A Large-Scale Measurement Study of the PROXY Protocol and its Security Implications

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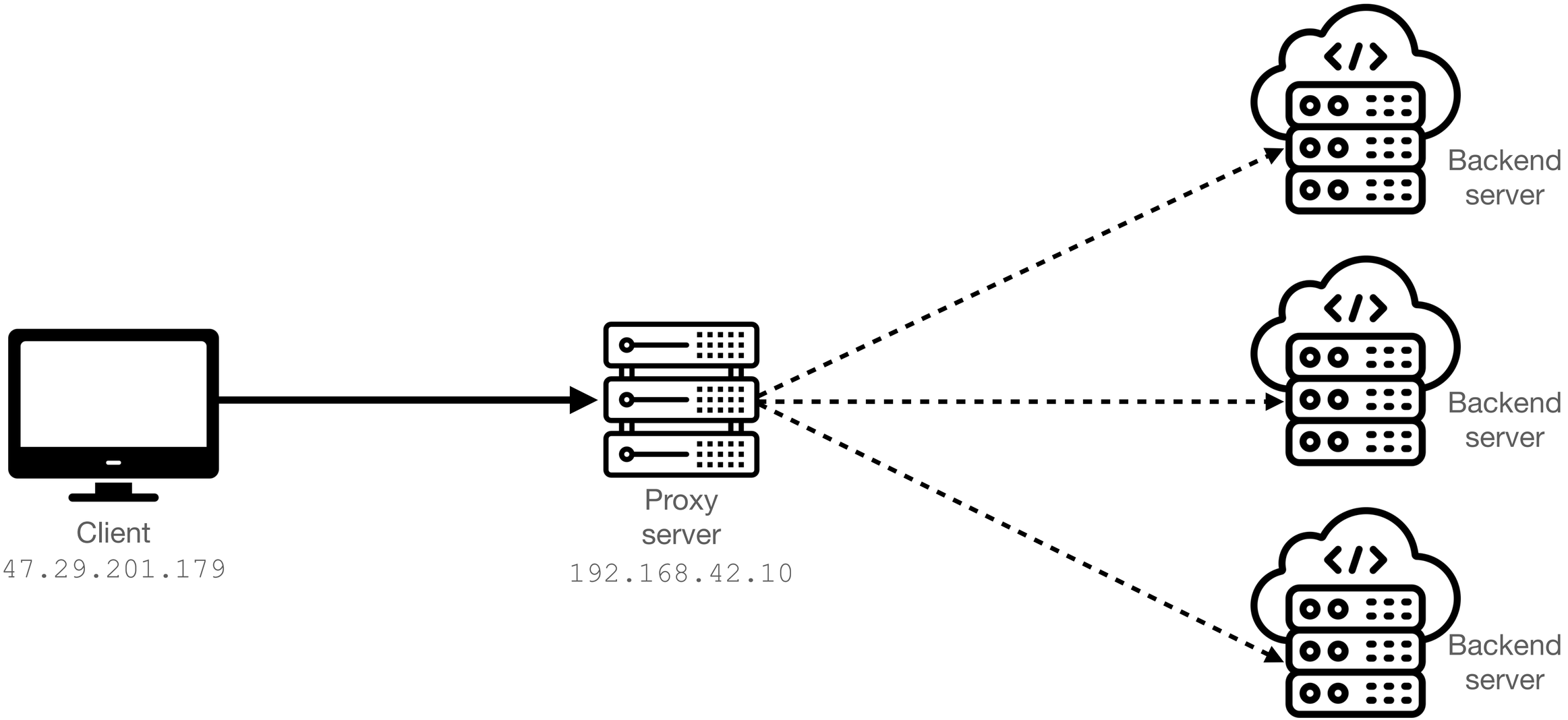
University of California, Santa Barbara

SECLAB

(Reverse) Proxy Servers



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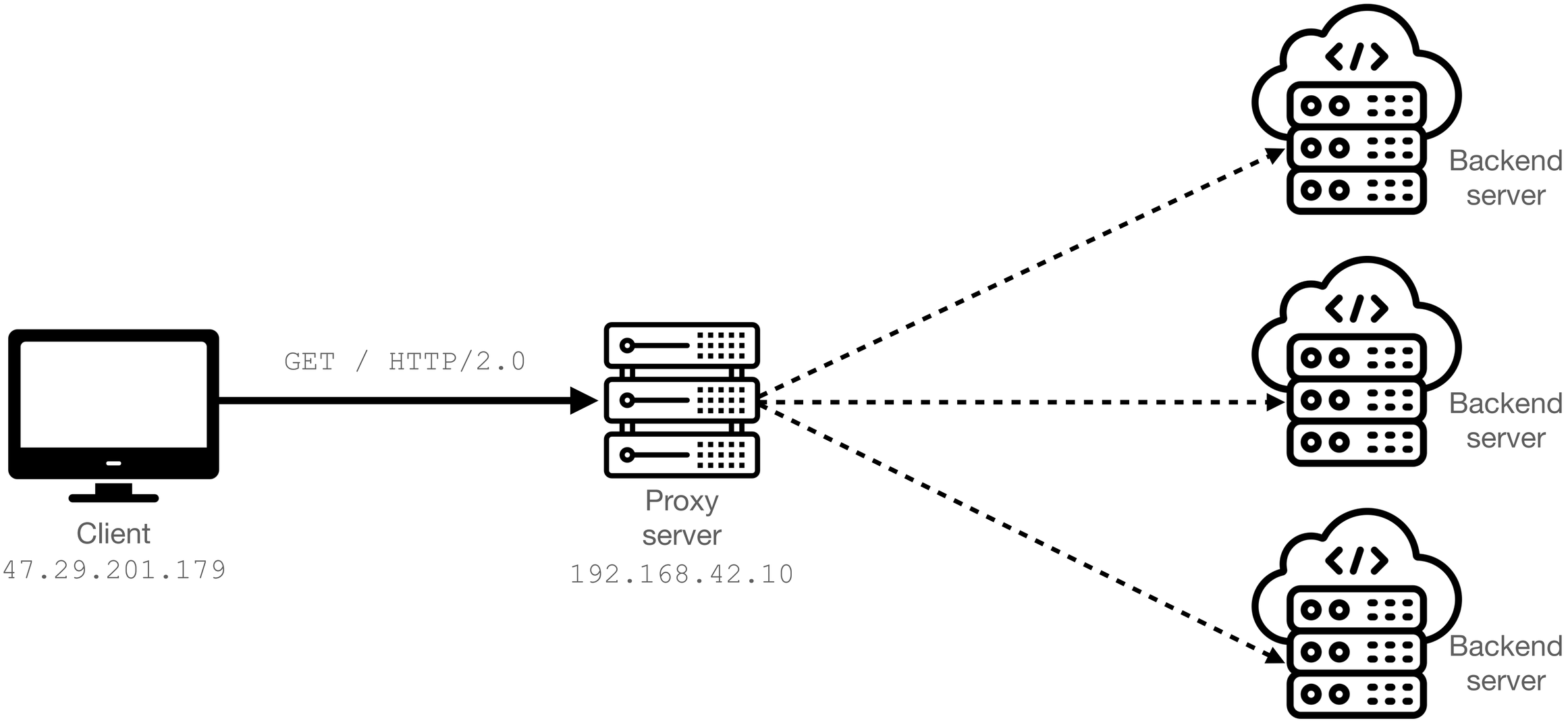

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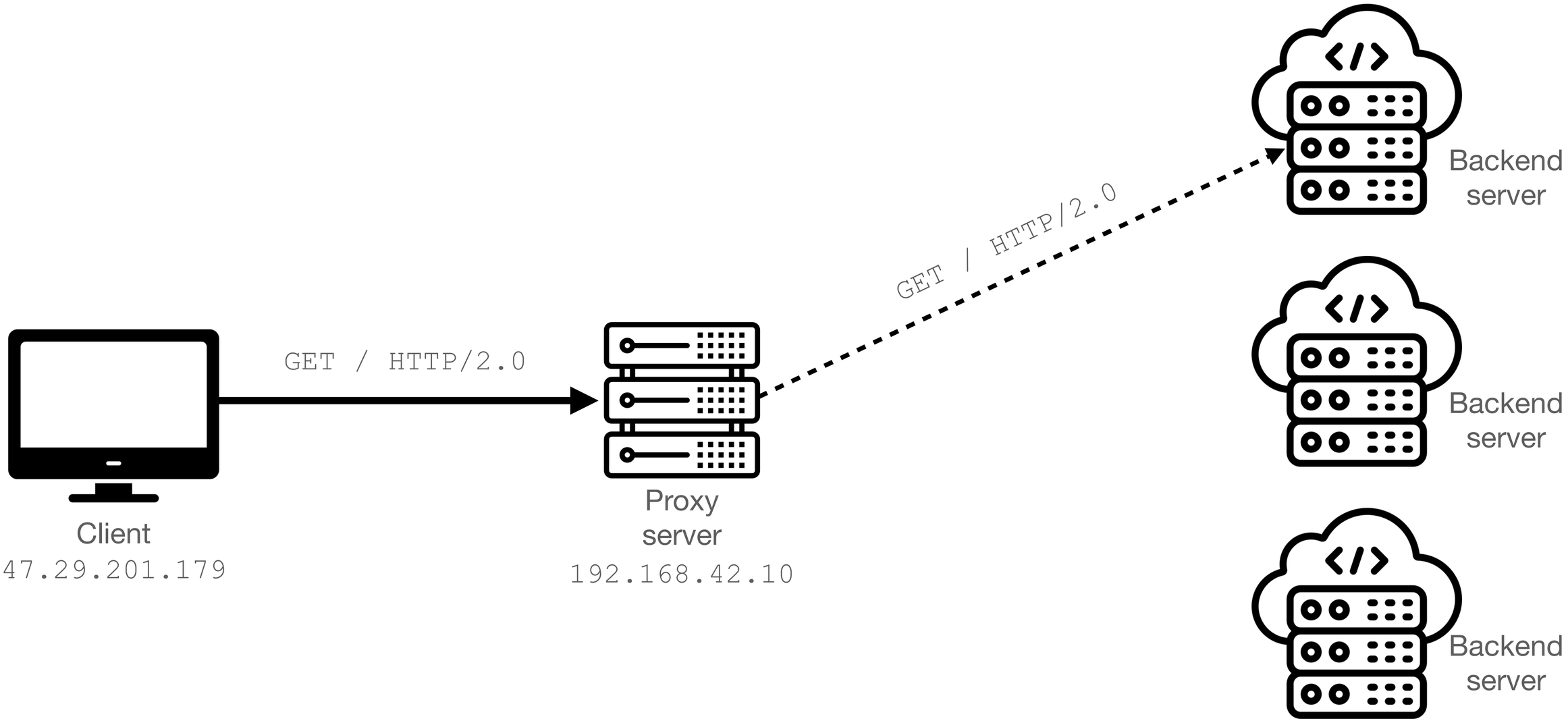

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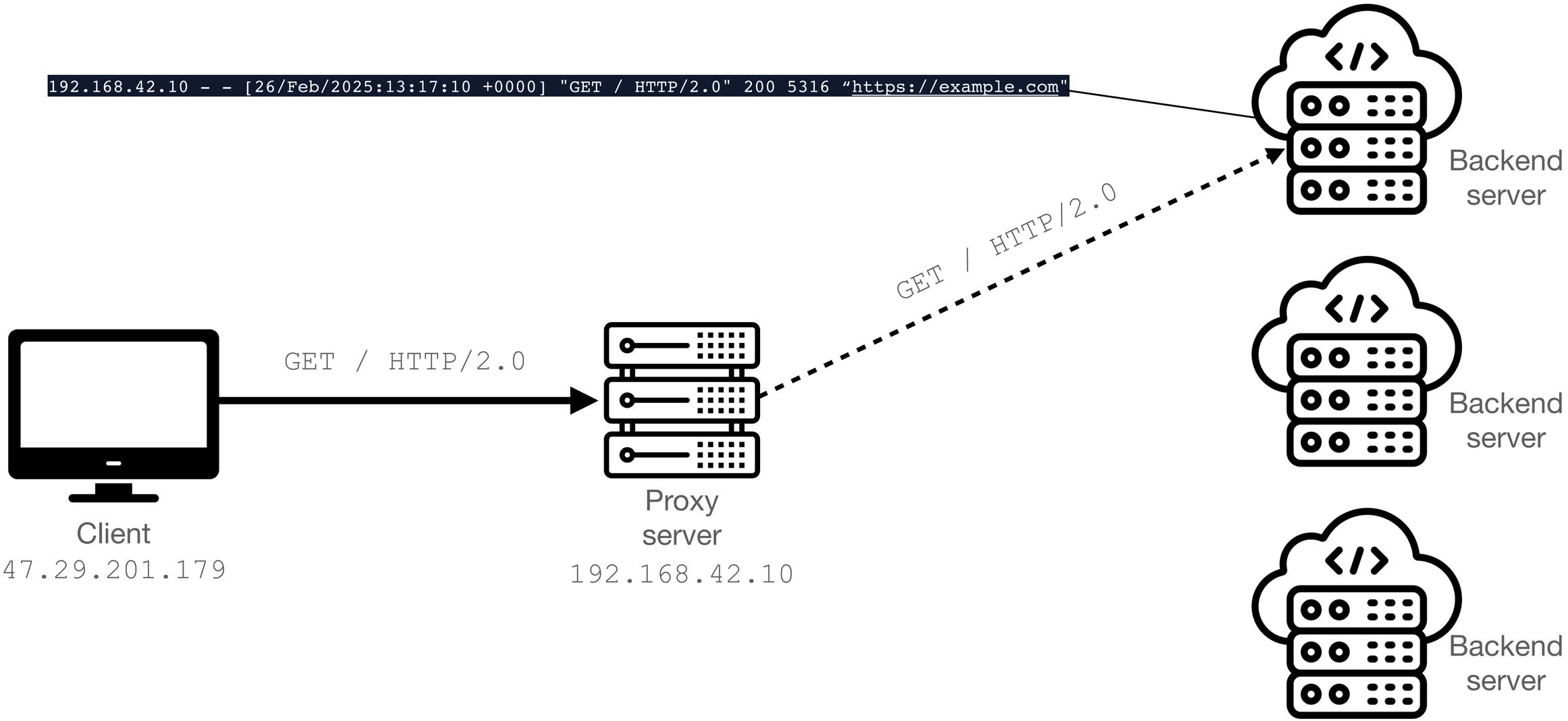

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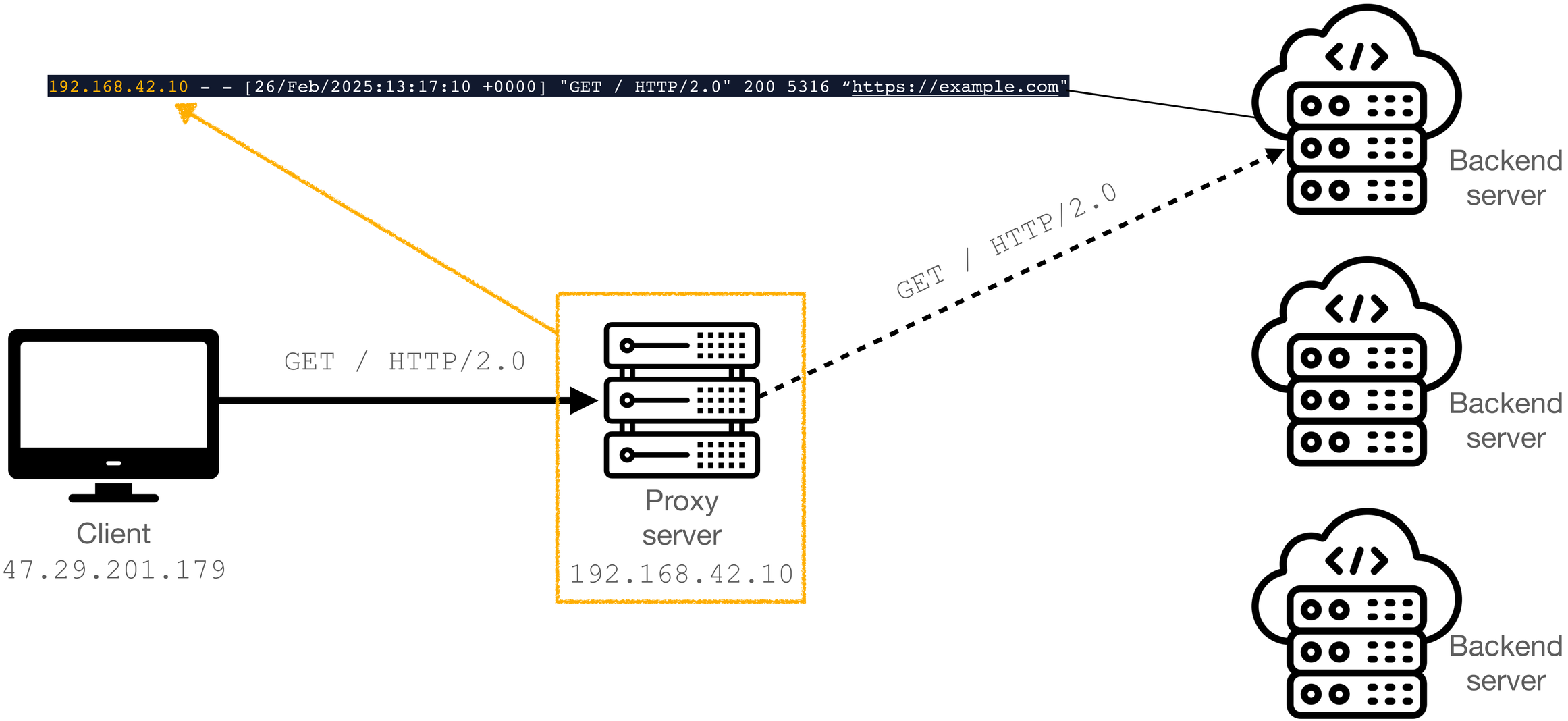
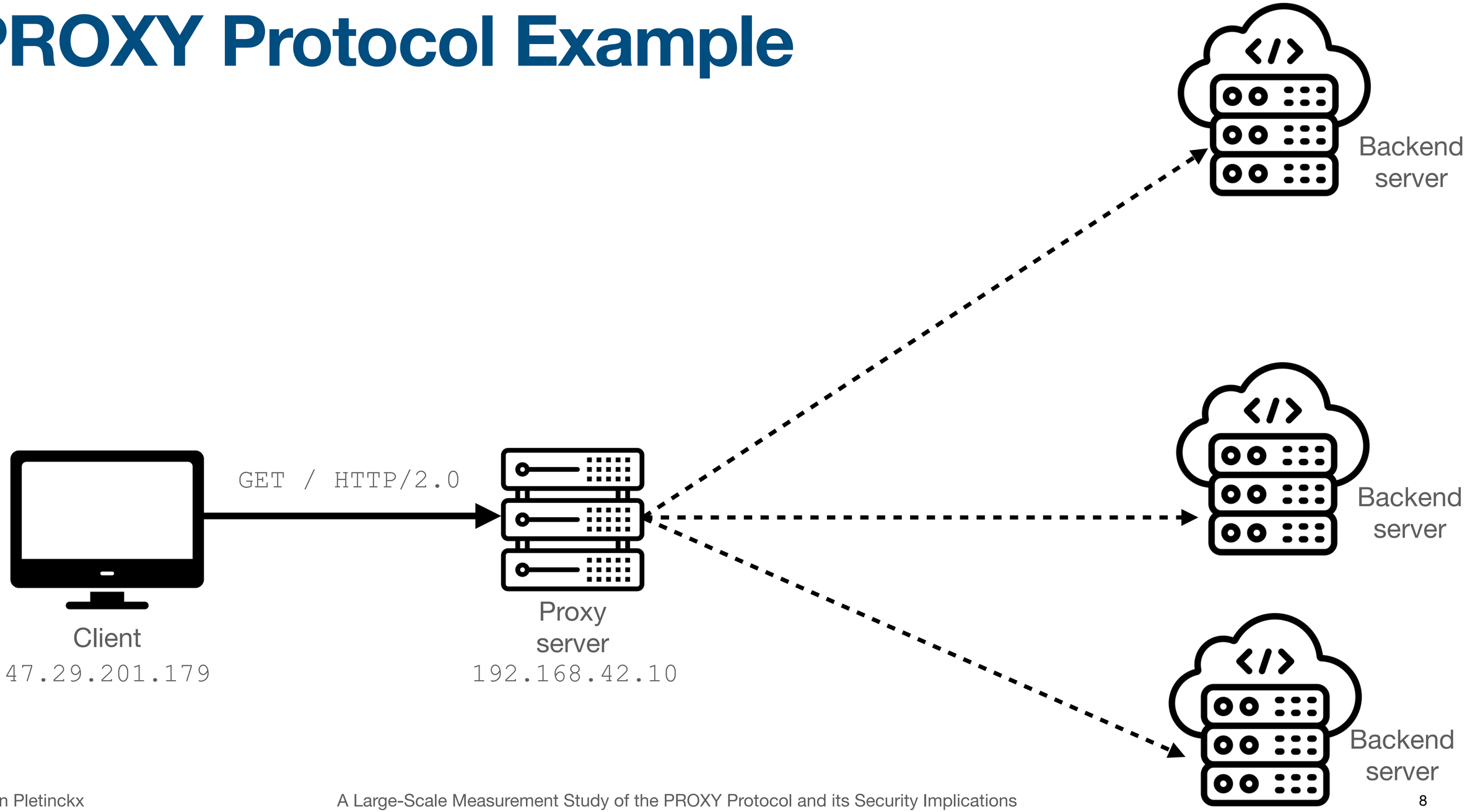


The PROXY Protocol

- Convey client information from the proxy server to the backend server
- Application agnostic (protocol interacts on layer 4)
- Appends PROXY header during connection setup

PROXY Protocol Example



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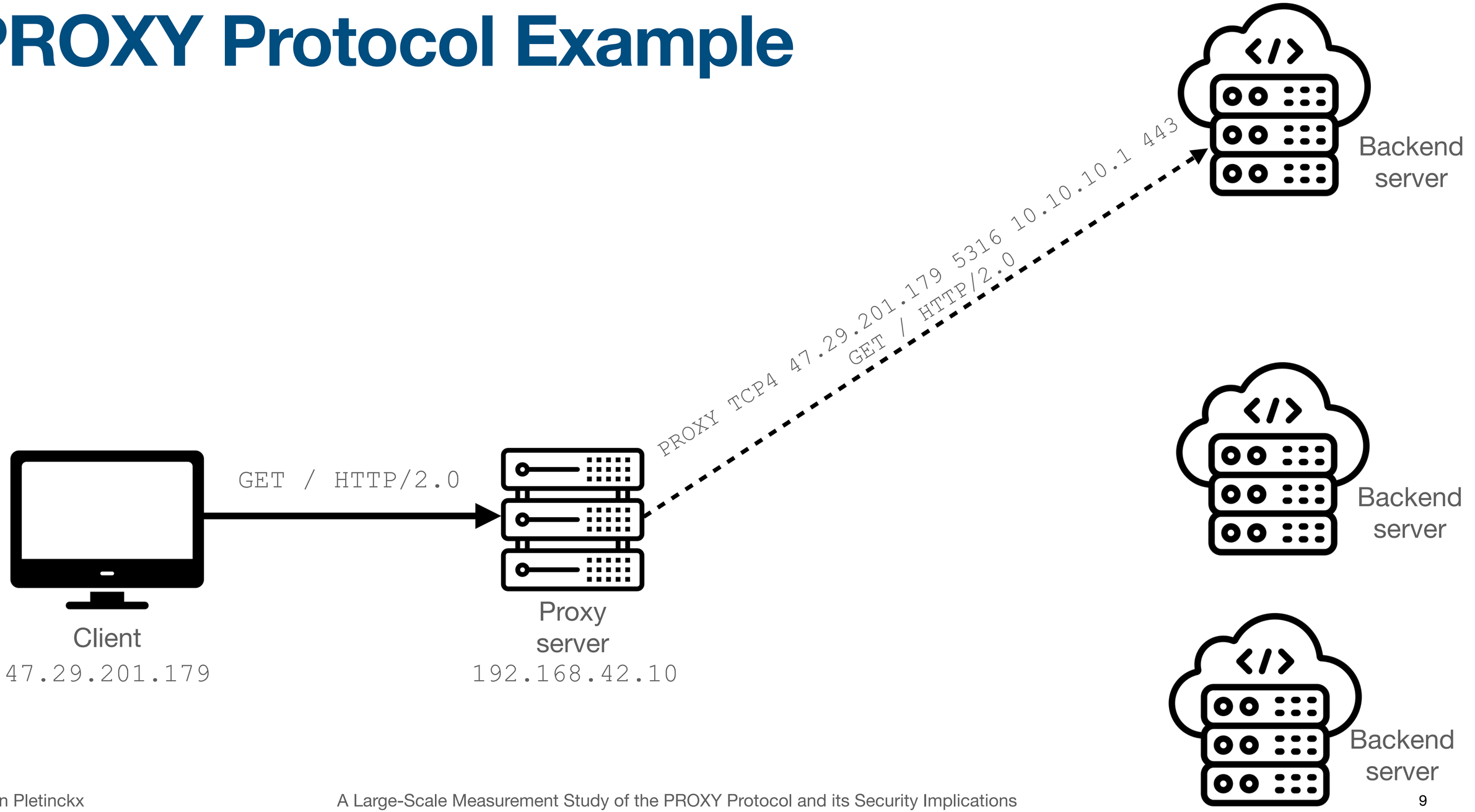

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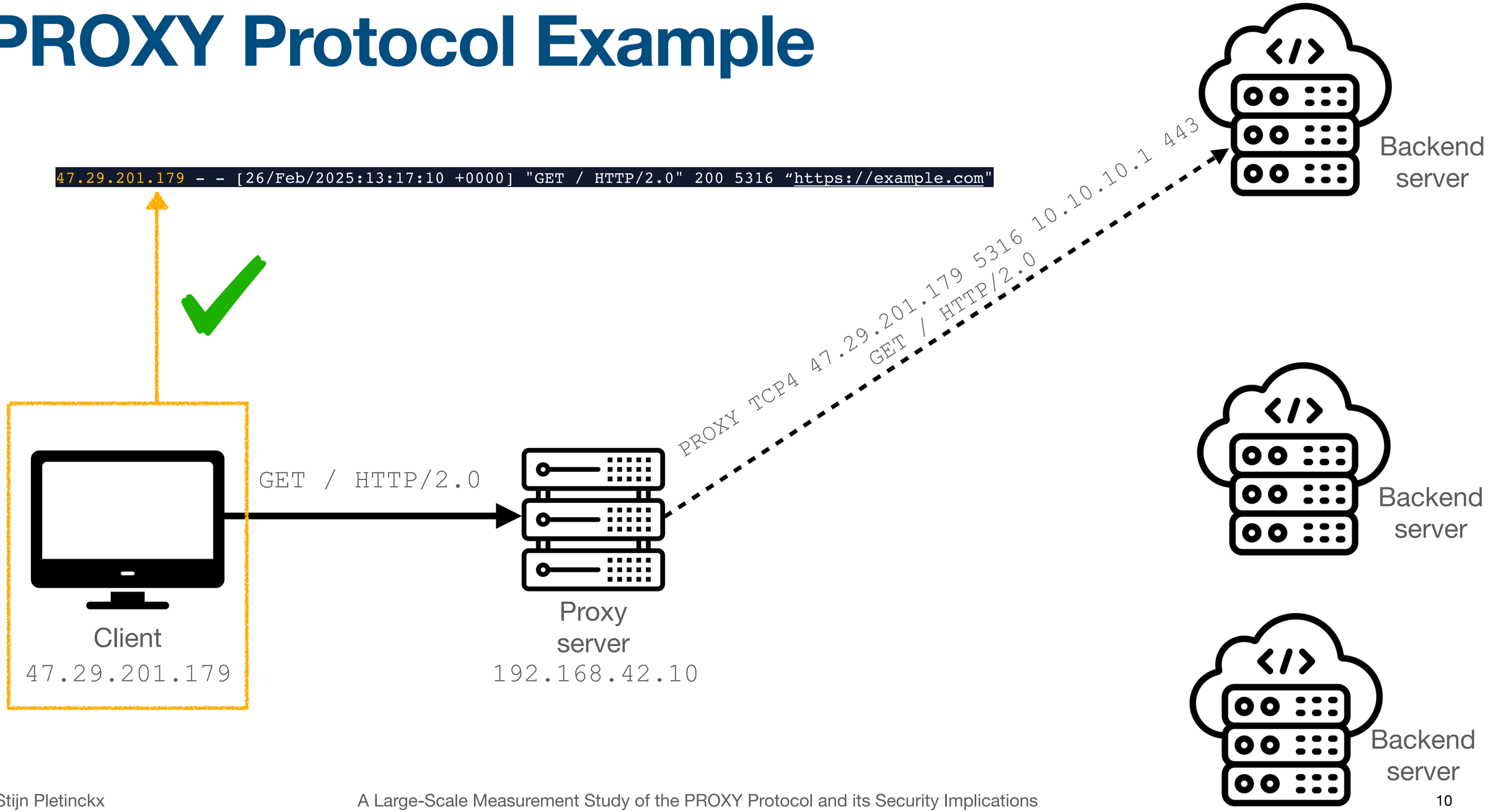

The PROXY Header (v1)

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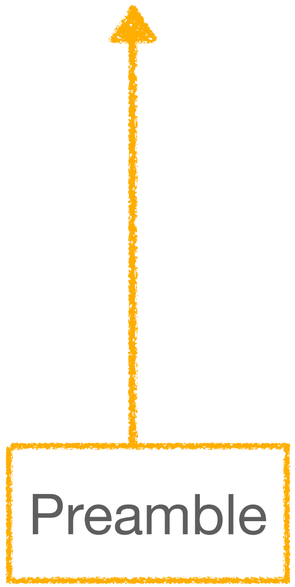

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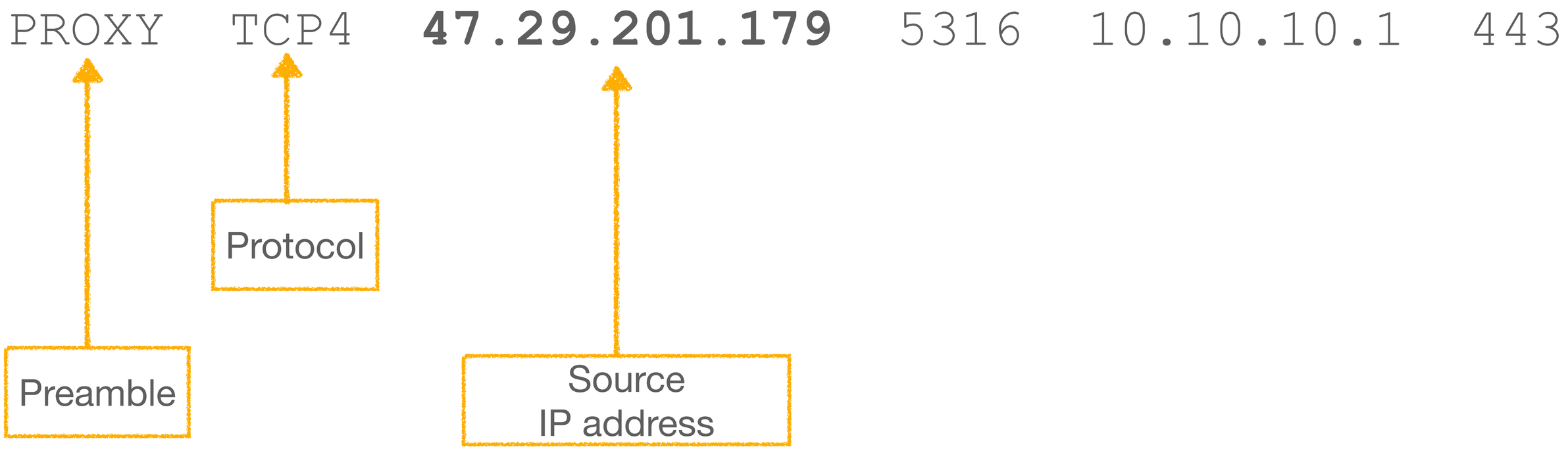

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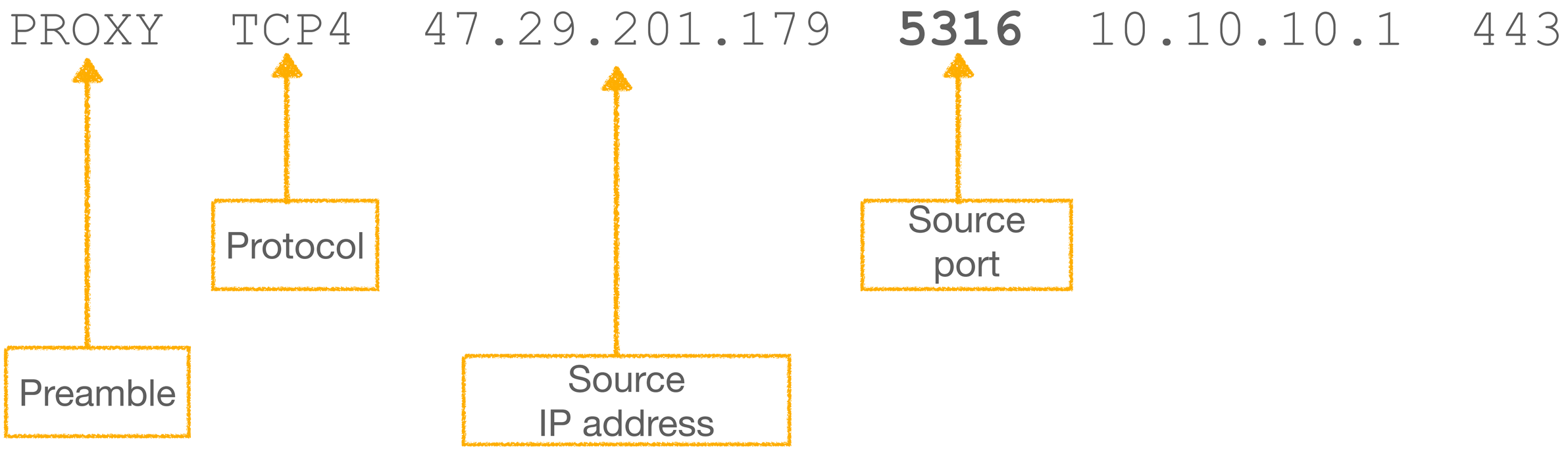

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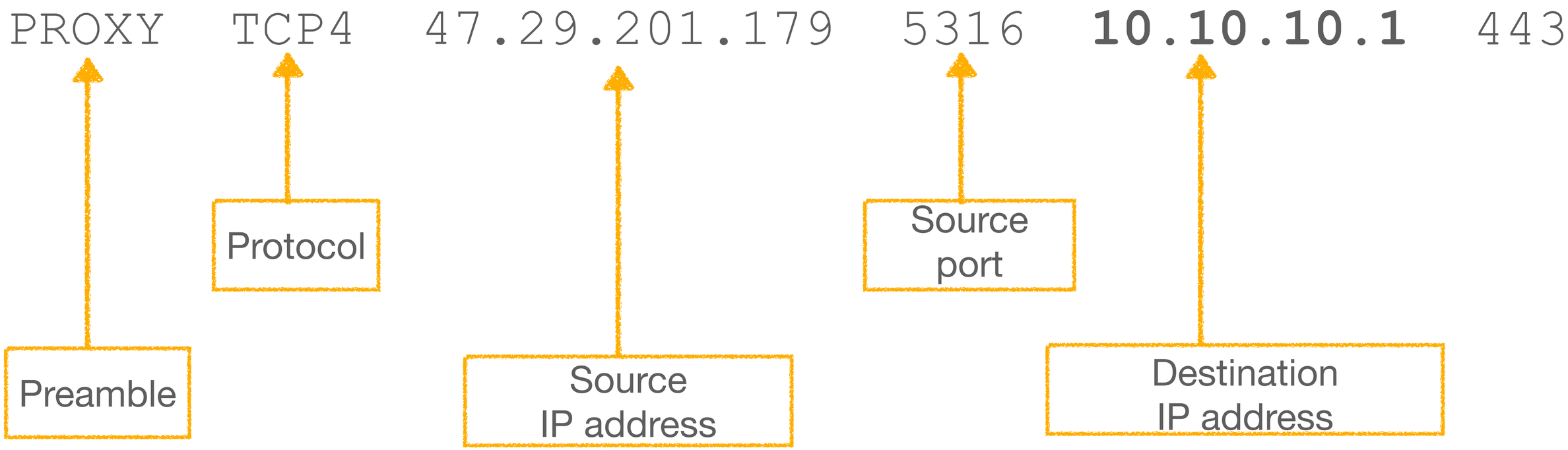

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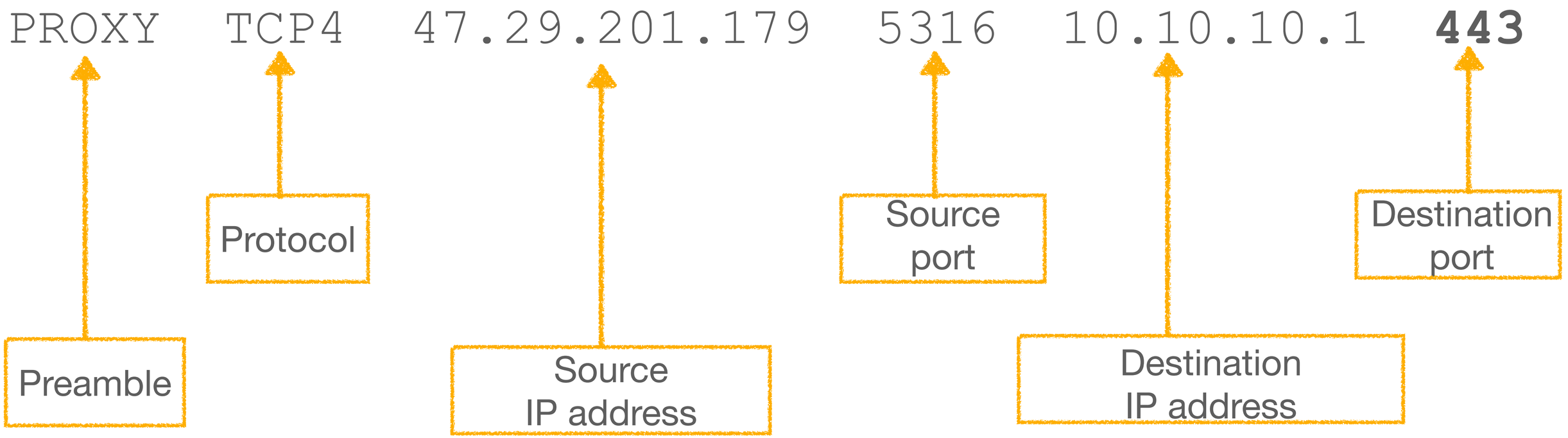
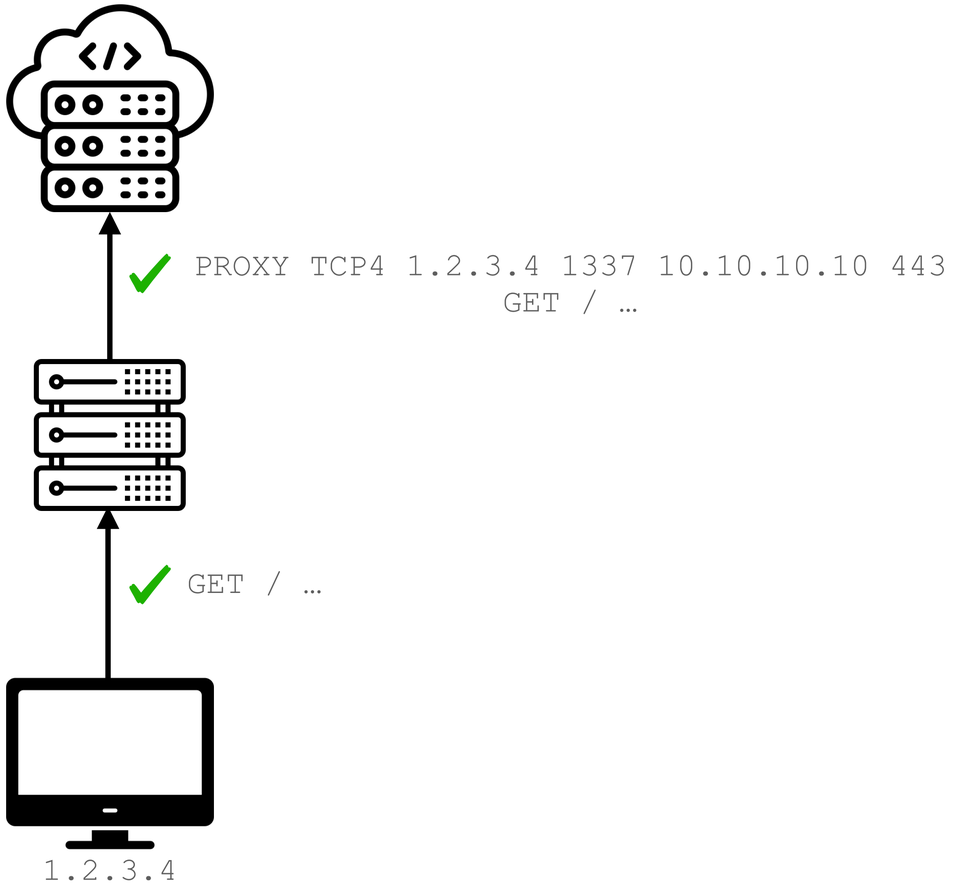
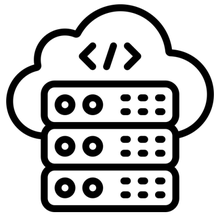


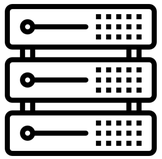
PROXY Protocol and Security



- Access control
- Denial of Service (DoS) protection
- Central blocklisting

PROXY Protocol and Security





5.6.7.8

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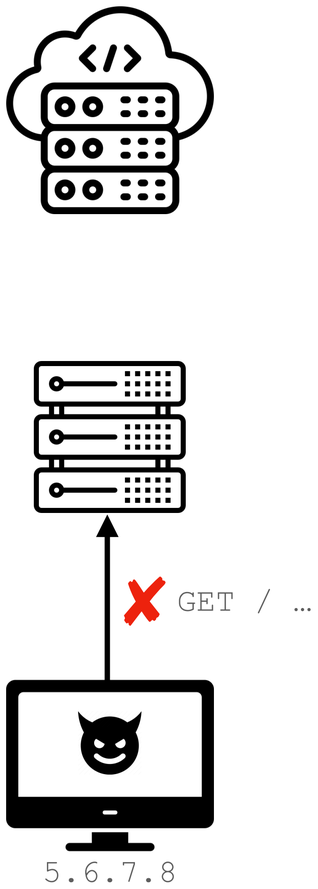

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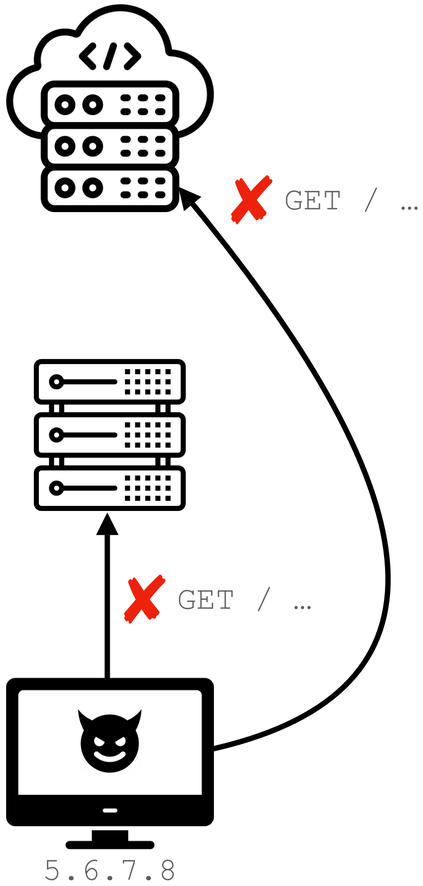

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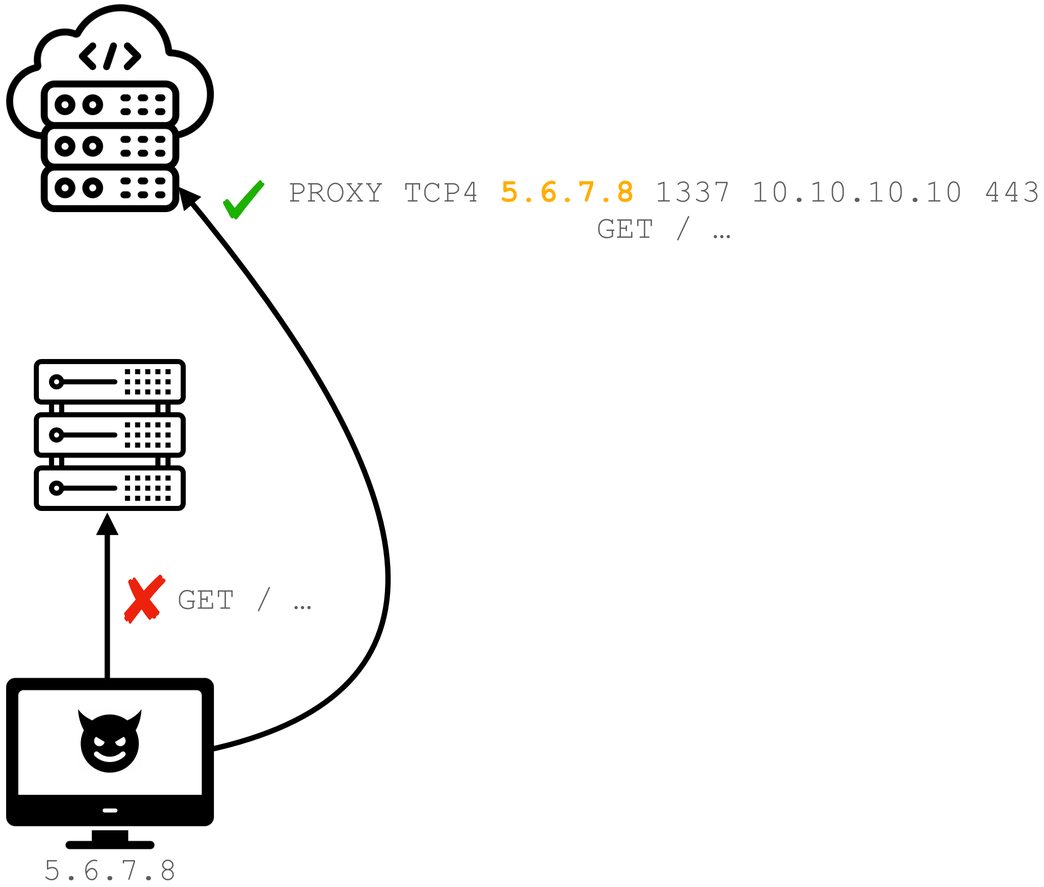

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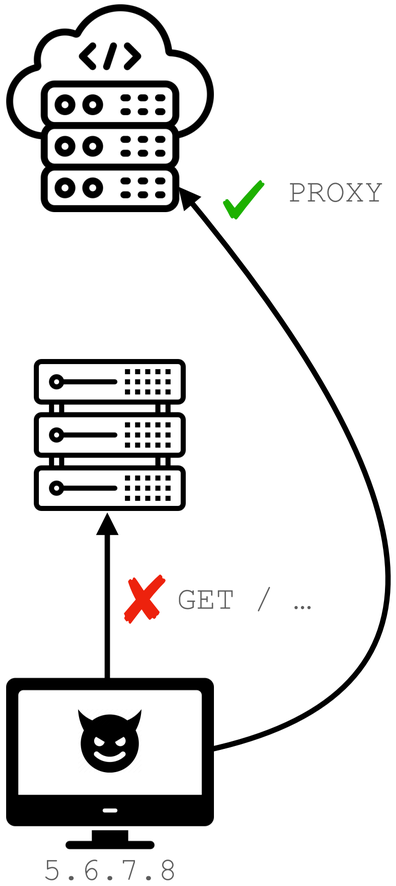

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2. **Backend server does not perform IP-based access control**

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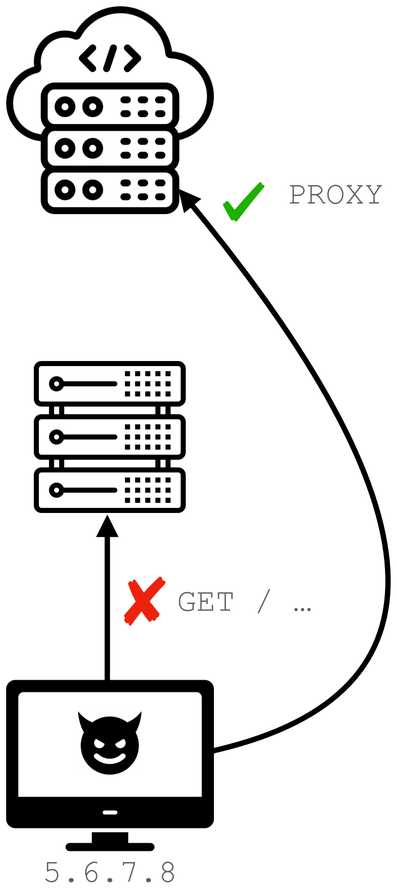

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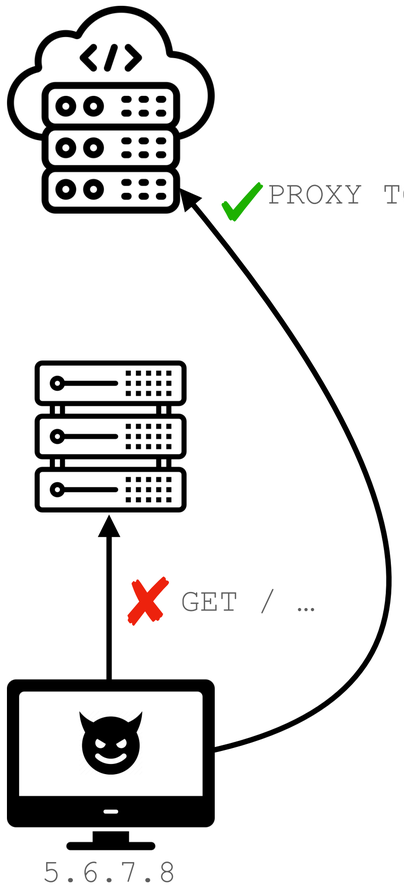

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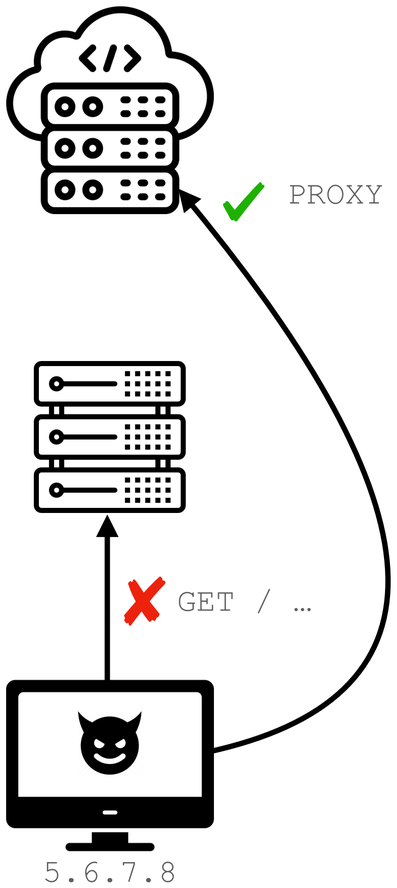

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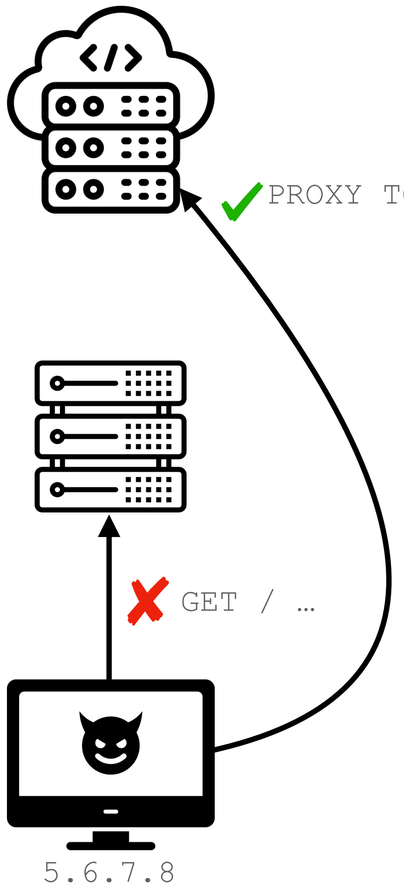
Regular bypass



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Spoofed bypass

Our Work

1. How prevalent are regular bypasses and spoofed bypasses in the wild?

2. What are the security implications of these bypasses?

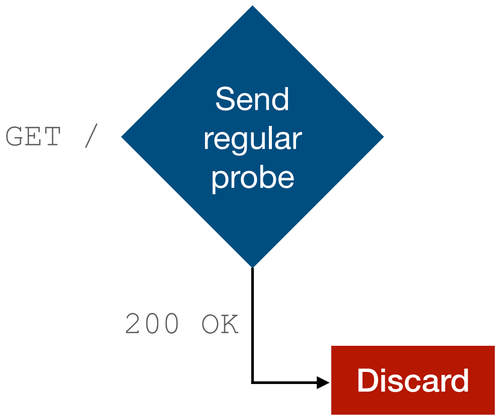
Our Method

- Large-scale measurement study on the full IPv4 address space
- Three protocols:
  - HTTP
  - SMTP
  - SSH
- Use ZMap for initial port scan, then ZGrab for full handshake

Our Method

GET /

Our Method



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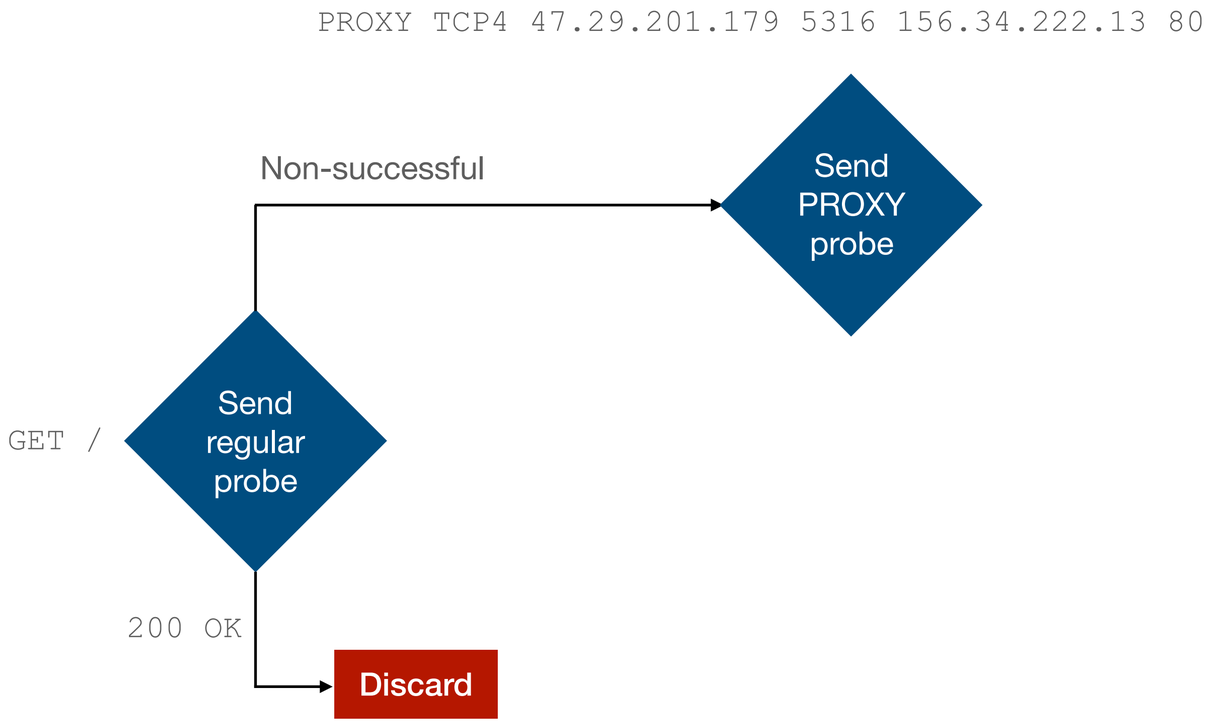
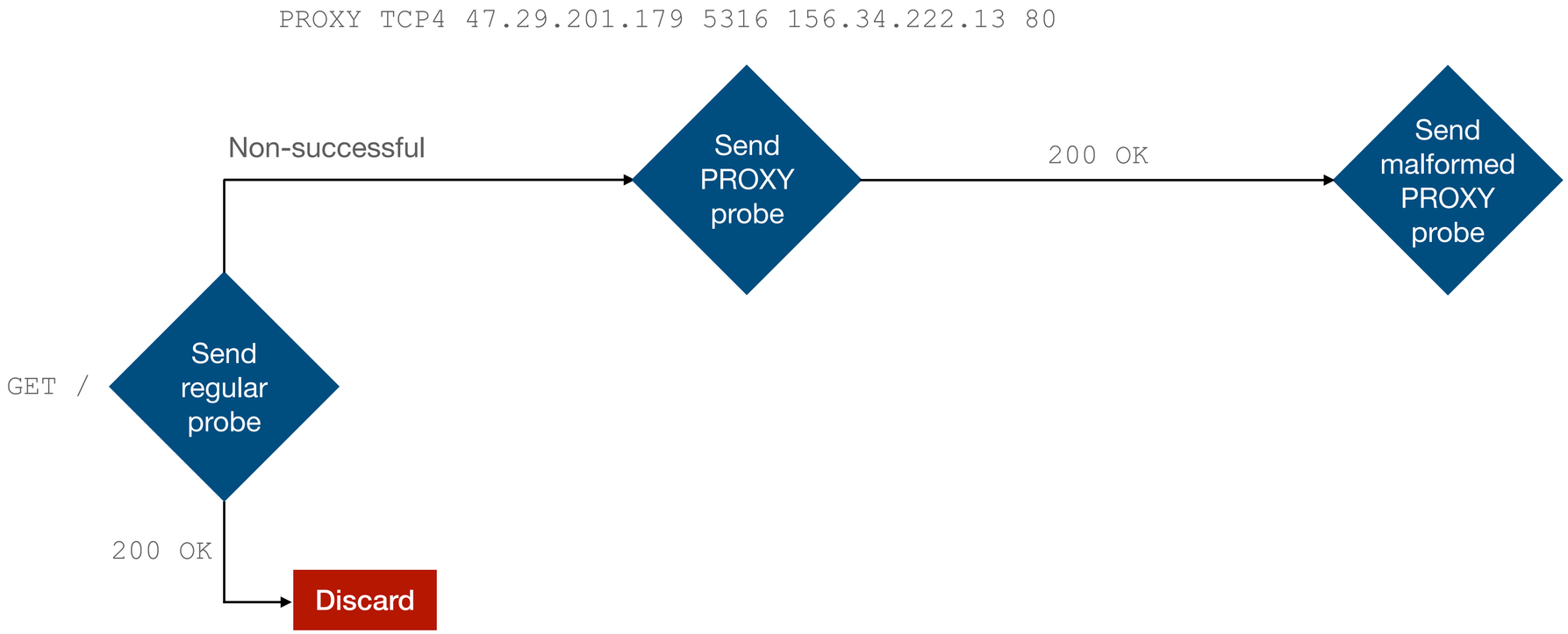

PROXY TCP4 47.29.201.179 5316 156.34.222.13 80
Non-successful
Send PROXY probe
Send regular probe
GET /
200 OK
Discard

Our Method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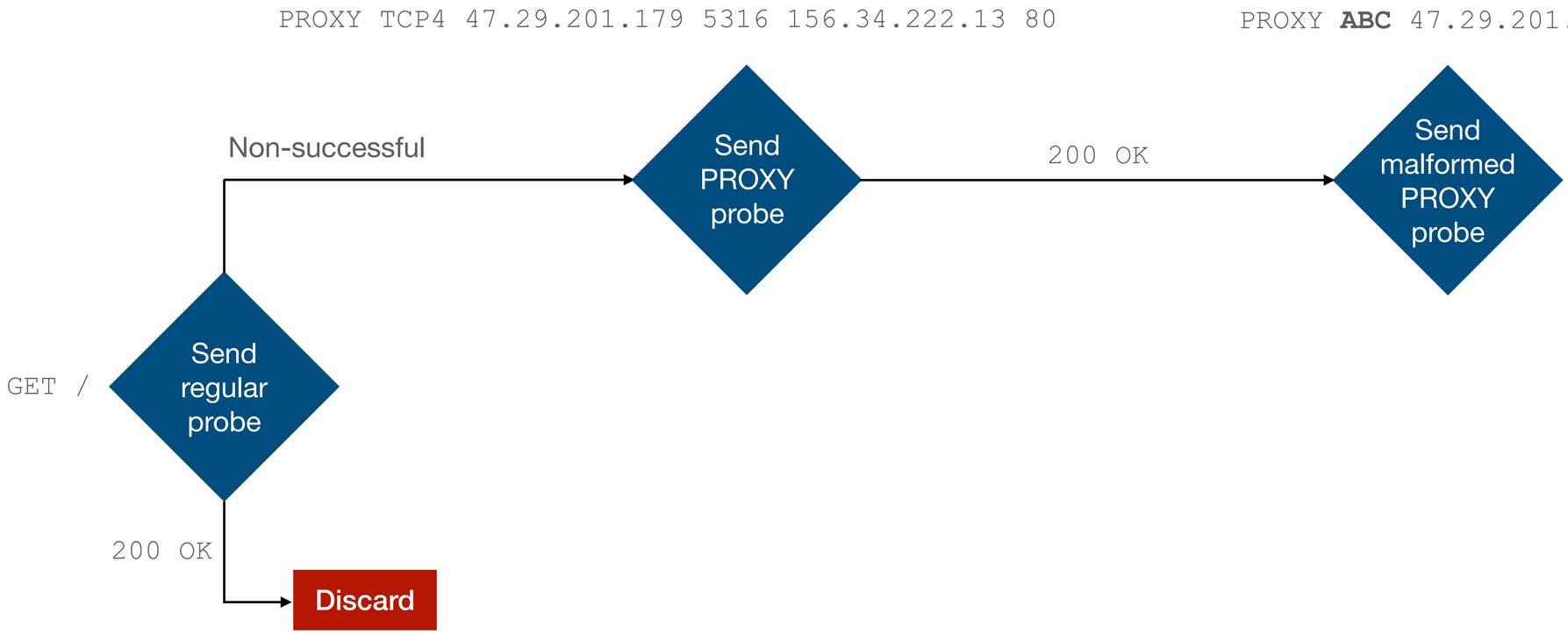
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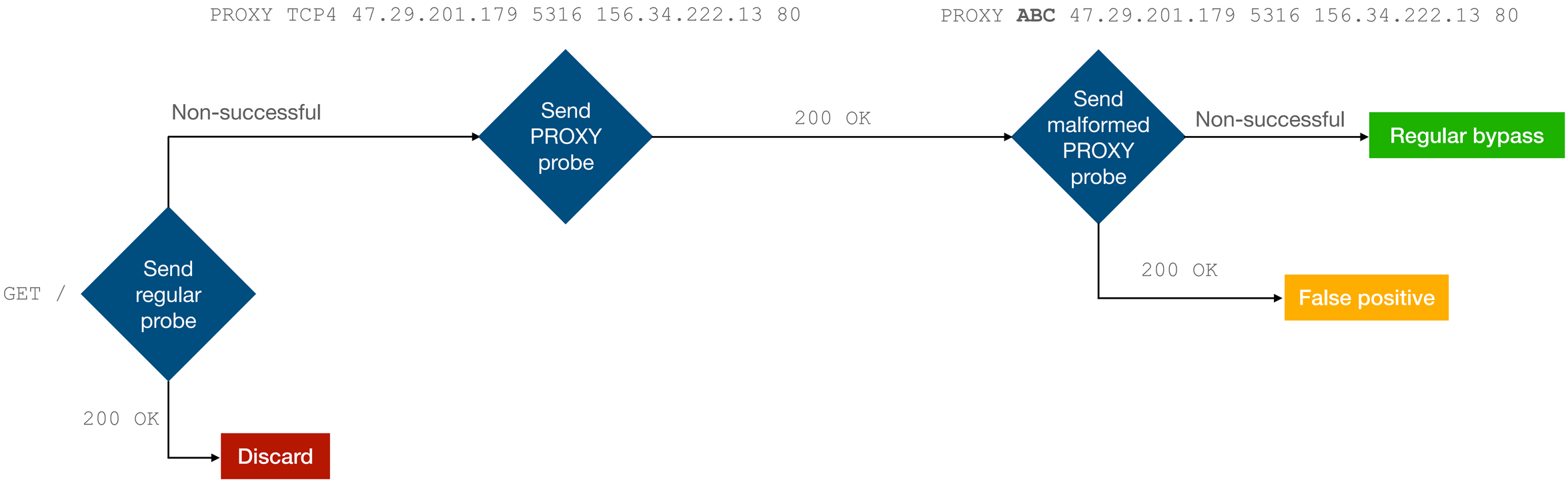
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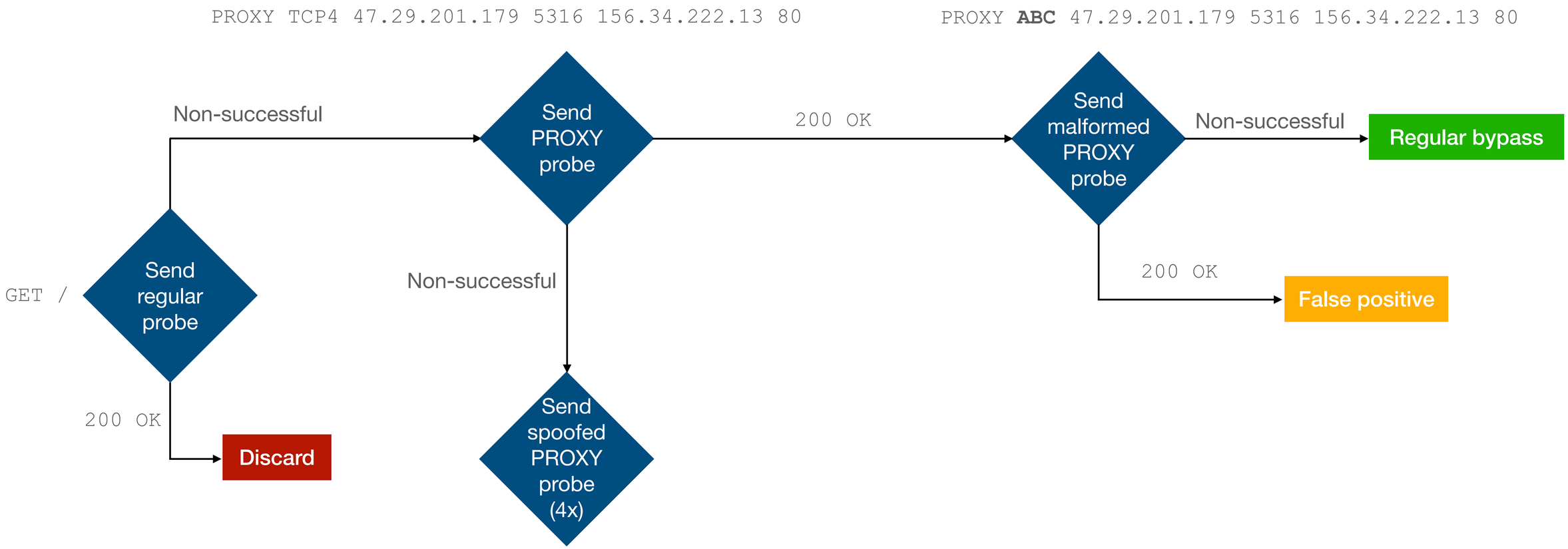
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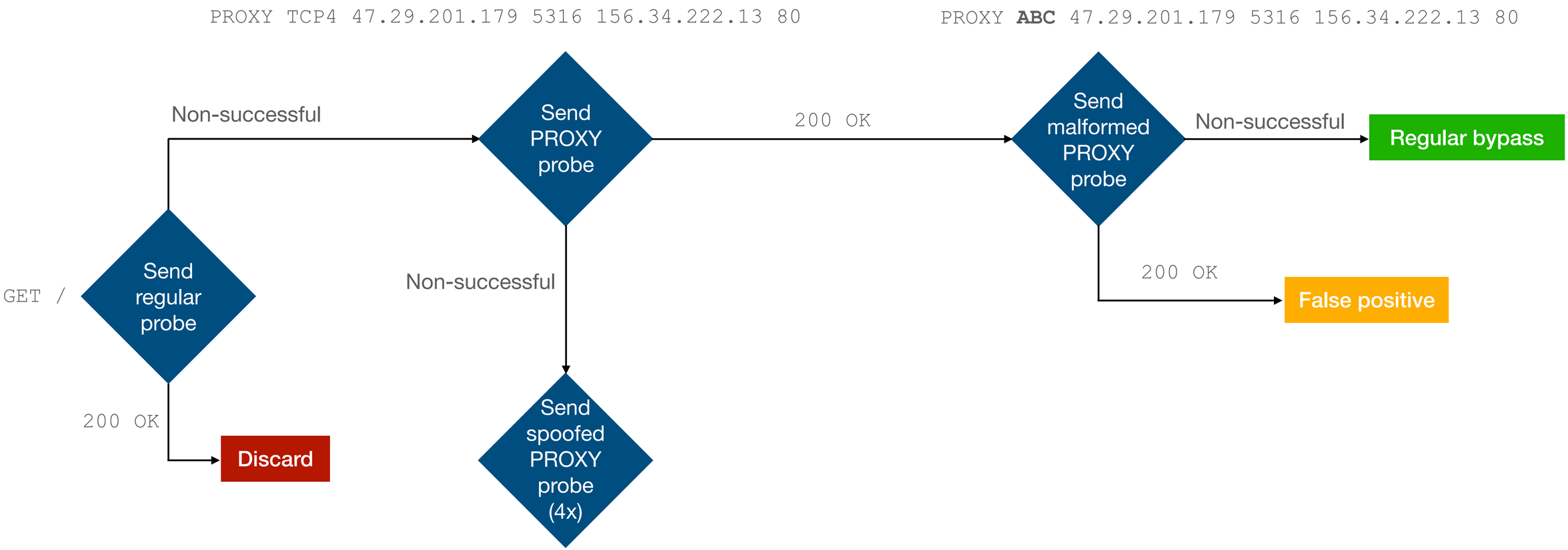
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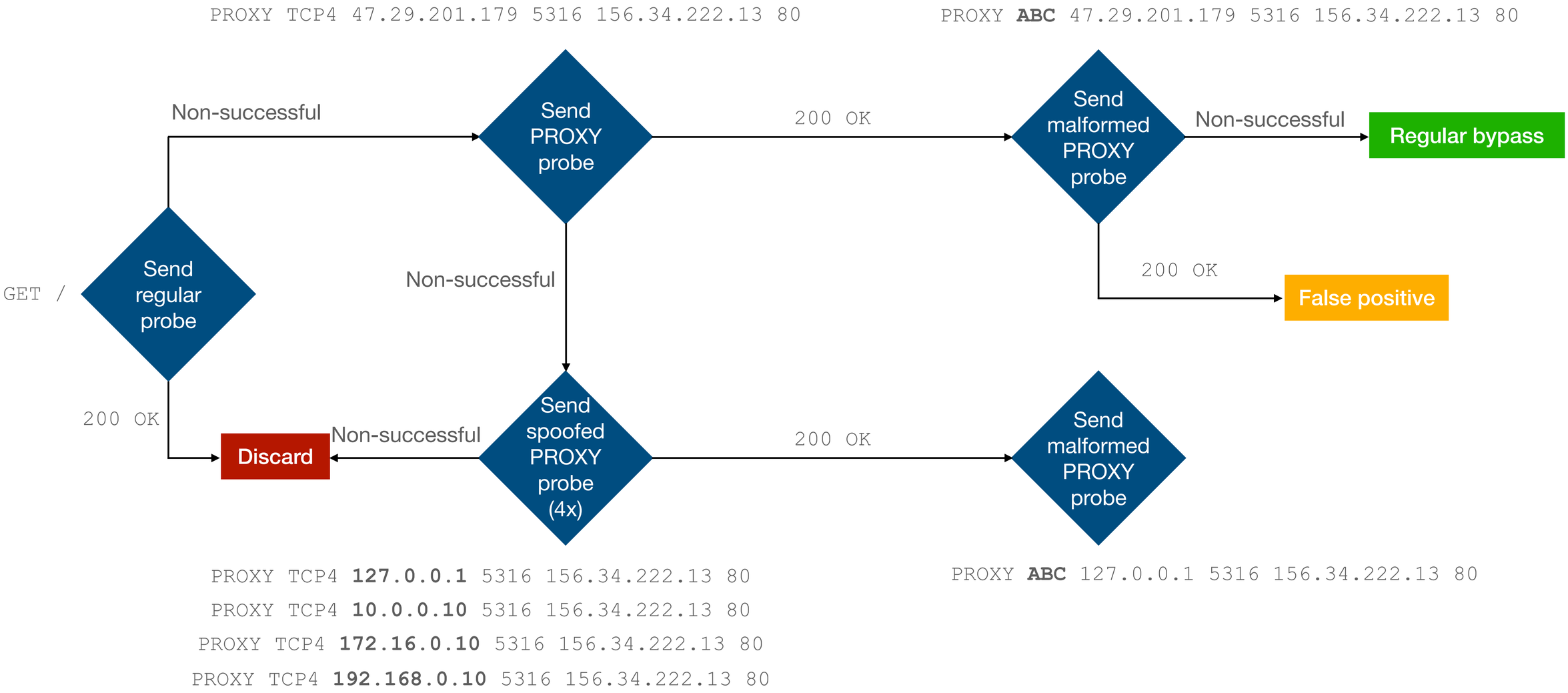
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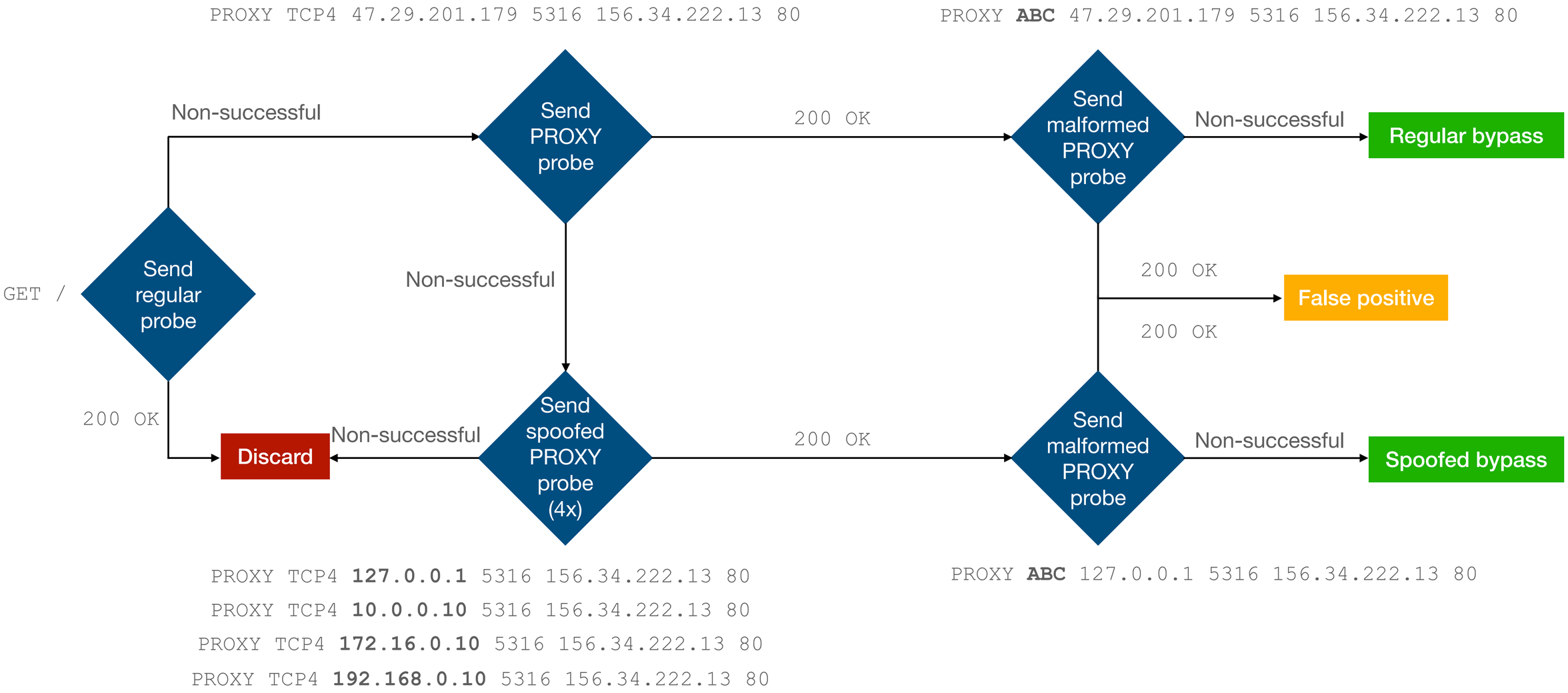
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Our Results

Large number of hosts accept PROXY headers from unknown sources

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- 2,332,377 over SMTP
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Analysis of 177,983 Web Pages

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Boilerplate	118,641 (66.66%)	64,544 (36.83%)
Login	34,474 (19.37%)	12,136 (6.82%)
Miscellaneous	12,791 (7.19%)	75,897 (42.64%)
Enable JavaScript	6,577 (3.70%)	1,439 (0.81%)
Cannot parse	3,697 (2.08%)	3,696 (2.08%)
NGINX	1,345 (0.76%)	12,875 (7.23%)
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Could potentially extend to over 4,600 pages!

Spoofed Bypasses

Header \ No Header	Unsuccessful	4xx	403
2xx Non-internal IP	5,863 (11,640)	648 (3,430)	211 (953)
2xx 127.0.0.1	6,609 (12,235)	1,041 (3,773)	252 (978)
2xx 10.0.0.10	7,480 (13,107)	1,029 (3,762)	246 (974)
2xx 172.16.0.10	7,660 (13,313)	1,011 (3,754)	235 (961)
2xx 192.168.0.10	5,899 (11,527)	1,027 (3,766)	239 (967)

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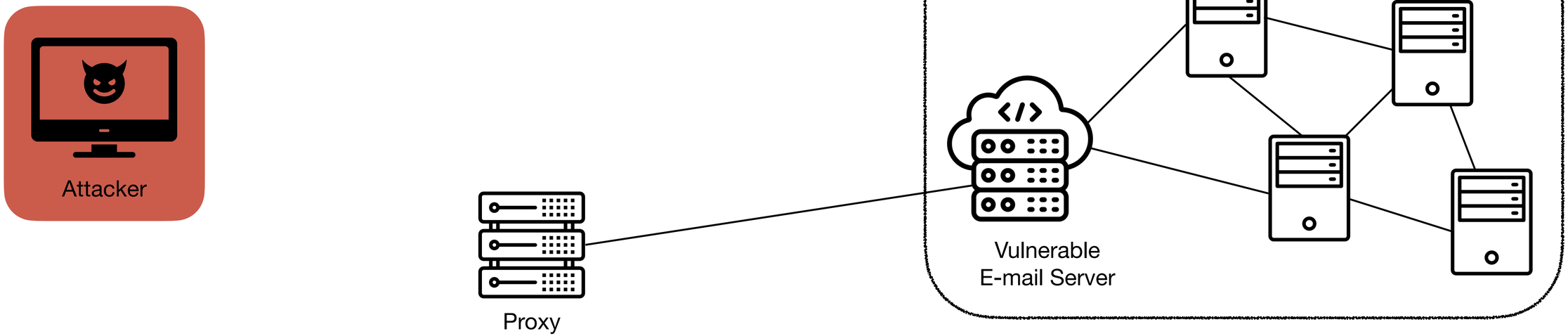
PROXY header injection can turn SMTP servers into open relays

SMTP Example: Postfix

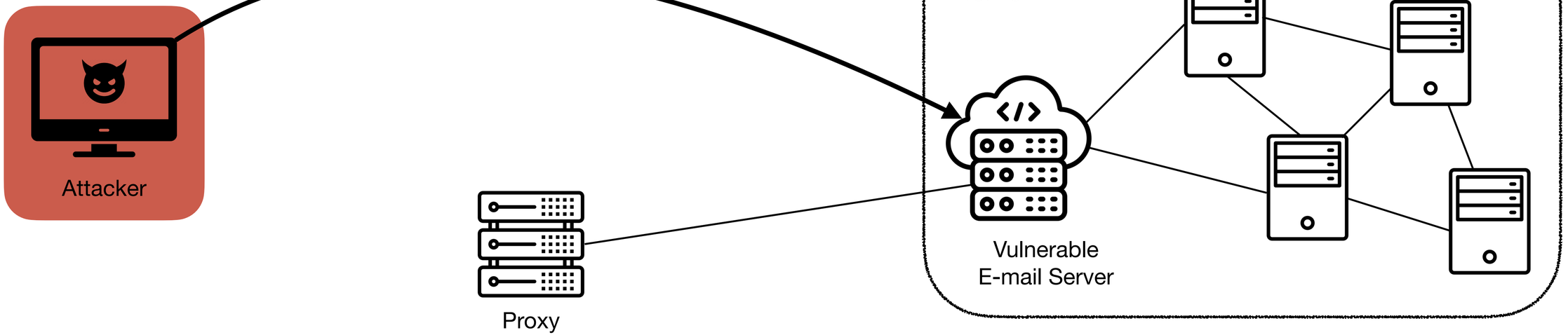
- By default, Postfix only relays emails coming from the `localhost` address
- To bypass this, an attacker needs to “convince” the Postfix server that the email originates from the `localhost` address
  - We can use the PROXY protocol for this! (Spoofed bypass)

Example

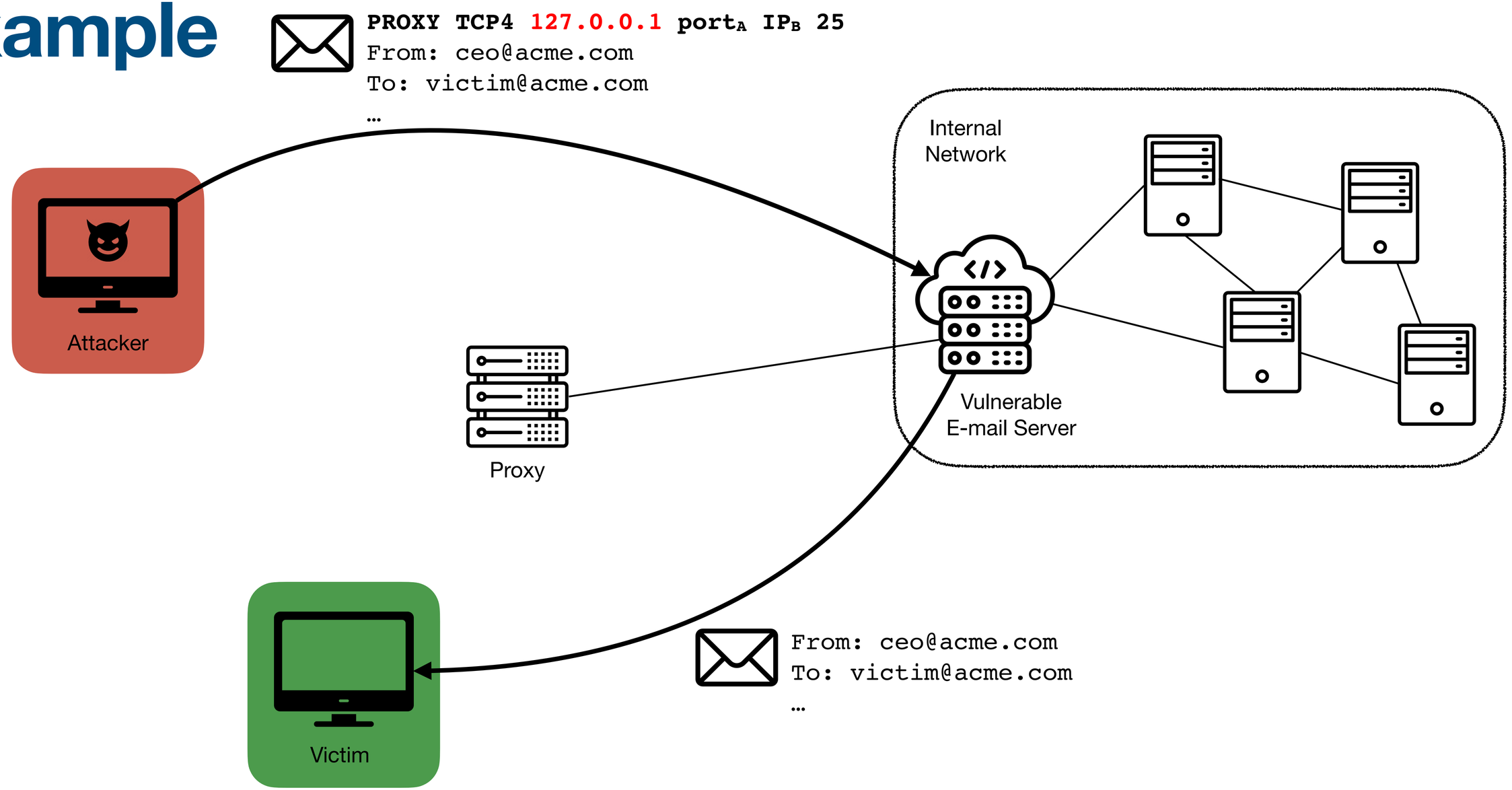

Attacker
Proxy
Internal
Network
Vulnerable
E-mail Server
Victim

Example

```
PROXY TCP4 127.0.0.1 portA IPB 25
From: ceo@acme.com
To: victim@acme.com
…
```



Example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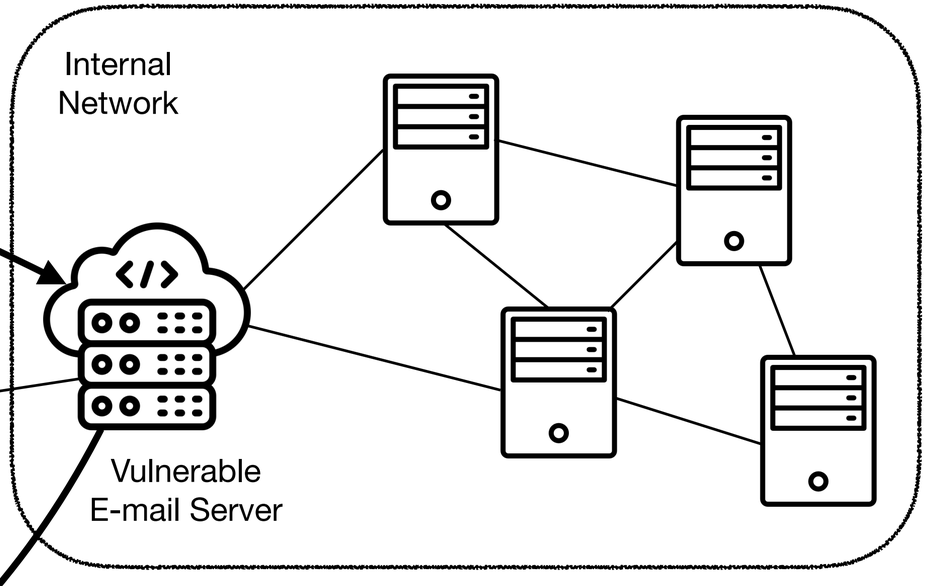
Example

```
PROXY TCP4 127.0.0.1 portA IPB 25
From: ceo@acme.com
To: victim@acme.com
…
```

We found 373 SMTP servers vulnerable to this attack!



```
From: ceo@acme.com
To: victim@acme.com
…
```

Example

```
PROXY TCP4 127.0.0.1 portA IPB 25
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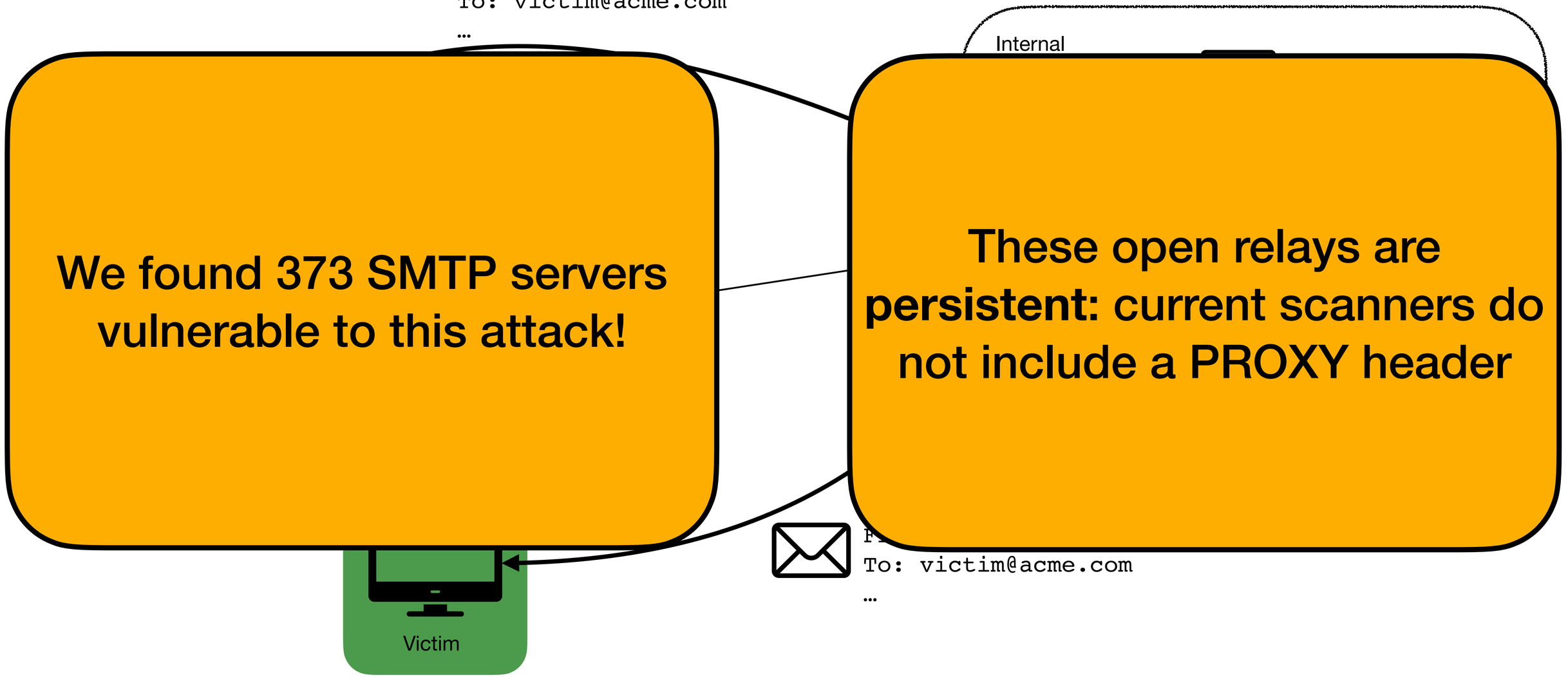

Our Results

Large number of hosts accept PROXY headers from unknown sources

- 177,983 over HTTP
- 2,332,377 over SMTP
- 2,343,420 over SSH

PROXY header injection can bypass access controls

Including to:
- Private dashboards
- Home automation devices
- IoT monitoring services

Potentially over 4,000 affected websites

PROXY header injection can turn SMTP servers into open relays

- Impersonate any email address
- Undetectable by current scanners
- At least 373 vulnerable email servers

Ethics

- All scans contained opt-out mechanisms
- We used a `HEAD` request for the spoofed probes to avoid leaking sensitive information
- All emails were sent from and to addresses under our control
- All affected parties were notified through responsible disclosure
  - Yes, we received bounties

Summary

- First study on the prevalence and security implications of the PROXY protocol

- Many backend servers will happily accept unsolicited PROXY headers from unknown clients

- This can lead to severe security implications:
  - Exposes internal networks
  - Gives access to private information and control systems
  - Turns SMTP servers into open relays

Summary

- First study on the prevalence and security implications of the PROXY protocol

- Many backend servers will happily accept unsolicited PROXY headers from unknown clients

- This can lead to severe security implications:
  - Exposes internal networks
  - Gives access to private information and control systems
  - Turns SMTP servers into open relays

Thank You! Questions?

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