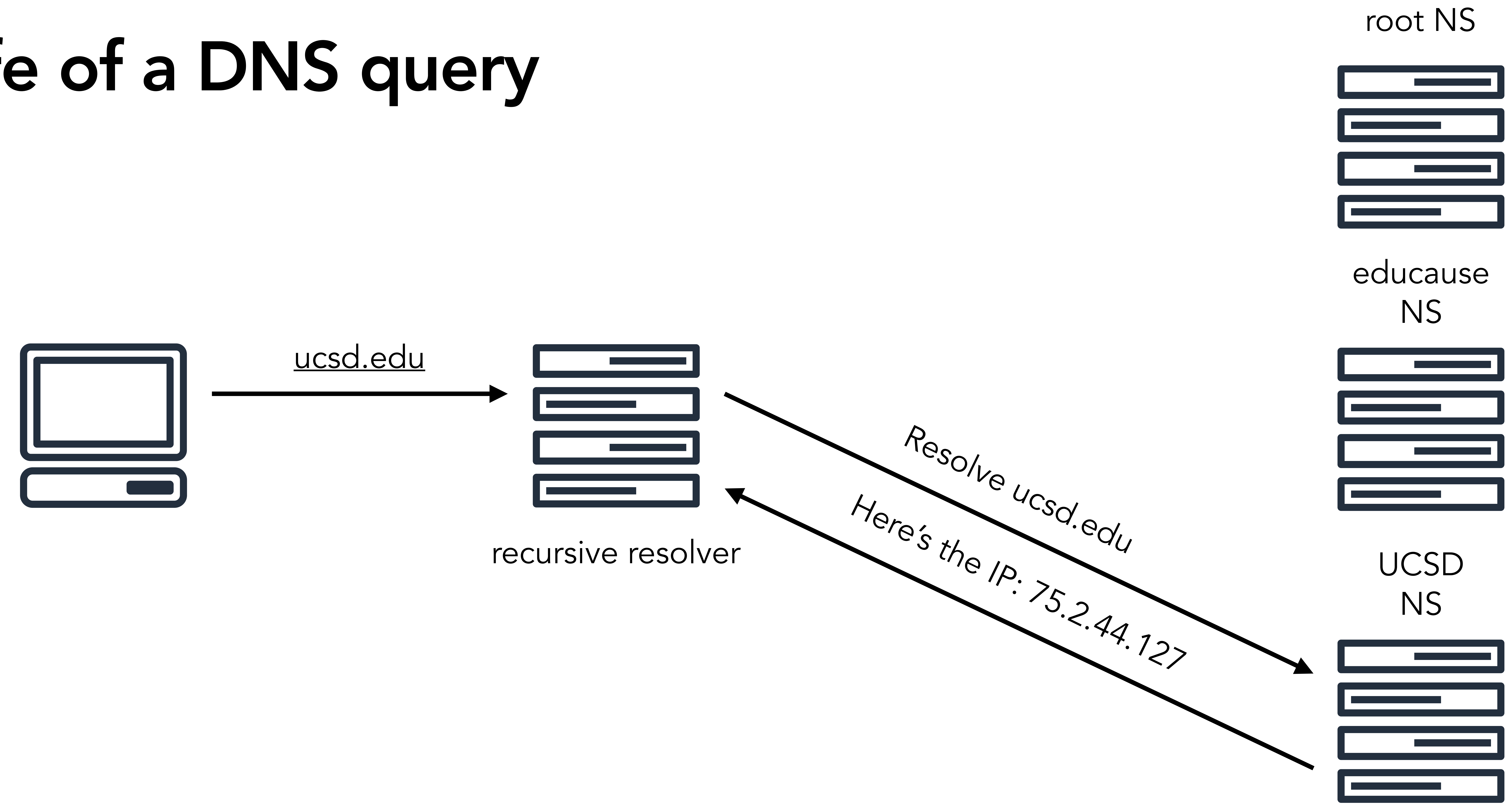

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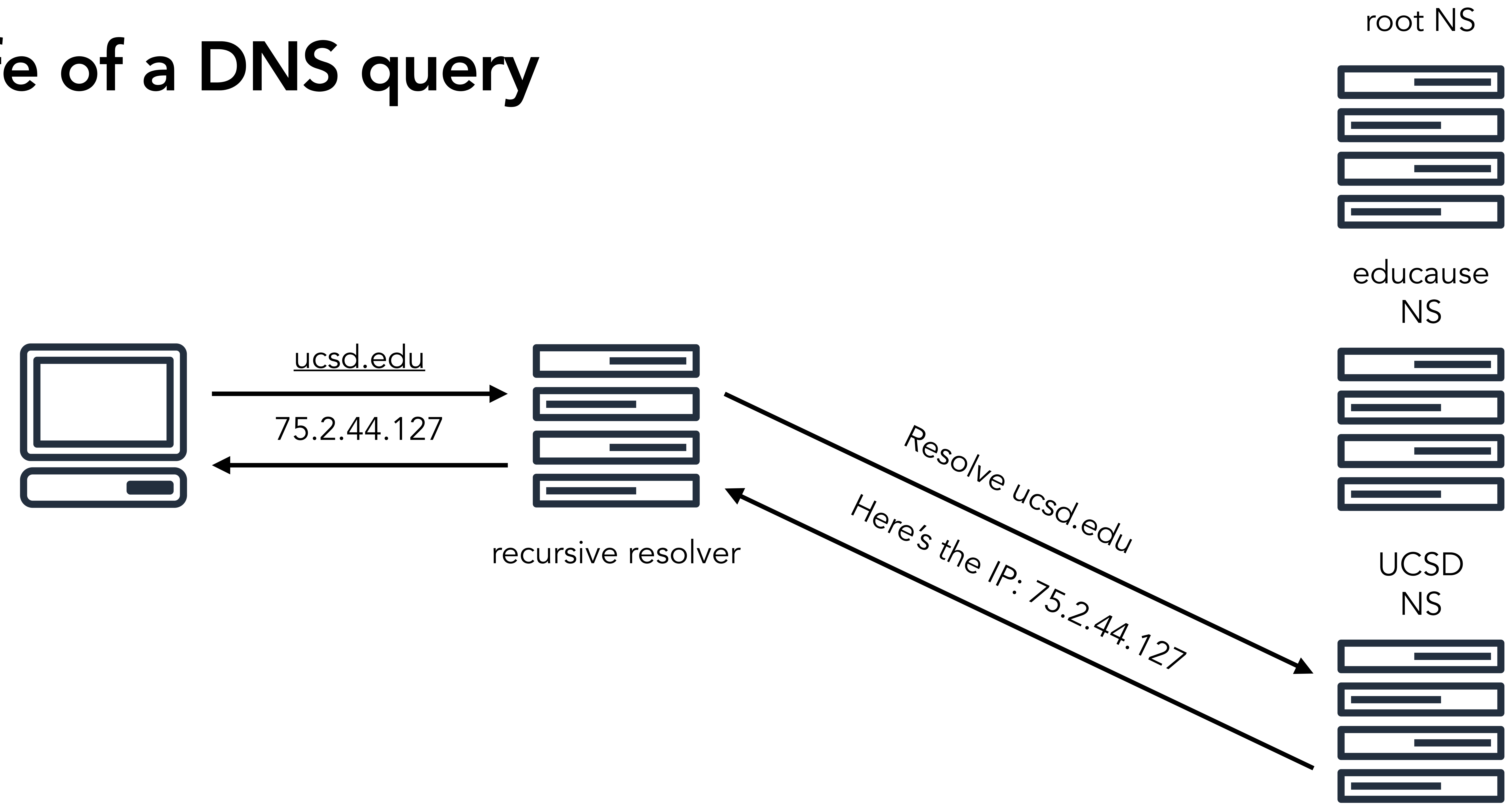

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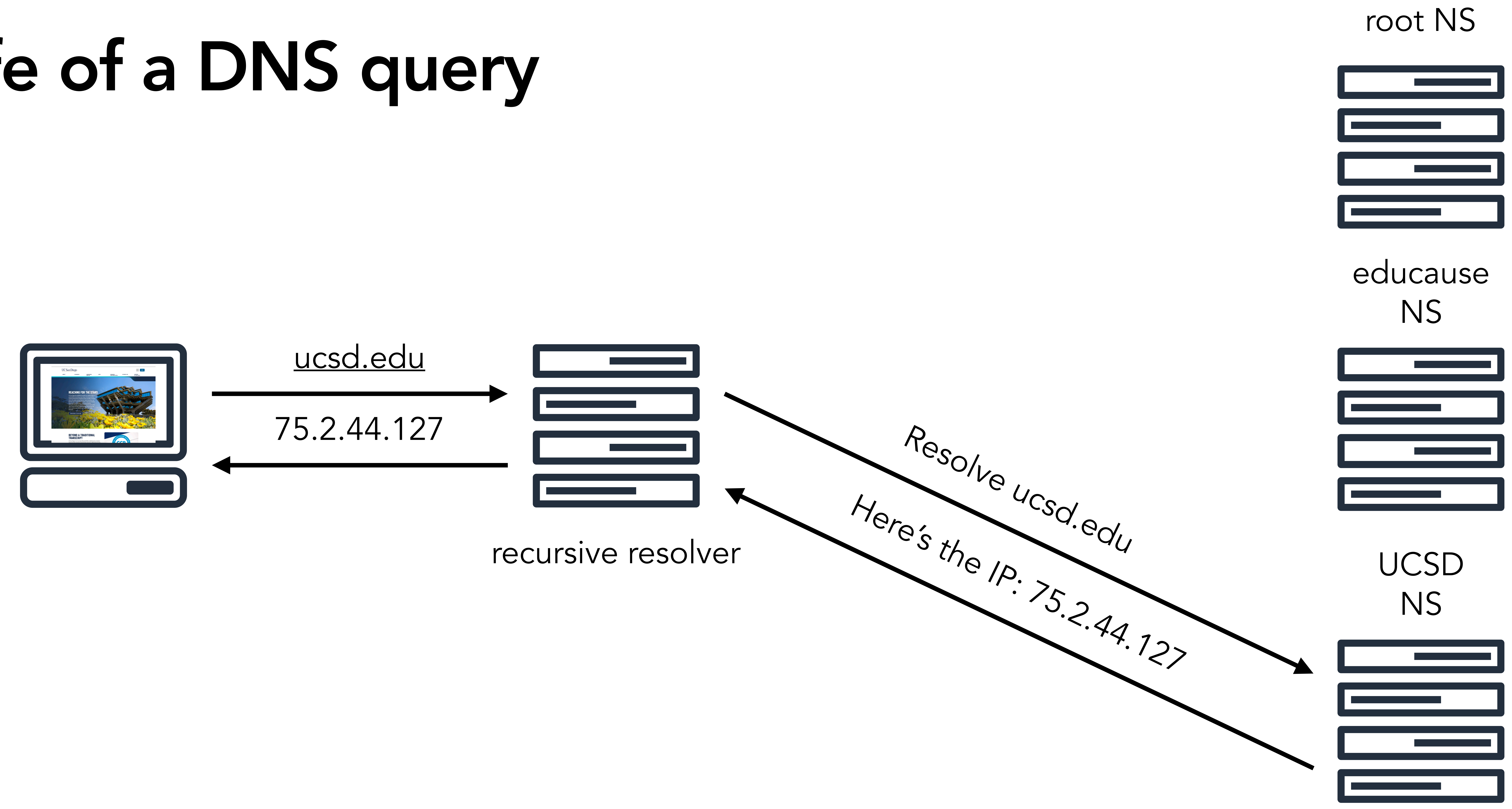

DNS Query Types

Many ways to encode things in the DNS

- Field in the DNS query packet called QTYPE defines the the thing you’re looking for on the other end
    - What is an NS query?
    - What is an A query?
    - What is an AAAA query?
    - What is an M query?
    - What is a TXT query?

Do we always need to hit a root server to get an answer?

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No! We have DNS *caches* for this purpose. What's a DNS cache?

DNS Caching

Making things fast

- Where do DNS records get cached? Who caches them?

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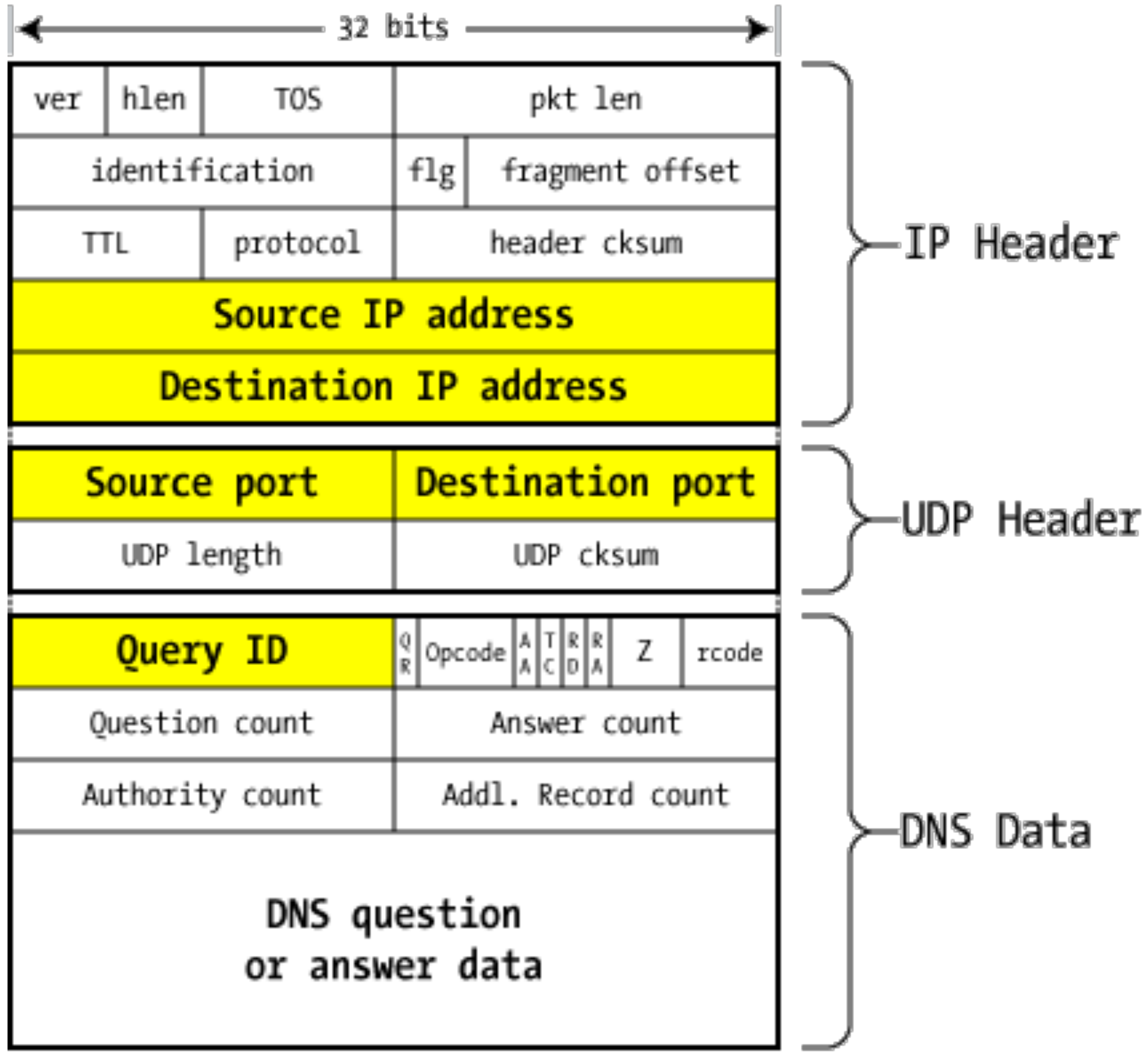
- What is the time-to-live (TTL)? How does this affect caching?
- Thought experiment: How frequently are the root servers contacted?

Unpacking DNS Packets



DNS packet on the wire

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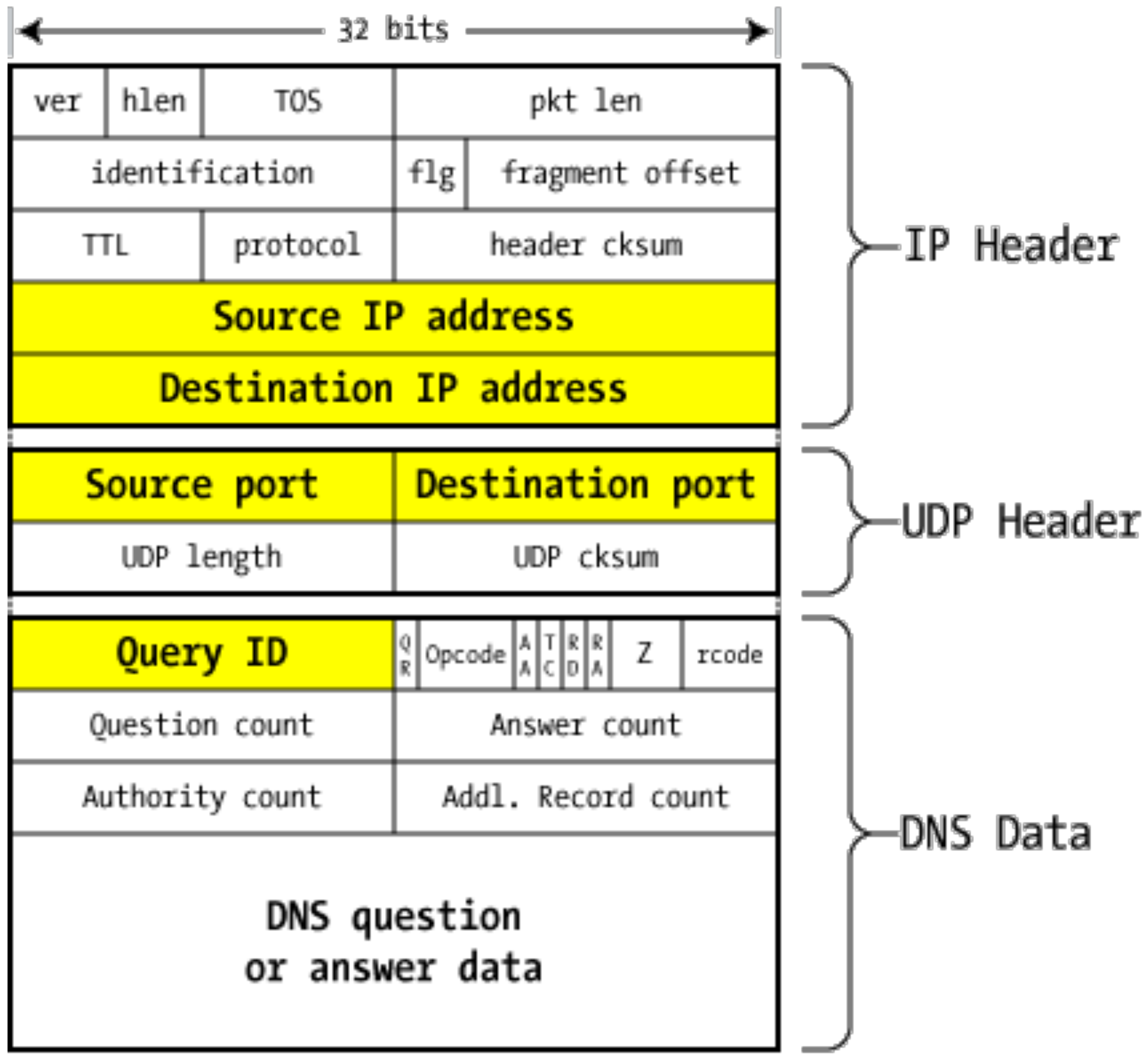

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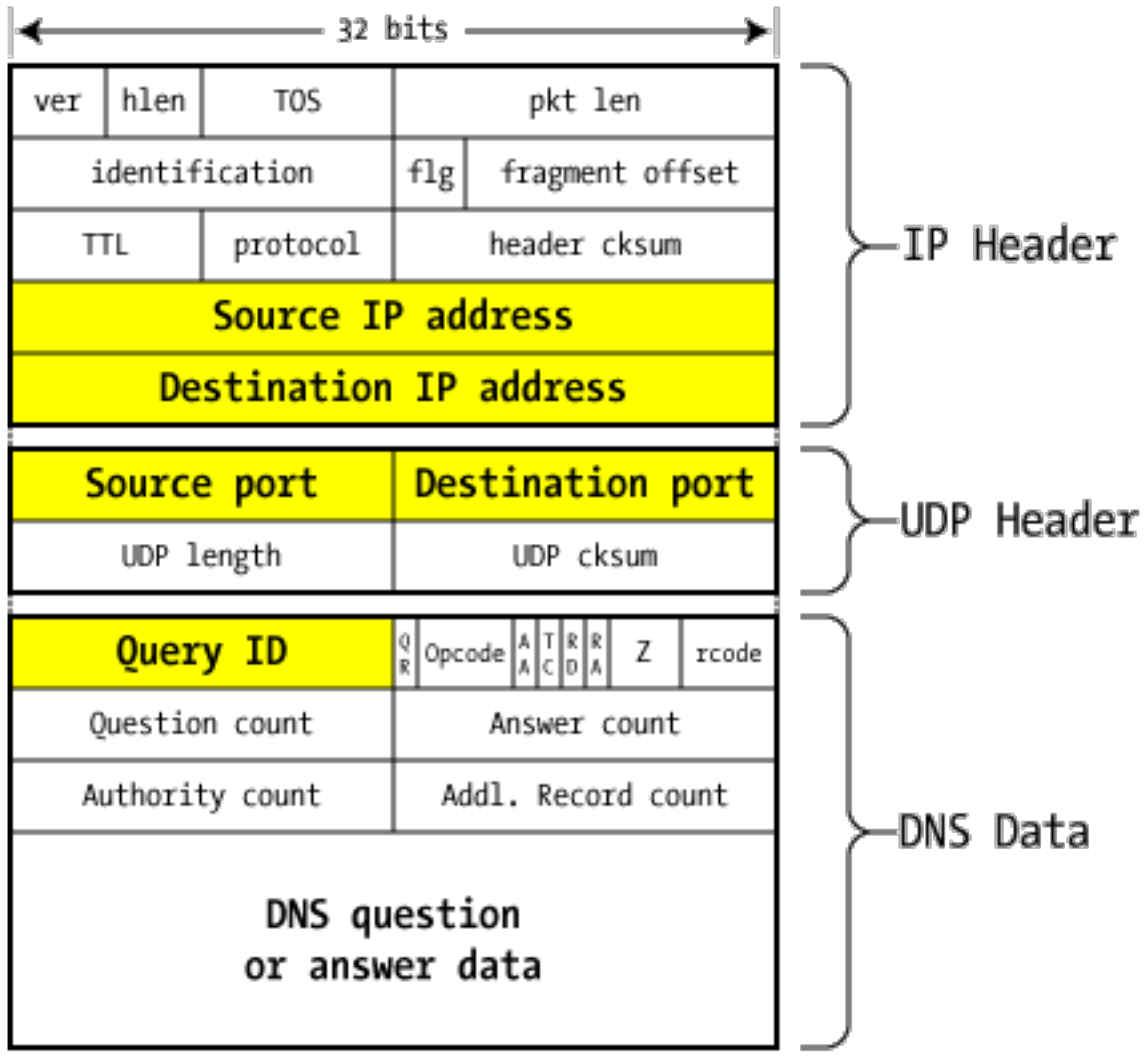

DNS packet on the wire

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    - What is UDP? How is it different from TCP?
- What are ports? What's a source port and destination port?
- What's a query ID? How big is it?

Break Time + Attendance

Codeword:
Complex-Domains

https://tinyurl.com/cse227-attend

DNS Cache Poisoning

A few words on this vuln…

- Released in 2008, well after DNS was established for many years
- Affected almost every single DNS recursor / cache on the planet: which made it *very* important to fix quickly
- While we're talking: think about what this means for *trust* on the Internet

Basic Premise of the Attack

- What is the goal of an attacker in the DNS cache poisoning attack?

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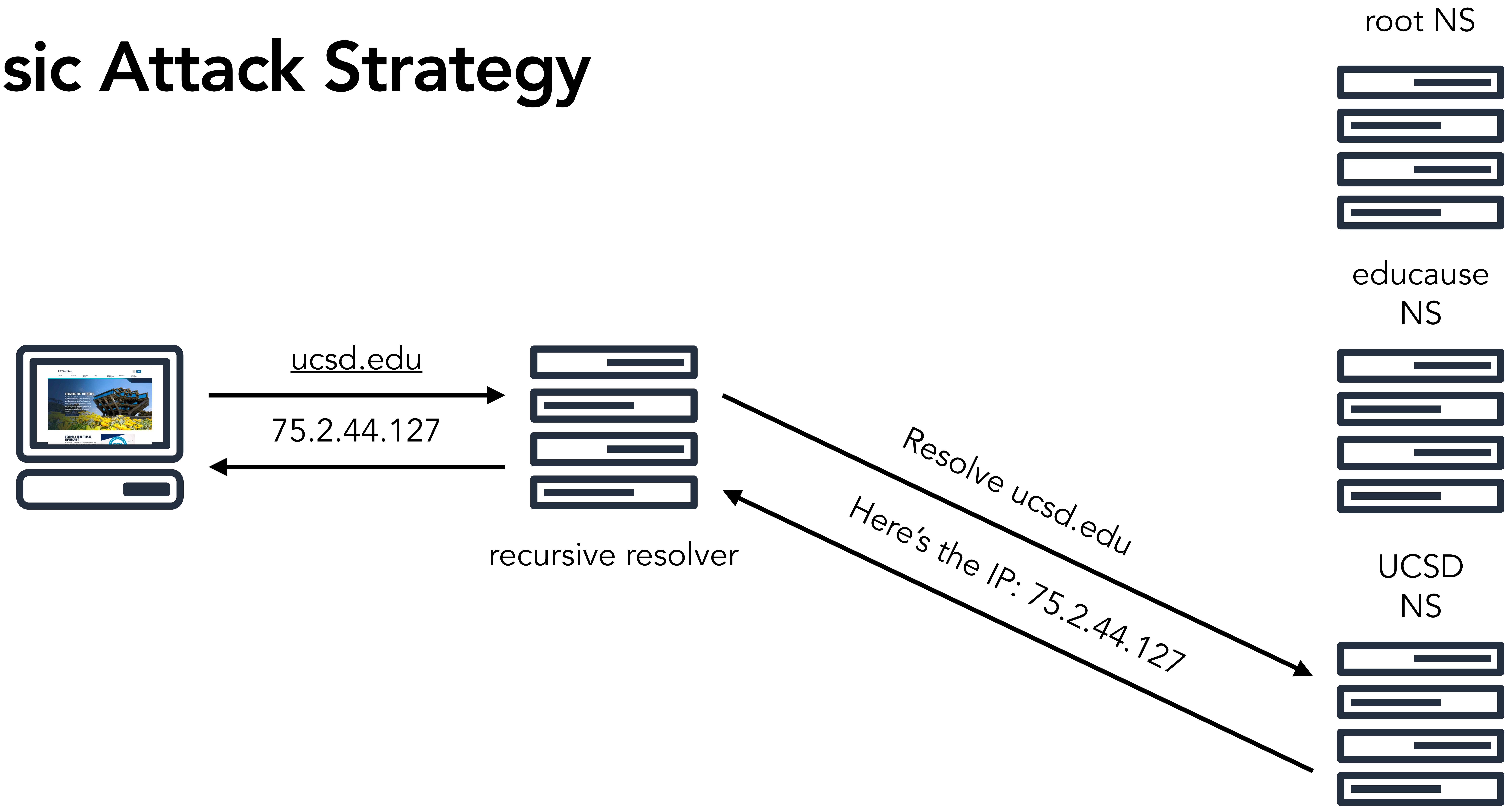
- What is the goal of an attacker in the DNS cache poisoning attack?
  - Goal: Get a record inside of a DNS cache that is **wrong,** tricking clients transparently
  - Simple version: Record for a single hostname
  - Kaminsky version: NS record for an *entire zone*

Basic Attack Strategy



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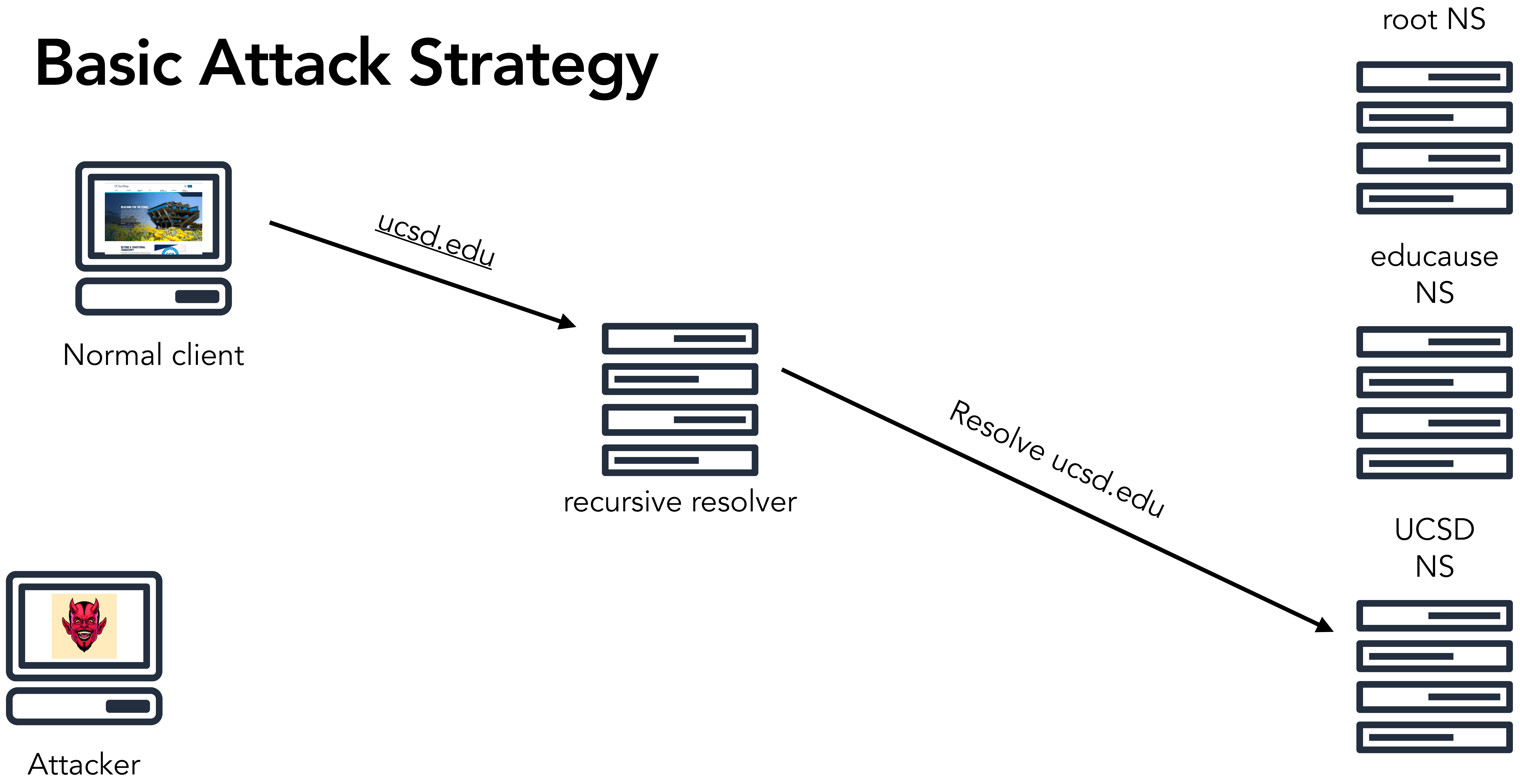

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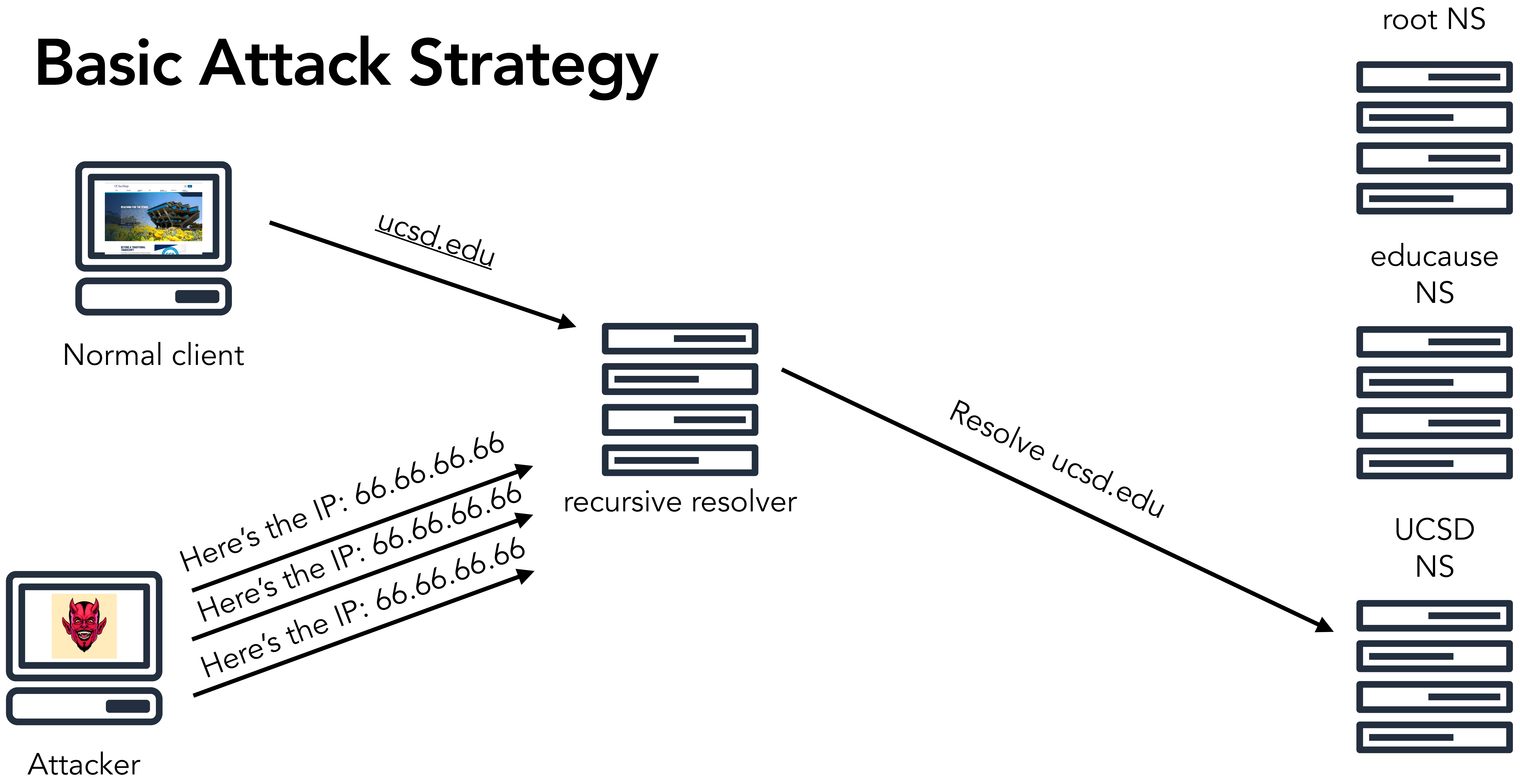

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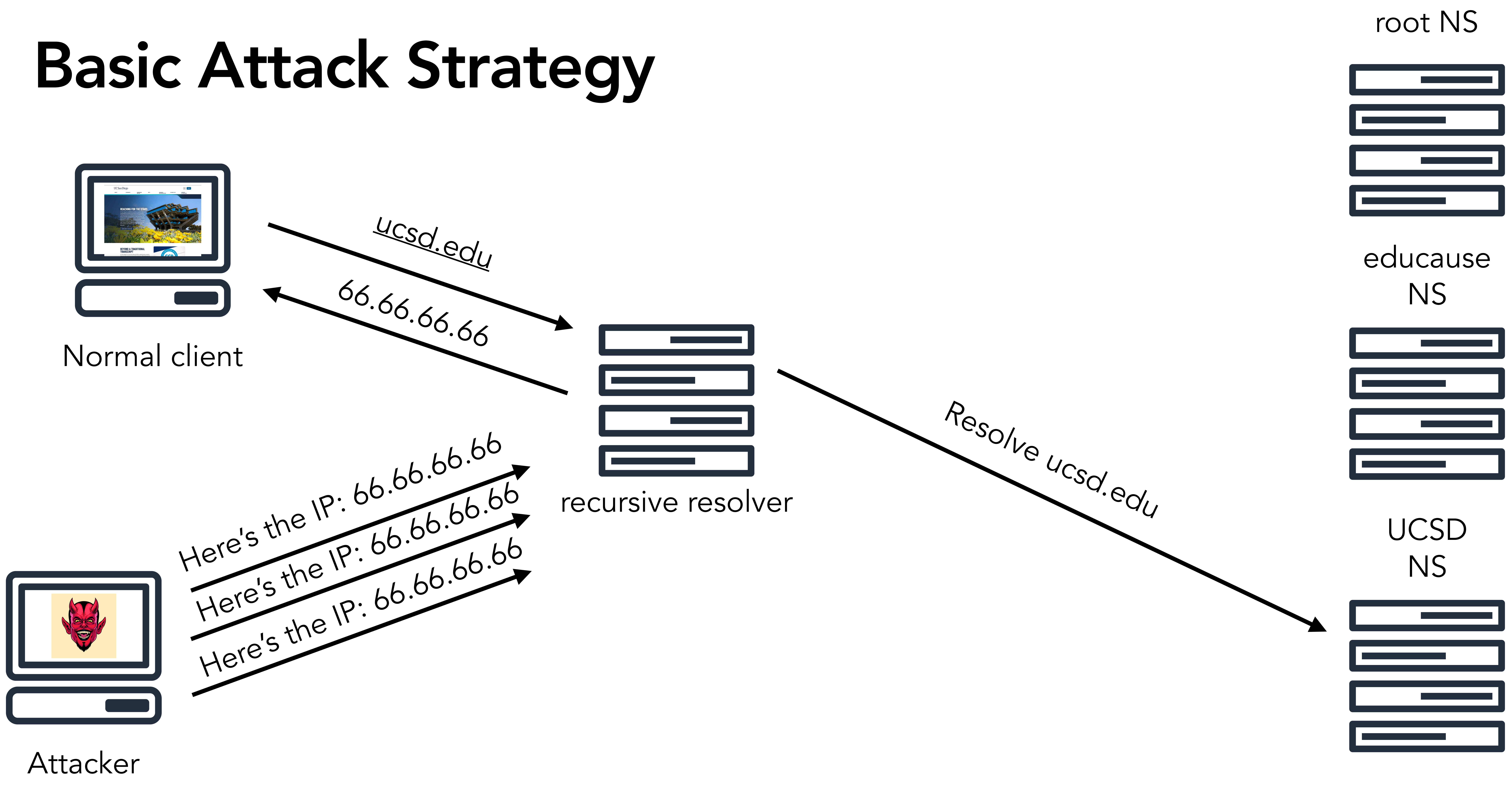

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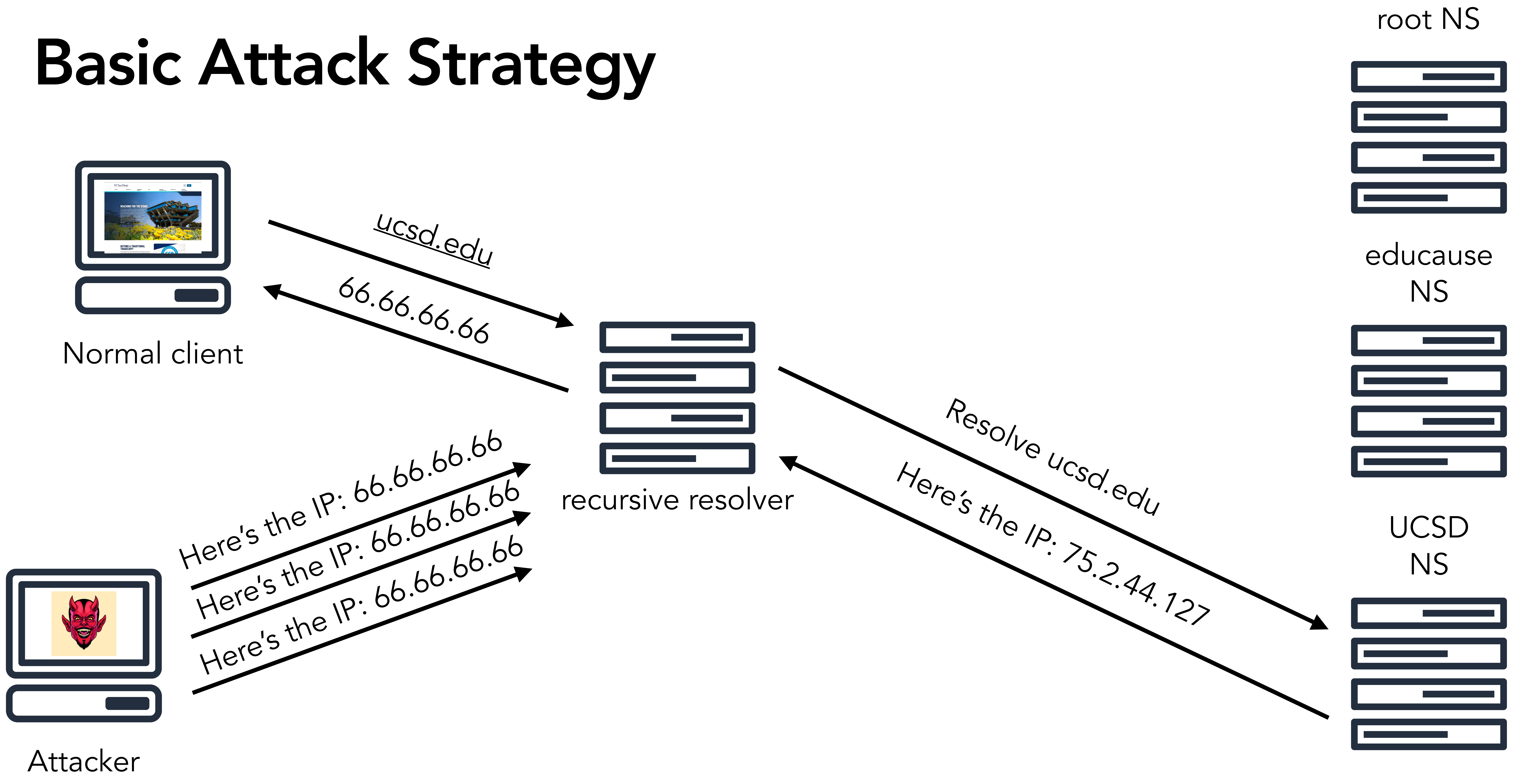

root NS
educause NS
UCSD NS
Normal client
ucsd.edu
66.66.66.66
recursive resolver
Resolve ucsd.edu
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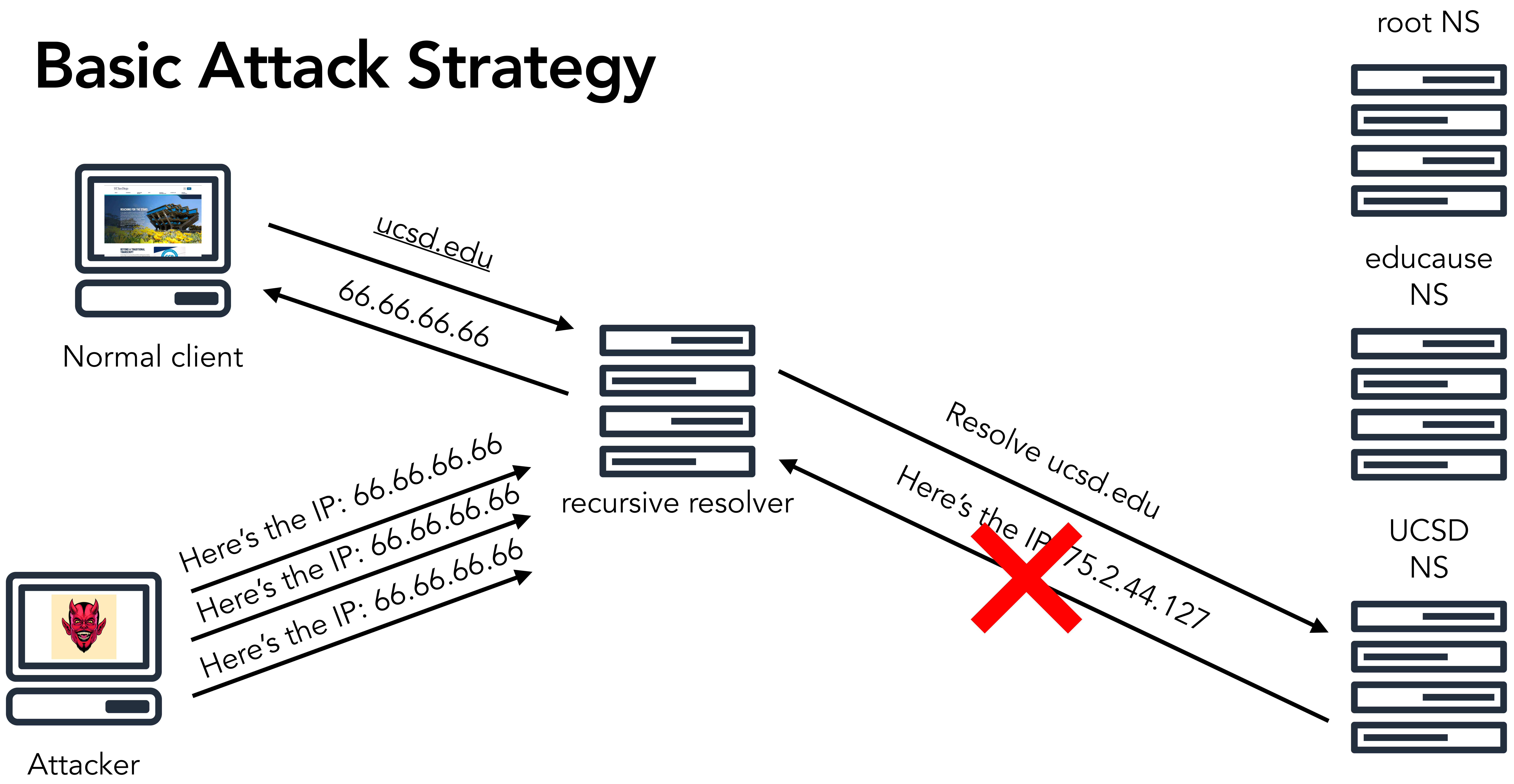
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- How does the recursive resolver know that the NS responding the query actually owns the name it’s claiming to know about?
  - It *doesn’t*. Anyone can be authoritative for any name!

Back in ’08…

- Attacker needs to spoof NS responses
  - How did the attacker learn the Query ID?
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Attacker
recursive resolver
attacker controlled NS

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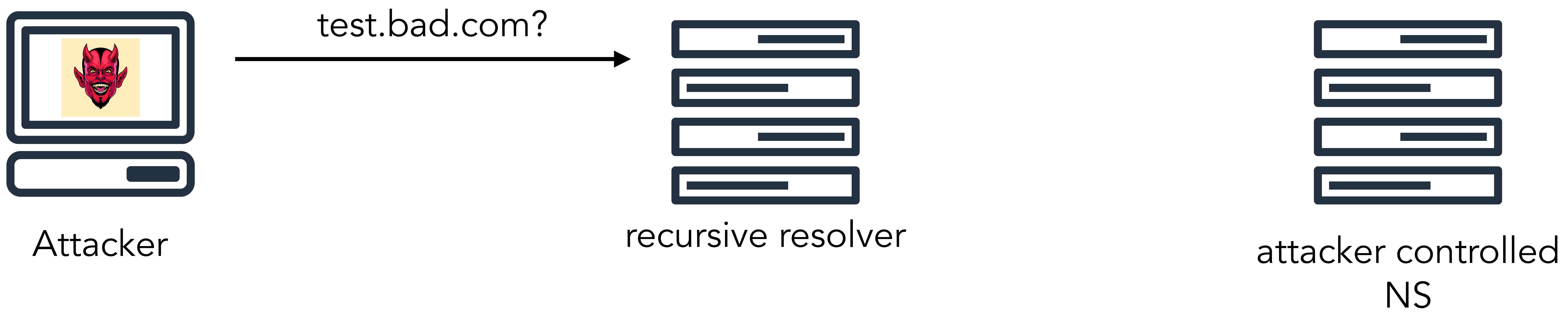

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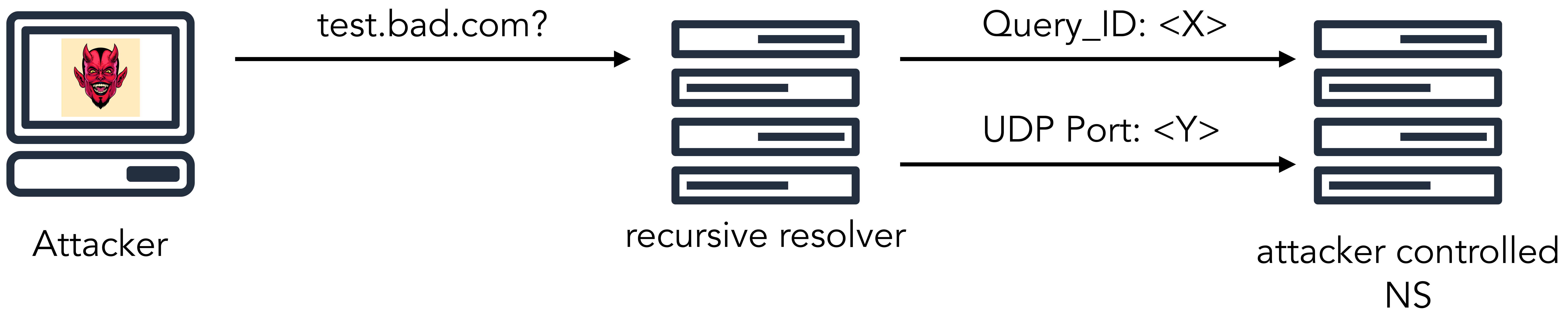
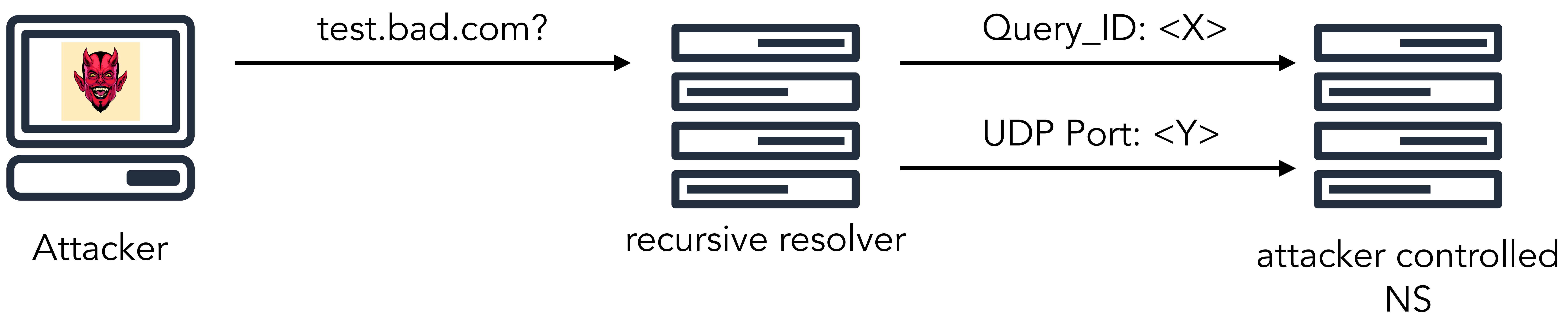


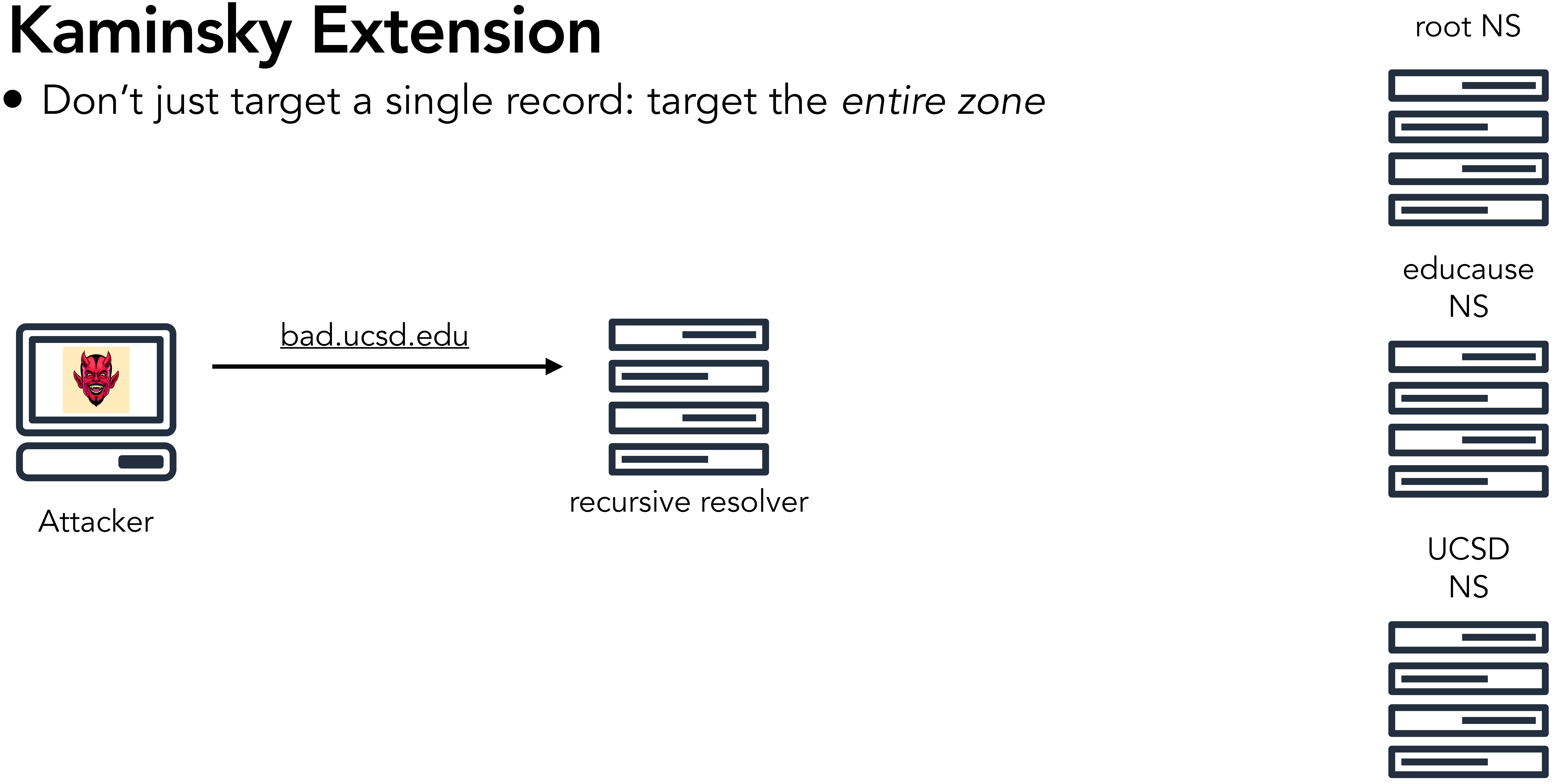
Back in ’08…

- Attacker needs to spoof NS responses
  - How did the attacker learn the Query ID? **Global, monotonically increasing**
  - How did the attacker learn the UDP port used? **Fixed for all DNS queries**



Kaminsky Extension

- Don’t just target a single record: target the *entire zone*



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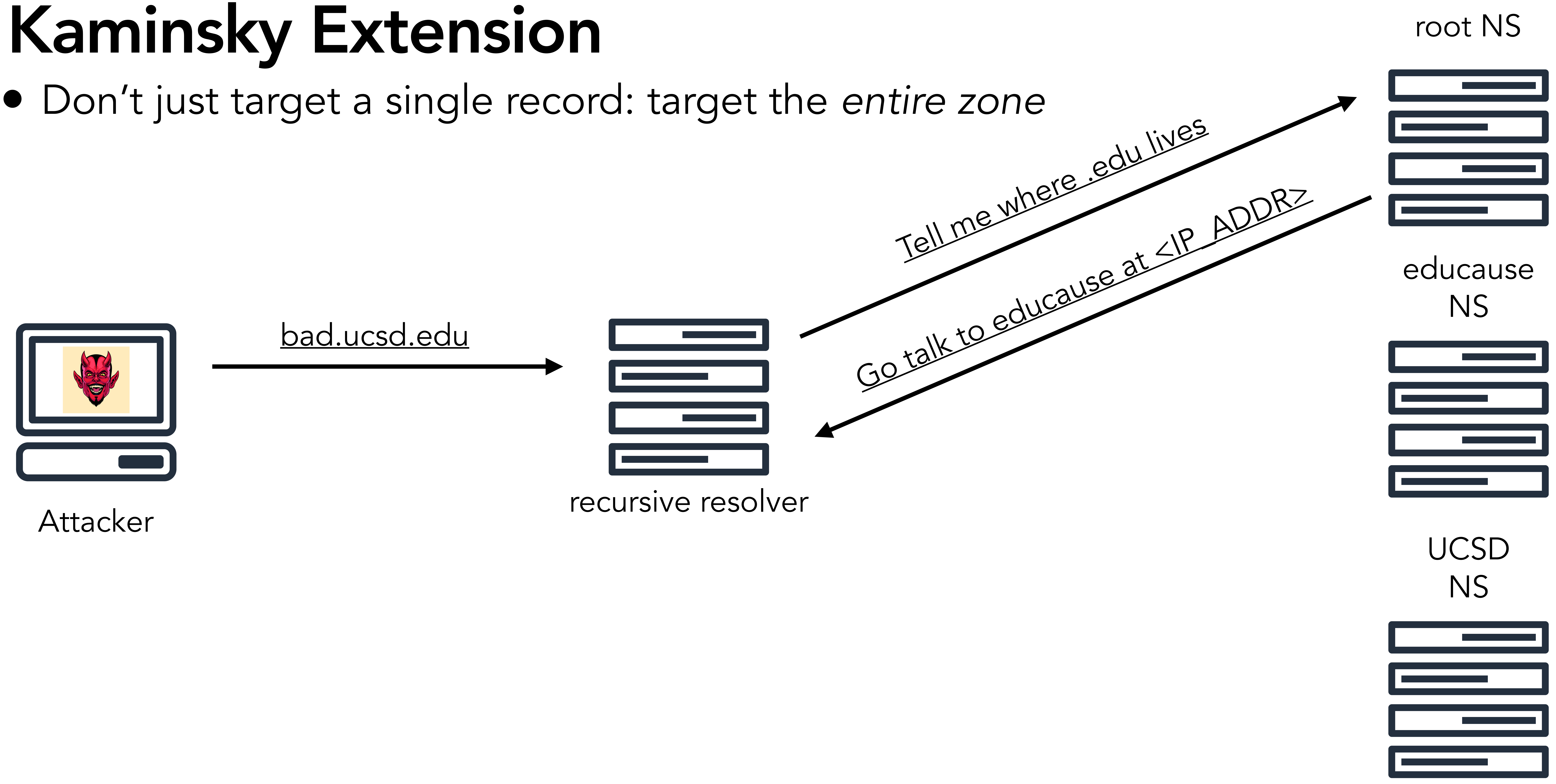

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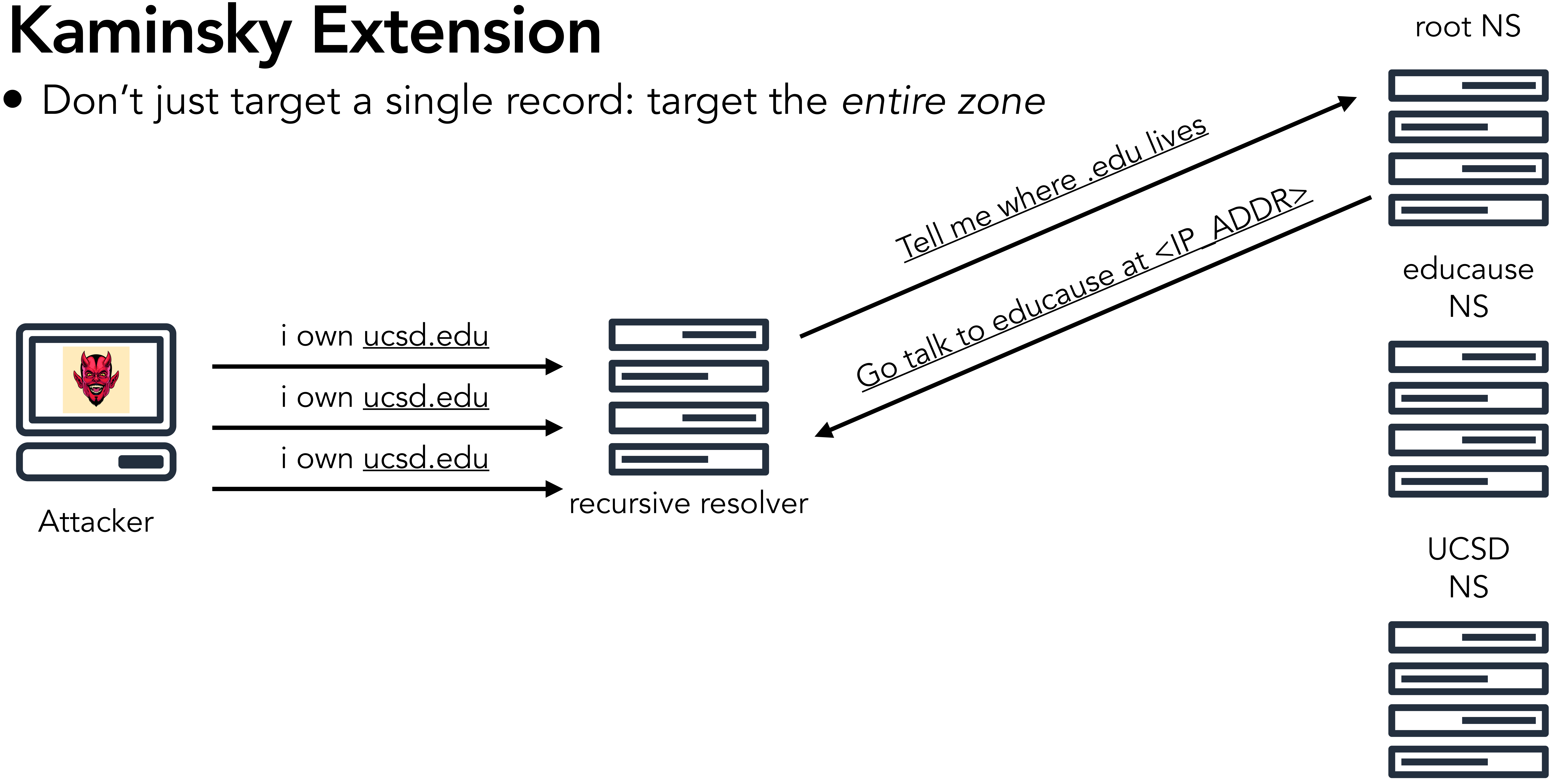

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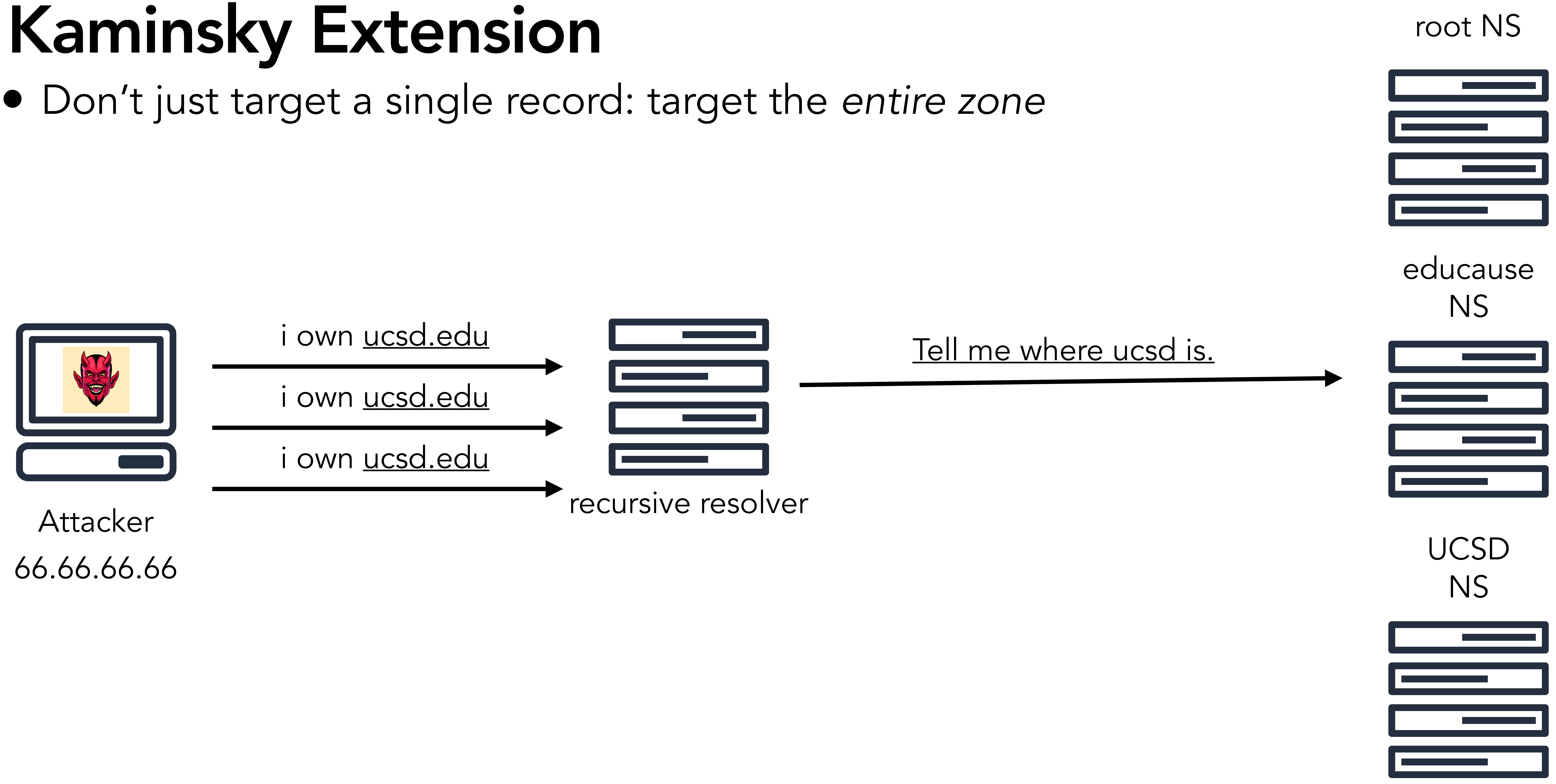

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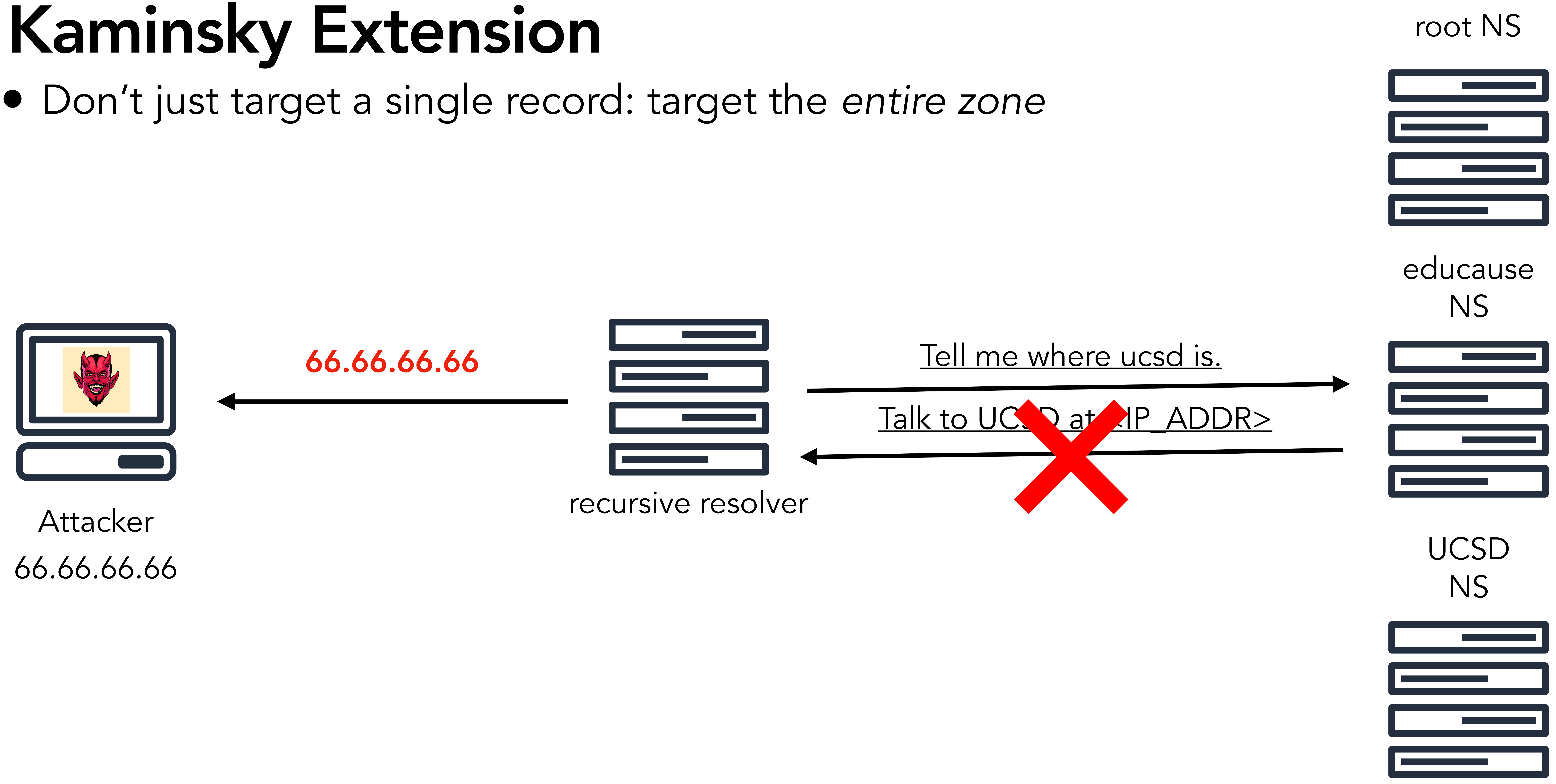

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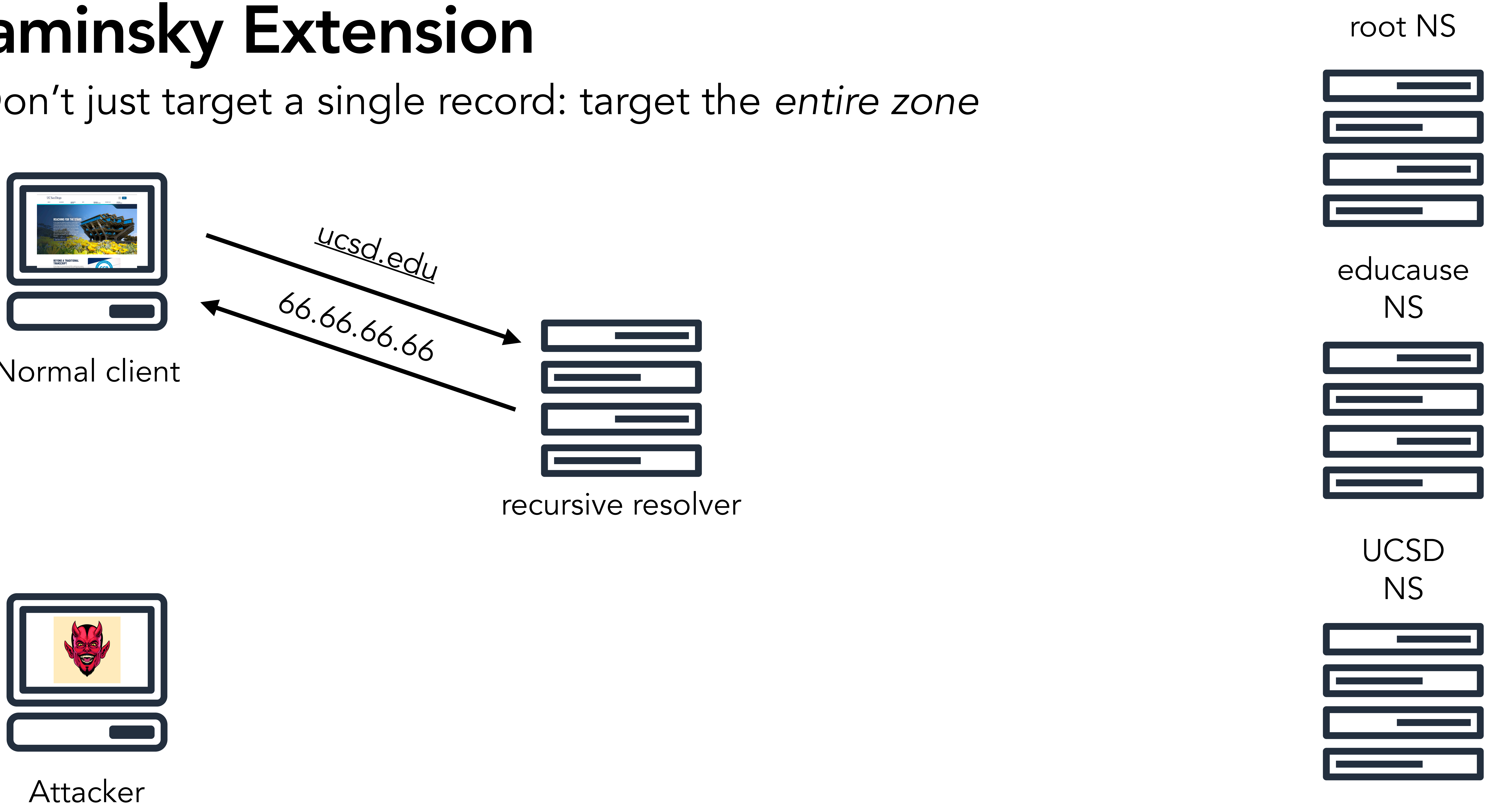

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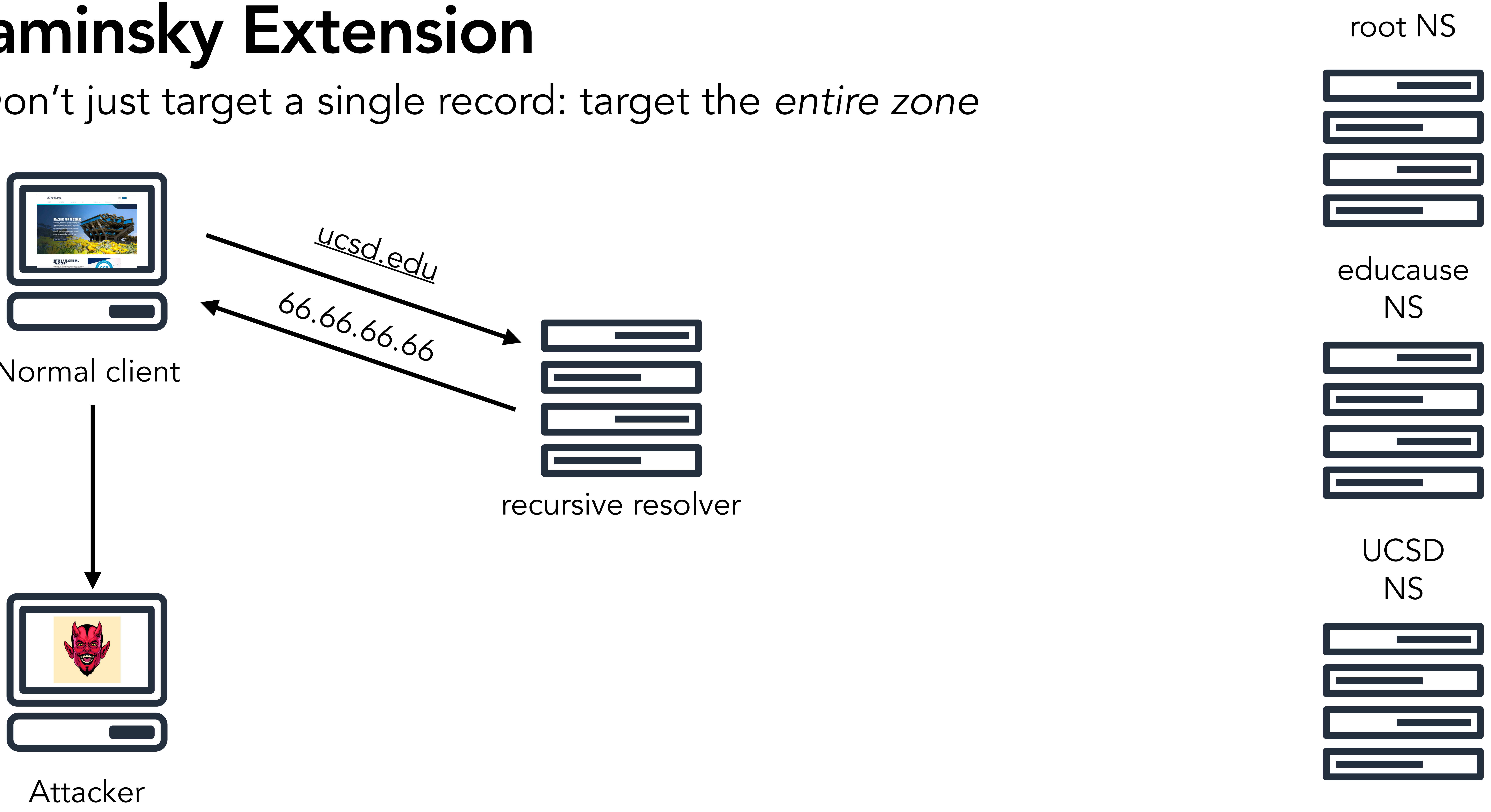

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- How do we get things out of the cache…?
  - Flood the recursive with **lots** of queries

Countermeasures

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    - QID leakage, and a **small** attack surface (16-bit query ID)
    - Ports were static across every request
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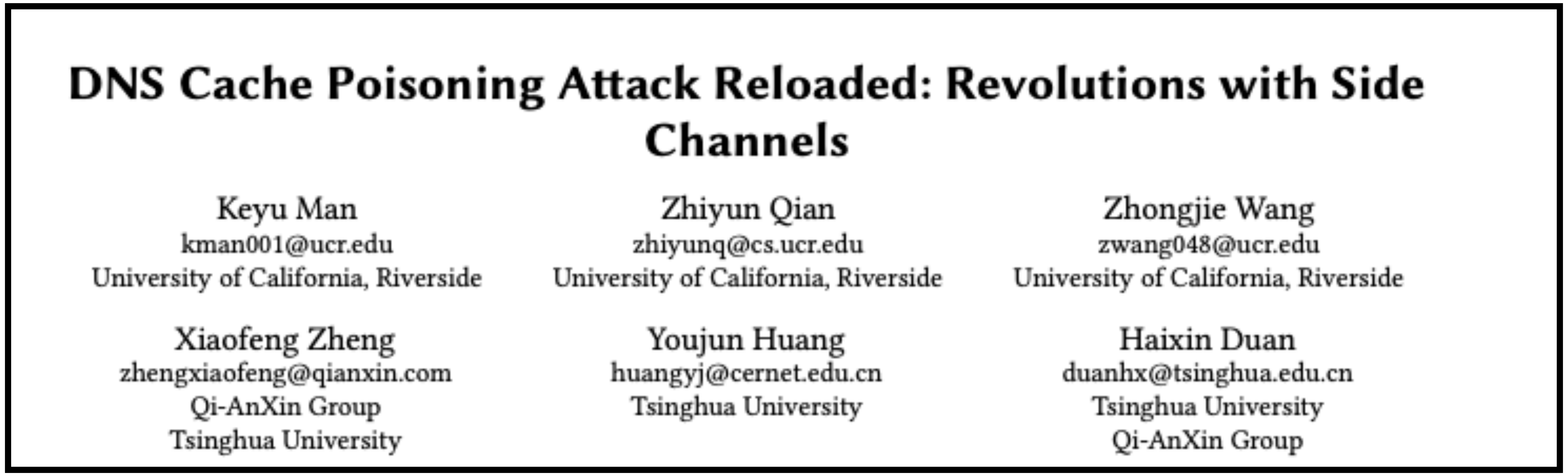

DNS Cache Poisoning Attack Reloaded: Revolutions with Side Channels

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Tsinghua University
Qi-AnXin Group

Discussion

- What surprised you about this attack? What did this attack make you think about trust?
- What surprised you about DNS if anything at all?
  - What do we do about it?
- For more, see: DNSSec (PKI for DNS to sign named records)

Next time…

- Final week on networks, focused this time on **censorship techniques** via the Network
- Midpoint check-in due **tomorrow!**