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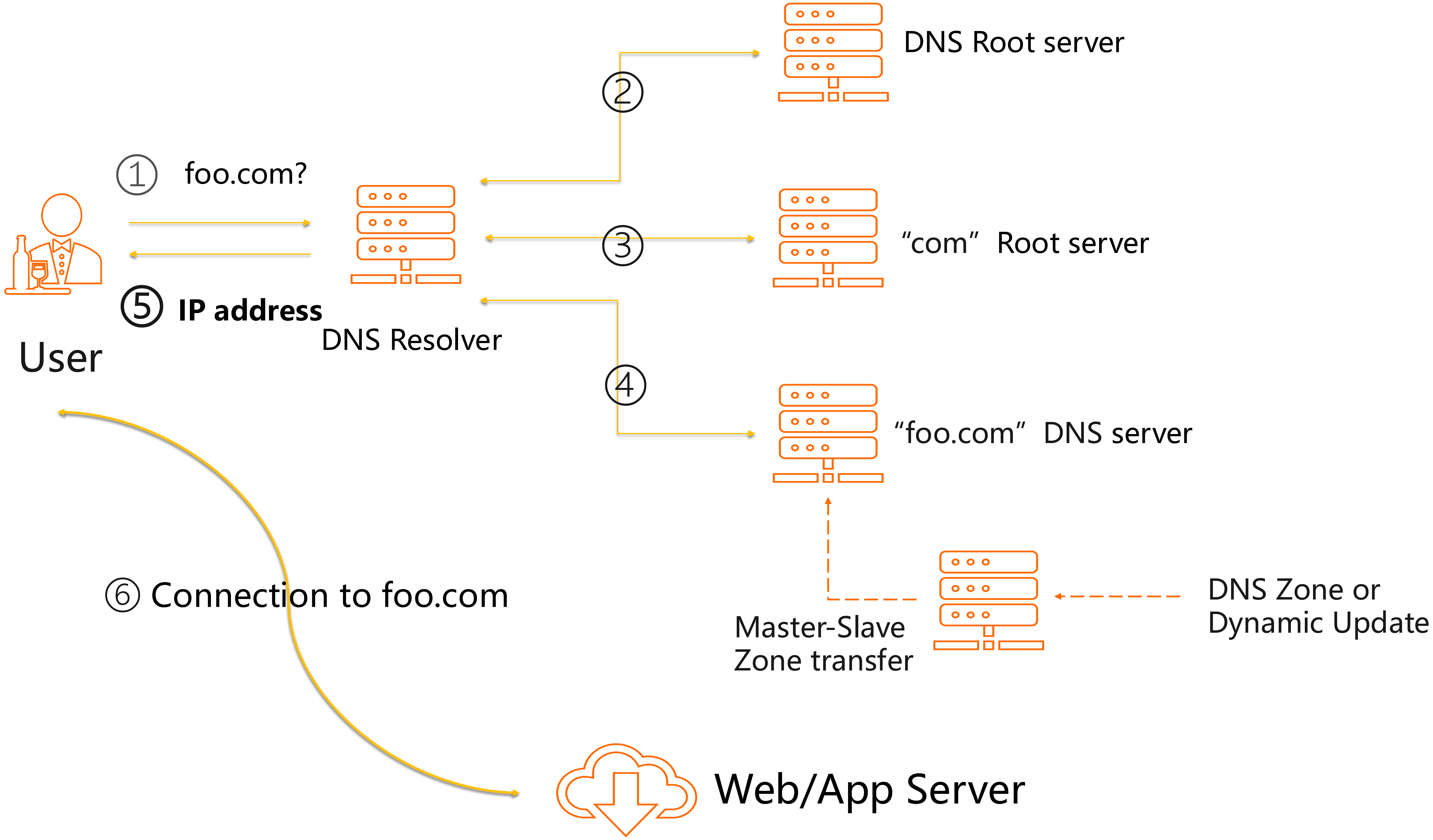
COMPUTING FOR VALUE BEYOND COMPUTATION

Who Forged My DNS Answers?

From a Real DNS Hijacking Case

Linjian (Davey) Song
songlinjian@gmail.com
@ OARC44

DNS Resolution



Troubleshooting DNS is very difficult

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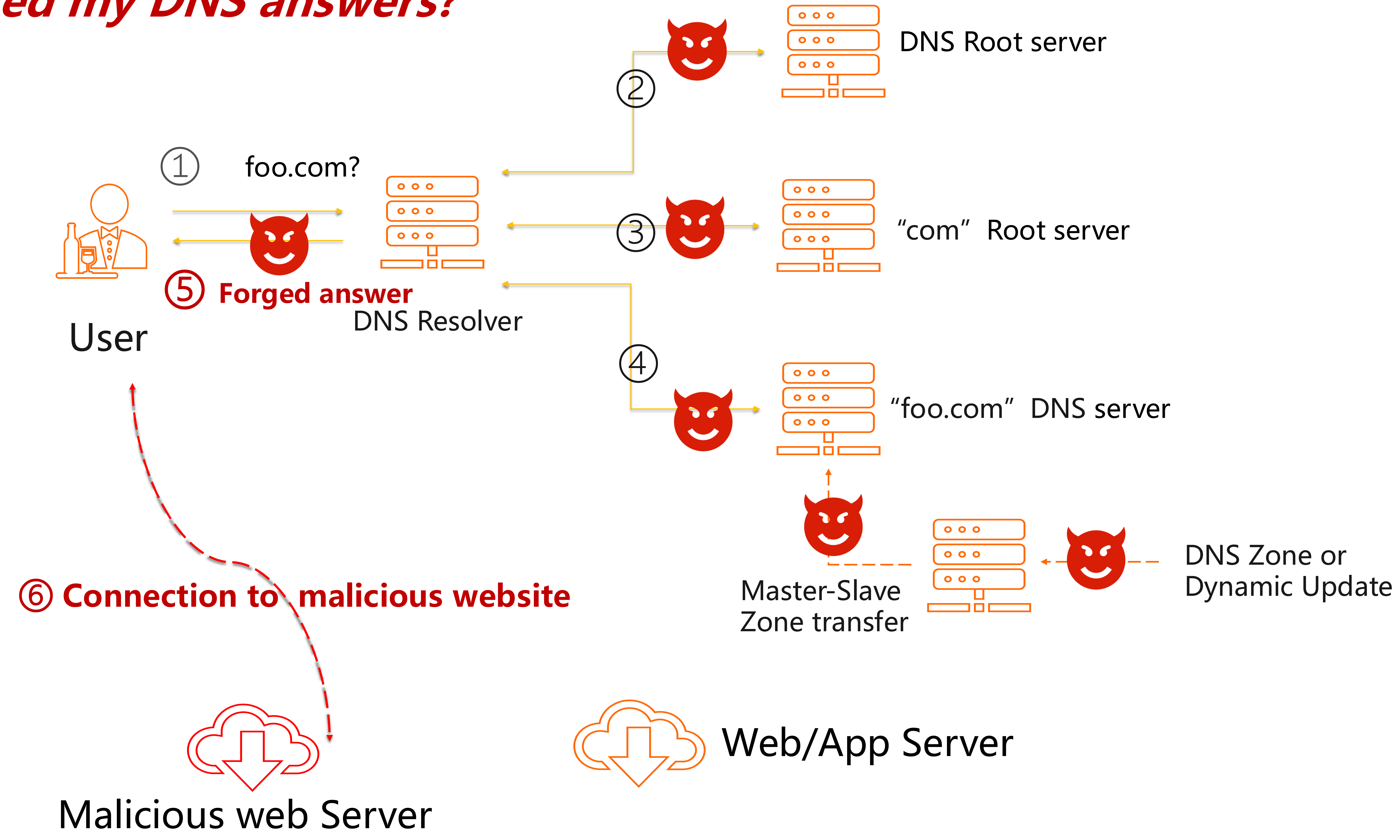
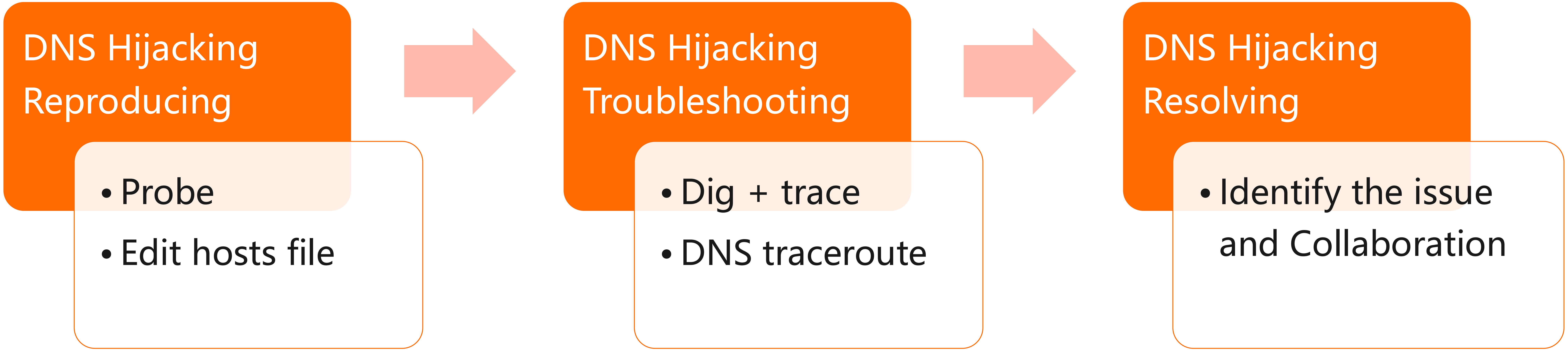
DNS Hijacking

Who forged my DNS answers?



Given that DNSSEC is not widely deployed....

A DNS Hijacking Real Case



DNS Hijacking Reproducing

- Probe
- Edit hosts file

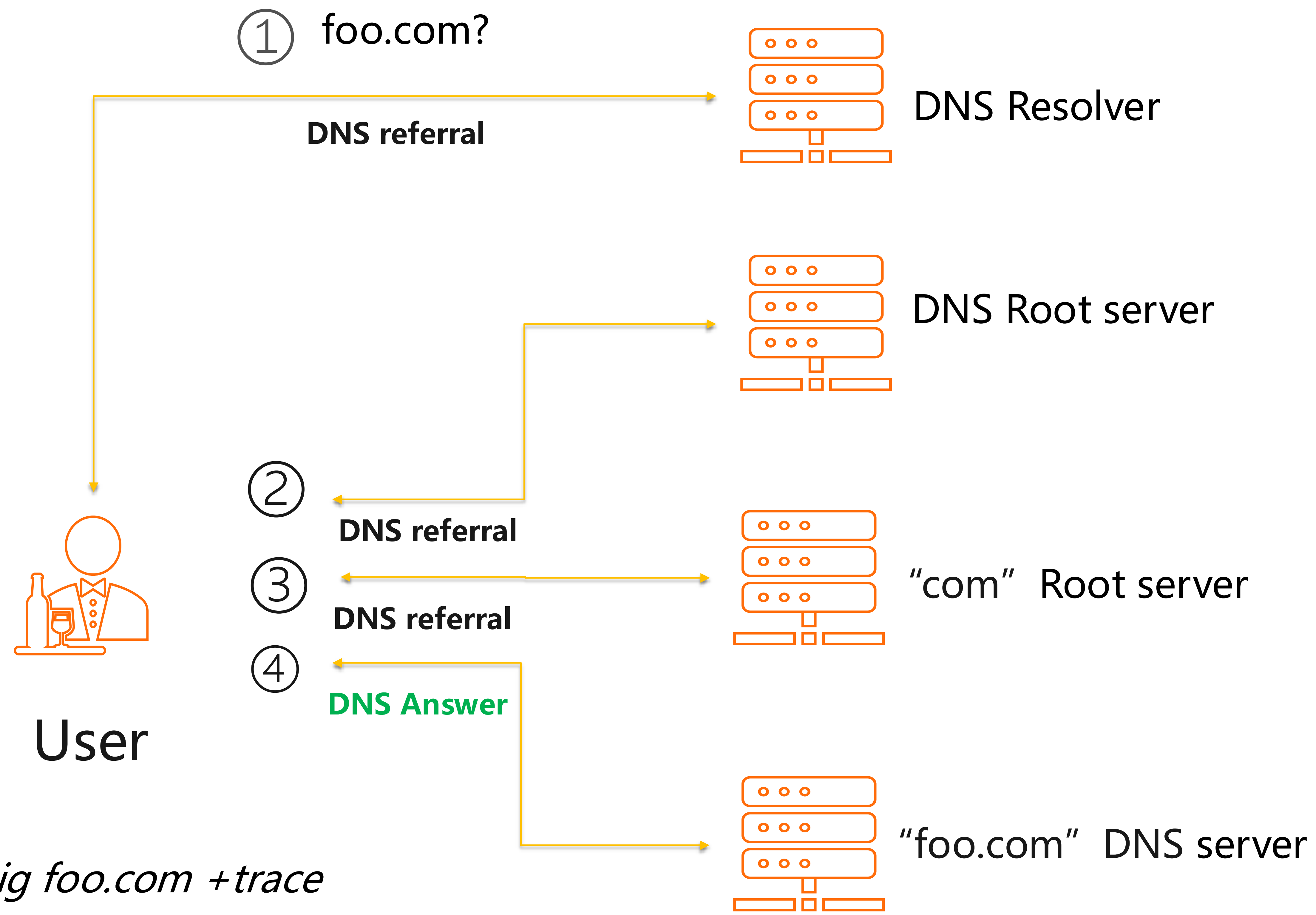
DNS Hijacking Troubleshooting

- Dig + trace
- DNS traceroute

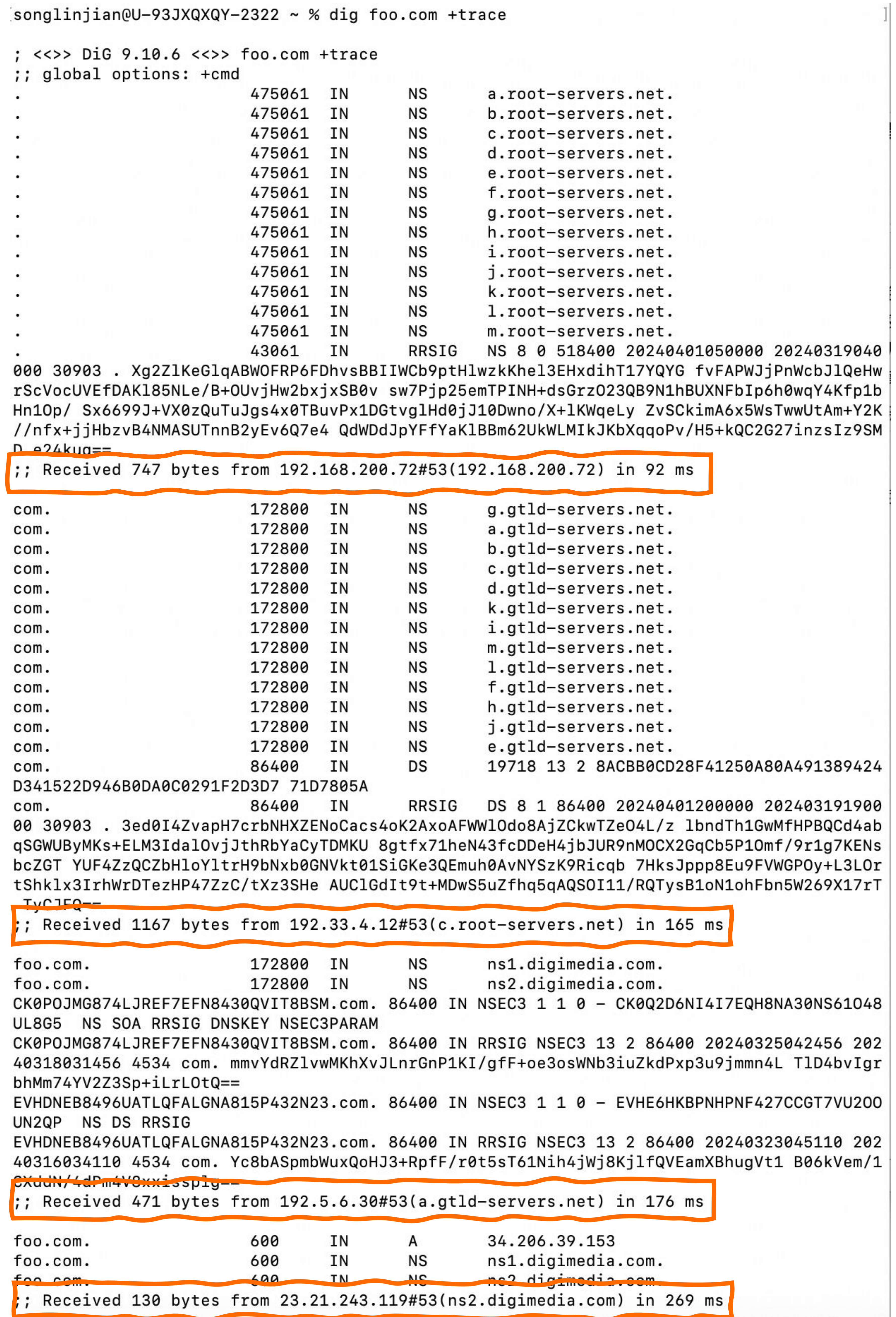
DNS Hijacking Resolving

- Identify the issue and Collaboration

Dig +trace Command (Normal Response)

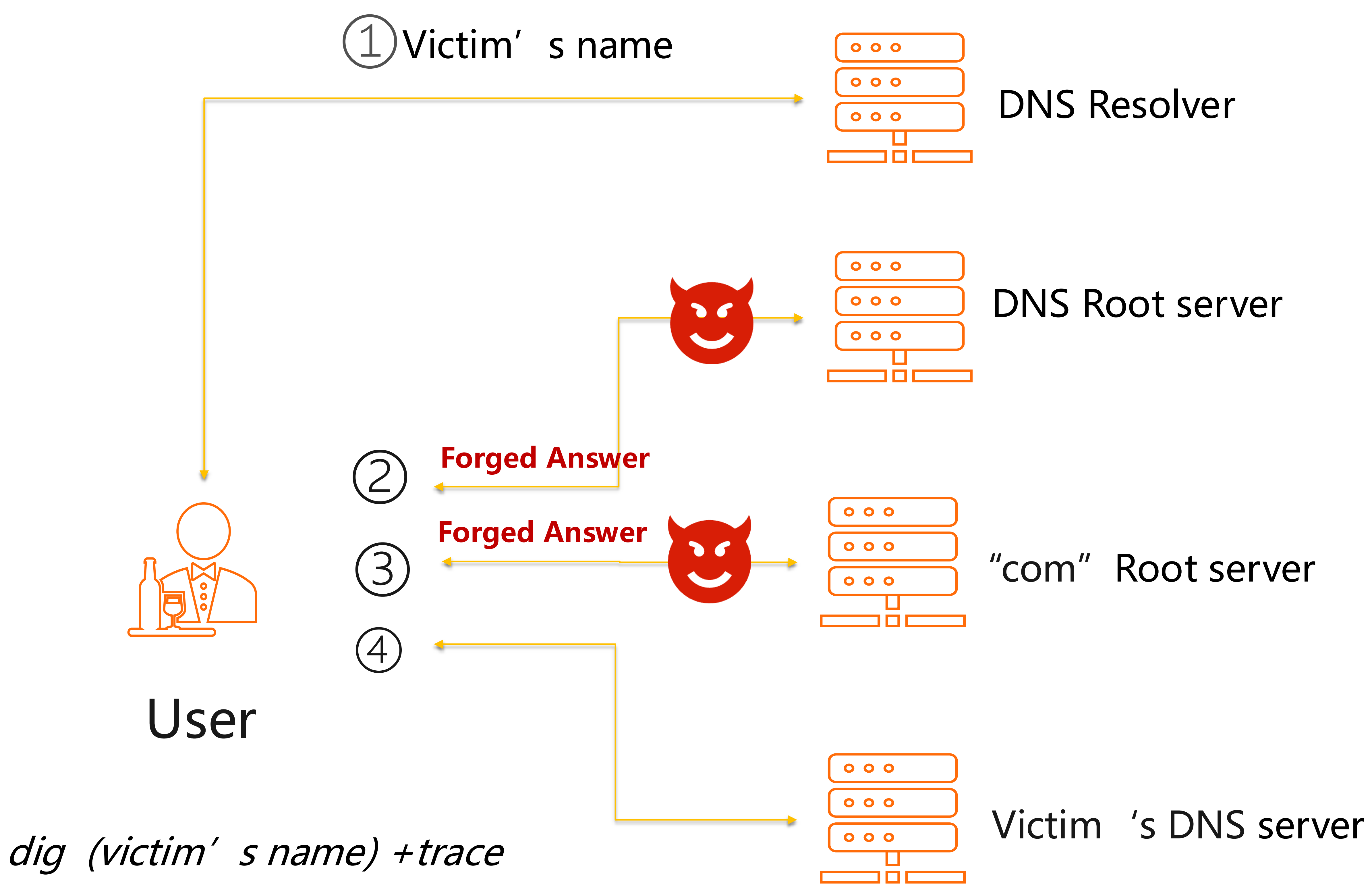


dig foo.com +trace



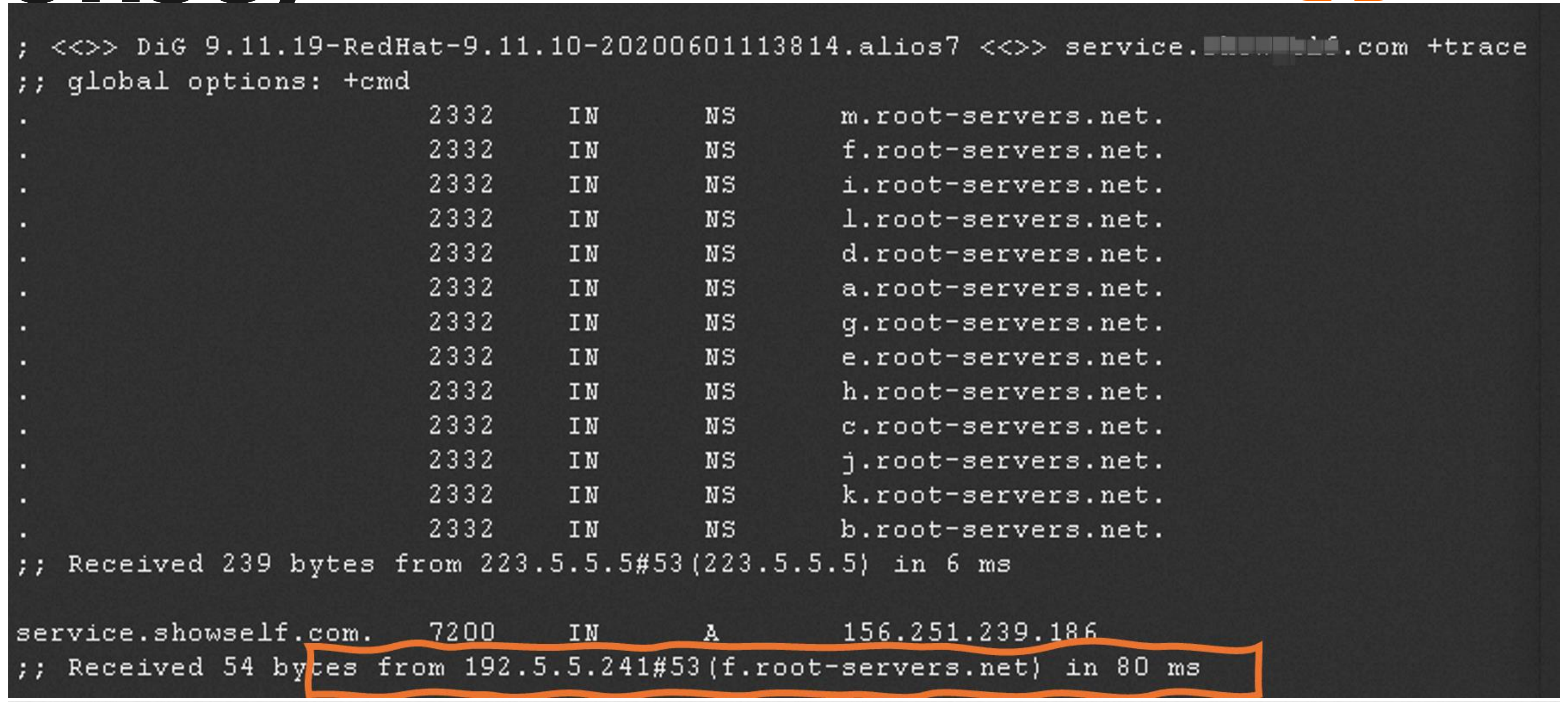
```
songlinjian@U-93JXQXQY-2322 ~ % dig foo.com +trace

; <<>> DiG 9.10.6 <<>> foo.com +trace
;; global options: +cmd
.                       475061  IN      NS      a.root-servers.net.
.                       475061  IN      NS      b.root-servers.net.
.                       475061  IN      NS      c.root-servers.net.
.                       475061  IN      NS      d.root-servers.net.
.                       475061  IN      NS      e.root-servers.net.
.                       475061  IN      NS      f.root-servers.net.
.                       475061  IN      NS      g.root-servers.net.
.                       475061  IN      NS      h.root-servers.net.
.                       475061  IN      NS      i.root-servers.net.
.                       475061  IN      NS      j.root-servers.net.
.                       475061  IN      NS      k.root-servers.net.
.                       475061  IN      NS      l.root-servers.net.
.                       475061  IN      NS      m.root-servers.net.
.                       43061   IN      RRSIG   NS 8 0 518400 20240401050000 20240319040
000 30903 . Xg2ZlKeGlqABWOFRP6FDhvsBBIIWCb9ptHlwzkKhel3EHxdihT17YQYG fvFAPWJjPnWcbJlQeHw
rScVocUVEfDAKl85NLe/B+OUvjHw2bxjxSB0v sw7Pjp25emTPINH+dsGrzO23QB9N1hBUXNFbIp6h0wqY4Kfp1b
Hn1Op/ Sx6699J+VX0zQuTuJgs4x0TBuvPx1DGtvglHd0jJ10Dwno/X+lKWqeLy ZvSCkimA6x5WsTwwUtAm+Y2K
//nfx+jjHbzvB4NMASUTnnB2yEv6Q7e4 QdWDdJpYFfYaKlBBm62UkWLMIkJKbXqqoPv/H5+kQC2G27inzsIz9SM
D e24kug==
;; Received 747 bytes from 192.168.200.72#53(192.168.200.72) in 92 ms

com.                    172800  IN      NS      g.gtld-servers.net.
com.                    172800  IN      NS      a.gtld-servers.net.
com.                    172800  IN      NS      b.gtld-servers.net.
com.                    172800  IN      NS      c.gtld-servers.net.
com.                    172800  IN      NS      d.gtld-servers.net.
com.                    172800  IN      NS      k.gtld-servers.net.
com.                    172800  IN      NS      i.gtld-servers.net.
com.                    172800  IN      NS      m.gtld-servers.net.
com.                    172800  IN      NS      l.gtld-servers.net.
com.                    172800  IN      NS      f.gtld-servers.net.
com.                    172800  IN      NS      h.gtld-servers.net.
com.                    172800  IN      NS      j.gtld-servers.net.
com.                    172800  IN      NS      e.gtld-servers.net.
com.                    86400   IN      DS      19718 13 2 8ACBB0CD28F41250A80A491389424
D341522D946B0DA0C0291F2D3D7 71D7805A
com.                    86400   IN      RRSIG   DS 8 1 86400 20240401200000 202403191900
00 30903 . 3ed0I4ZvapH7crbNHXZENoCacs4oK2AxoAFWWlOdo8AjZCkwTZeO4L/z lbndTh1GwMfHPBQCd4ab
qSGWUByMKs+ELM3IdalOvjJthRbYaCyTDMKU 8gtfx71heN43fcDDeH4jbJUR9nMOCX2GqCb5P1Omf/9r1g7KENs
bcZGT YUF4ZzQCZbHloYltrH9bNxb0GNVkt01SiGKe3QEmuh0AvNYSzK9Ricqb 7HksJppp8Eu9FVWGPOy+L3LOr
tShklx3IrhWrDTezHP47ZzC/tXz3SHe AUClGdIt9t+MDwS5uZfhq5qAQSOI11/RQTysB1oN1ohFbn5W269X17rT
 TyCJFQ==
;; Received 1167 bytes from 192.33.4.12#53(c.root-servers.net) in 165 ms

foo.com.                172800  IN      NS      ns1.digimedia.com.
foo.com.                172800  IN      NS      ns2.digimedia.com.
CK0POJMG874LJREF7EFN8430QVIT8BSM.com. 86400 IN NSEC3 1 1 0 - CK0Q2D6NI4I7EQH8NA30NS61O48
UL8G5  NS SOA RRSIG DNSKEY NSEC3PARAM
CK0POJMG874LJREF7EFN8430QVIT8BSM.com. 86400 IN RRSIG NSEC3 13 2 86400 20240325042456 202
40318031456 4534 com. mmvYdRZlvwMKhXvJLnrGnP1KI/gfF+oe3osWNb3iuZkdPxp3u9jmmn4L TlD4bvIgr
bhMm74YV2Z3Sp+iLrLOtQ==
EVHDNEB8496UATLQFALGNA815P432N23.com. 86400 IN NSEC3 1 1 0 - EVHE6HKBPNHPNF427CCGT7VU2OO
UN2QP  NS DS RRSIG
EVHDNEB8496UATLQFALGNA815P432N23.com. 86400 IN RRSIG NSEC3 13 2 86400 20240323045110 202
40316034110 4534 com. Yc8bASpmbWuxQoHJ3+RpfF/r0t5sT61Nih4jWj8KjlfQVEamXBhugVt1 B06kVem/1
CXduN/4dPm4V8xxisplg==
;; Received 471 bytes from 192.5.6.30#53(a.gtld-servers.net) in 176 ms

foo.com.                600     IN      A       34.206.39.153
foo.com.                600     IN      NS      ns1.digimedia.com.
foo.com.                600     IN      NS      ns2.digimedia.com.
;; Received 130 bytes from 23.21.243.119#53(ns2.digimedia.com) in 269 ms
```

Dig +trace Command (Forged Response)

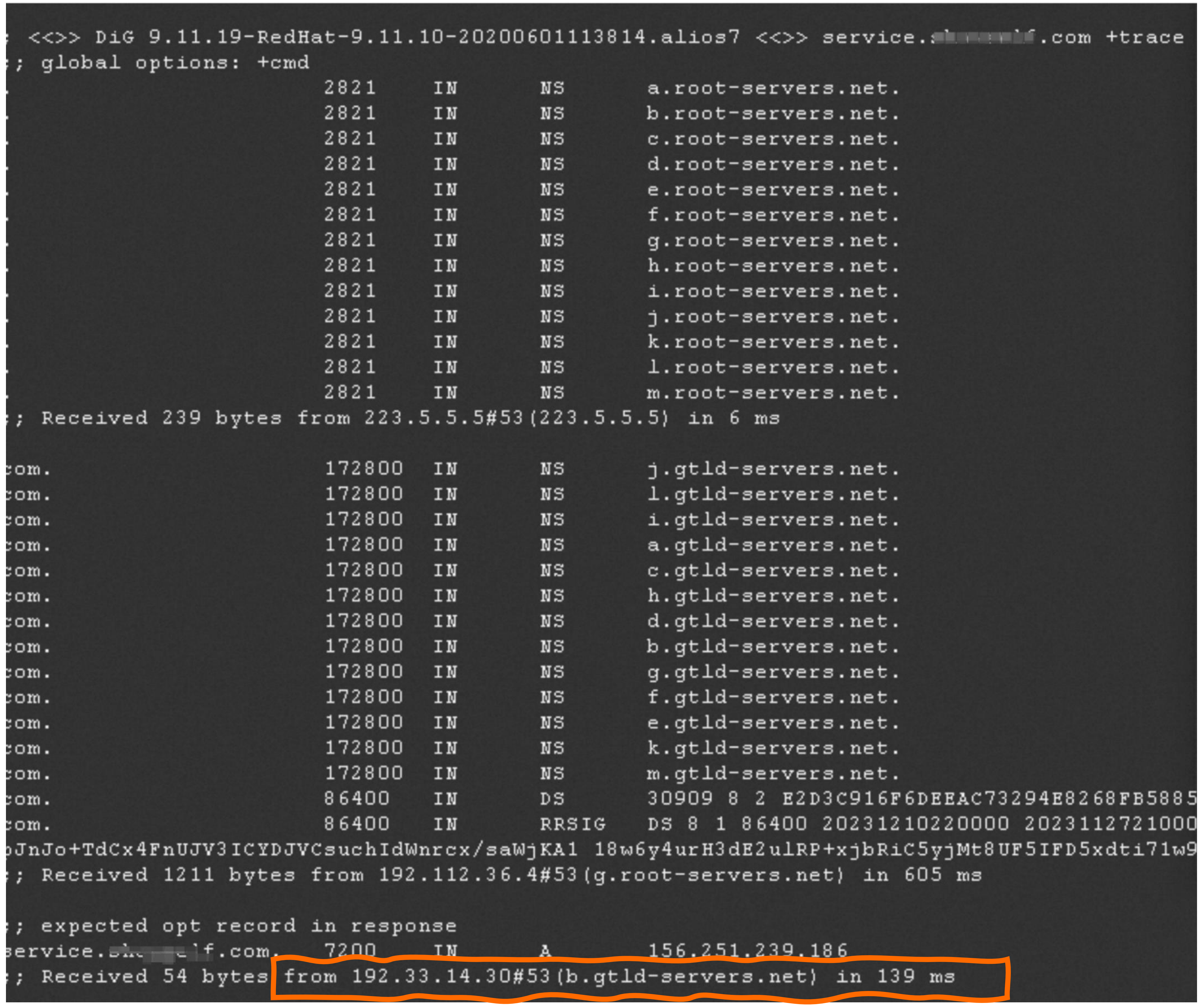


What happened in between ?

Who forged the answer?



```
; <<>> DiG 9.11.19-RedHat-9.11.10-20200601113814.alios7 <<>> service.[redacted].com +trace
;; global options: +cmd
.                       2332    IN      NS      m.root-servers.net.
.                       2332    IN      NS      f.root-servers.net.
.                       2332    IN      NS      i.root-servers.net.
.                       2332    IN      NS      l.root-servers.net.
.                       2332    IN      NS      d.root-servers.net.
.                       2332    IN      NS      a.root-servers.net.
.                       2332    IN      NS      g.root-servers.net.
.                       2332    IN      NS      e.root-servers.net.
.                       2332    IN      NS      h.root-servers.net.
.                       2332    IN      NS      c.root-servers.net.
.                       2332    IN      NS      j.root-servers.net.
.                       2332    IN      NS      k.root-servers.net.
.                       2332    IN      NS      b.root-servers.net.
;; Received 239 bytes from 223.5.5.5#53(223.5.5.5) in 6 ms

service.showself.com.   7200    IN      A       156.251.239.186
;; Received 54 bytes from 192.5.5.241#53(f.root-servers.net) in 80 ms
```



```
; <<>> DiG 9.11.19-RedHat-9.11.10-20200601113814.alios7 <<>> service.[redacted].com +trace
; global options: +cmd
                        2821    IN      NS      a.root-servers.net.
                        2821    IN      NS      b.root-servers.net.
                        2821    IN      NS      c.root-servers.net.
                        2821    IN      NS      d.root-servers.net.
                        2821    IN      NS      e.root-servers.net.
                        2821    IN      NS      f.root-servers.net.
                        2821    IN      NS      g.root-servers.net.
                        2821    IN      NS      h.root-servers.net.
                        2821    IN      NS      i.root-servers.net.
                        2821    IN      NS      j.root-servers.net.
                        2821    IN      NS      k.root-servers.net.
                        2821    IN      NS      l.root-servers.net.
                        2821    IN      NS      m.root-servers.net.
; Received 239 bytes from 223.5.5.5#53(223.5.5.5) in 6 ms

com.                    172800  IN      NS      j.gtld-servers.net.
com.                    172800  IN      NS      l.gtld-servers.net.
com.                    172800  IN      NS      i.gtld-servers.net.
com.                    172800  IN      NS      a.gtld-servers.net.
com.                    172800  IN      NS      c.gtld-servers.net.
com.                    172800  IN      NS      h.gtld-servers.net.
com.                    172800  IN      NS      d.gtld-servers.net.
com.                    172800  IN      NS      b.gtld-servers.net.
com.                    172800  IN      NS      g.gtld-servers.net.
com.                    172800  IN      NS      f.gtld-servers.net.
com.                    172800  IN      NS      e.gtld-servers.net.
com.                    172800  IN      NS      k.gtld-servers.net.
com.                    172800  IN      NS      m.gtld-servers.net.
com.                    86400   IN      DS      30909 8 2 E2D3C916F6DEEAC73294E8268FB5885
com.                    86400   IN      RRSIG   DS 8 1 86400 20231210220000 2023112721000
pJnJo+TdCx4FnUJV3ICYDJVCsuchIdWnrcx/saWjKA1 18w6y4urH3dE2ulRP+xjbRiC5yjMt8UF5IFD5xdti71w9
; Received 1211 bytes from 192.112.36.4#53(g.root-servers.net) in 605 ms

; expected opt record in response
ervice.[redacted]f.com.  7200    IN      A       156.251.239.186
; Received 54 bytes from 192.33.14.30#53(b.gtld-servers.net) in 139 ms
```

Traceroute Command (Normal Response)

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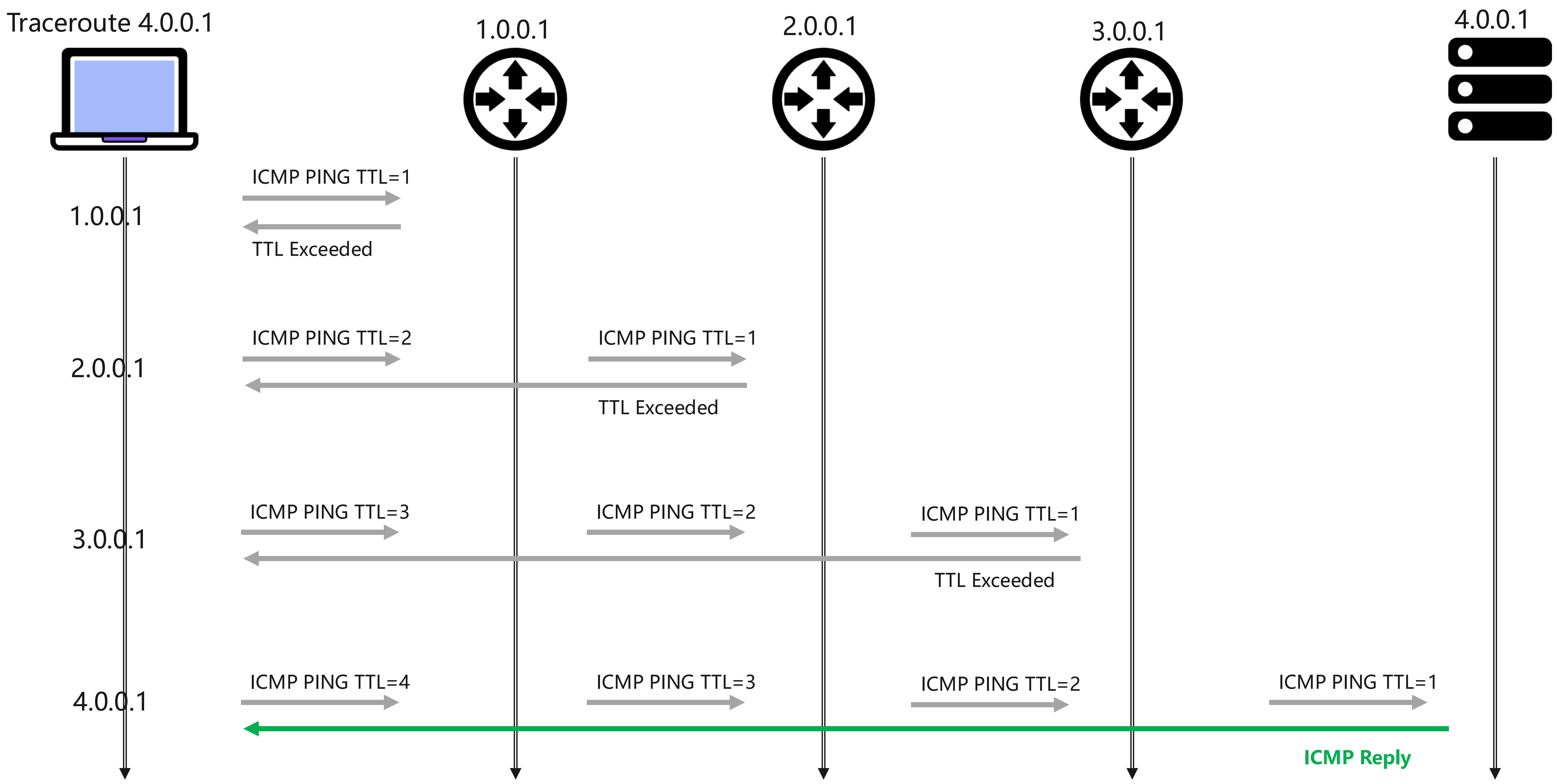
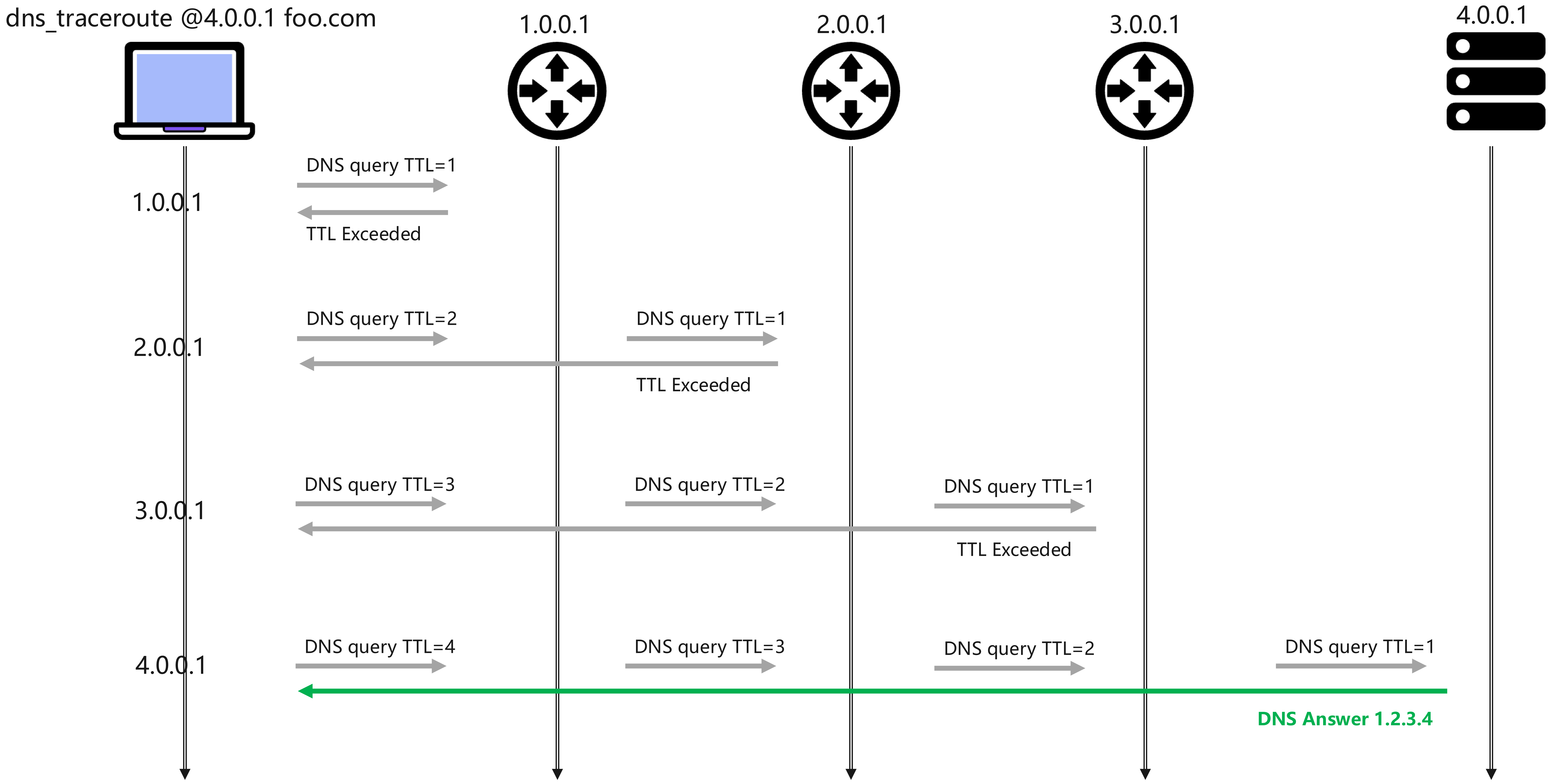


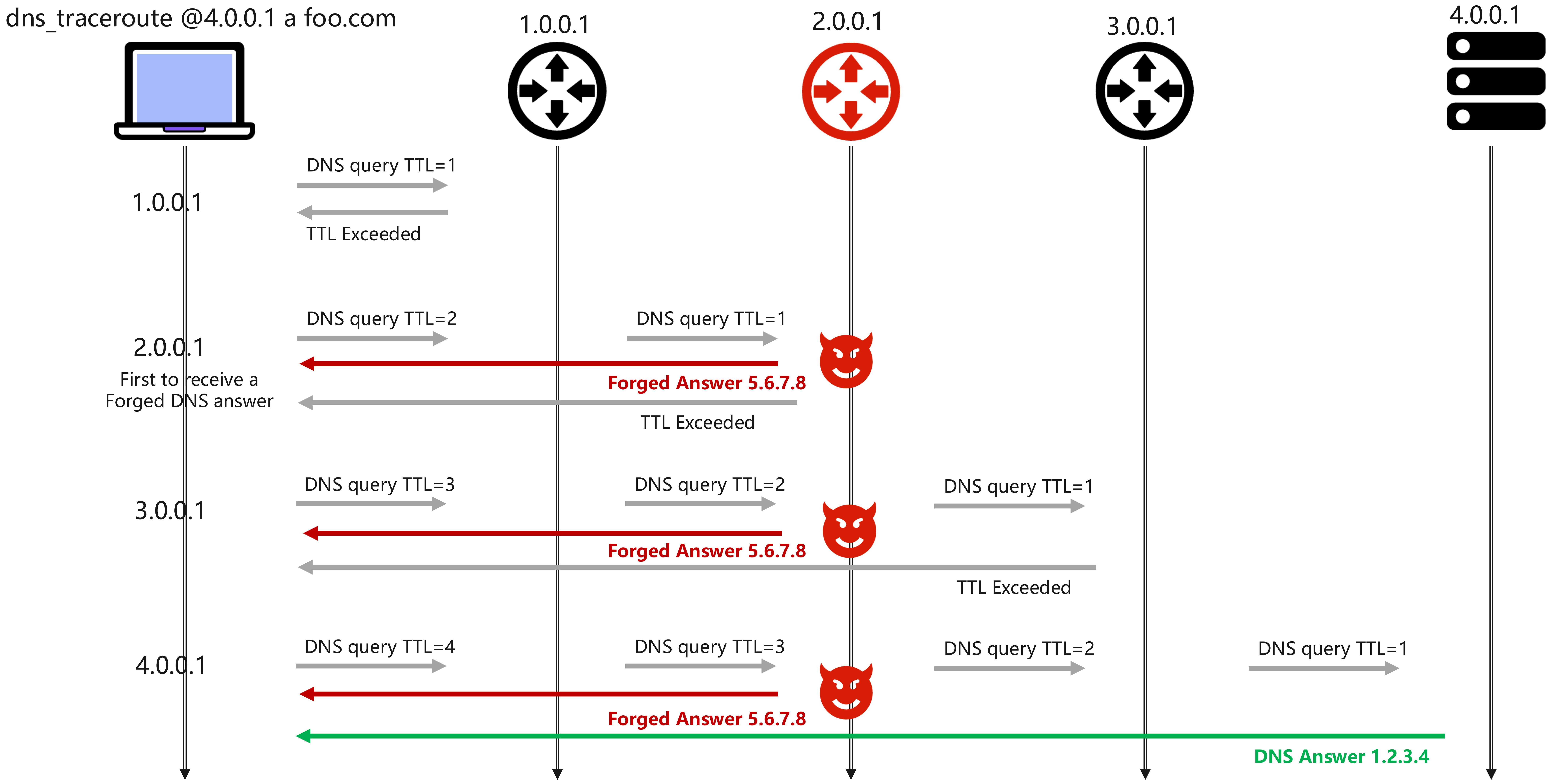
DNS Traceroute (Normal Response)

DNS traceroute uses IP-UDP-DNS packets with incremental TTL



DNS Traceroute (Forged Response)

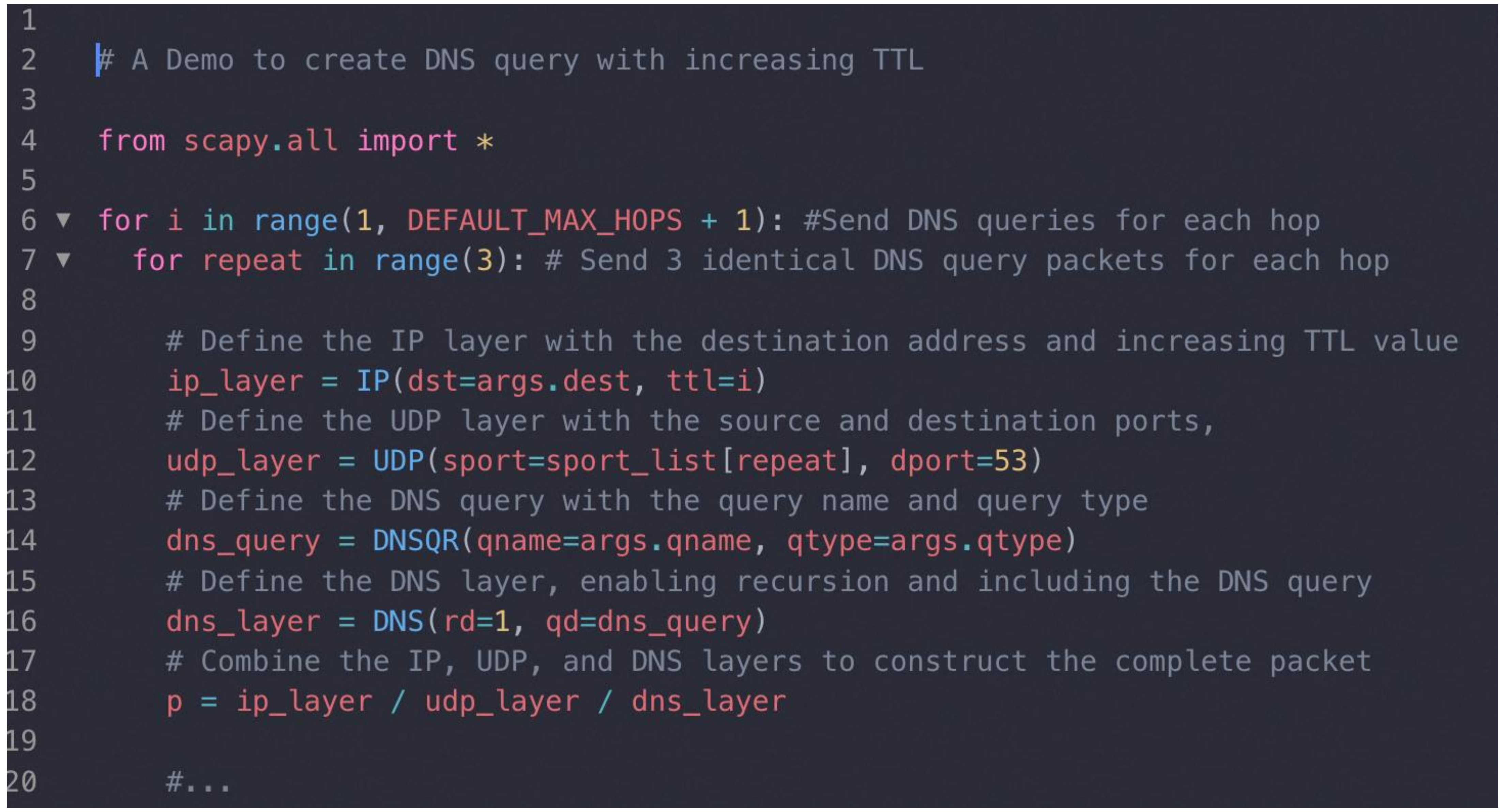
DNS traceroute uses IP-UDP-DNS packets with incremental TTL



Finally, the client receives 3 forged DNS answers and 1 true DNS answer

The key logic of DNS Traceroute

- Construct DNS query packets and increment the TTL (Time-To-Live) value for each hop. (Use Scapy in python)
- Send 3 identical DNS query packets for each hop. Record the ICMP and DNS answers it received.
- Set DEFAULT_MAX_HOPS to control the maximum number of hops (default is 32).
- Terminate the traceroute if the query reaches the destination address.
- Analyze the ICMP message and DNS answers. Print the results.

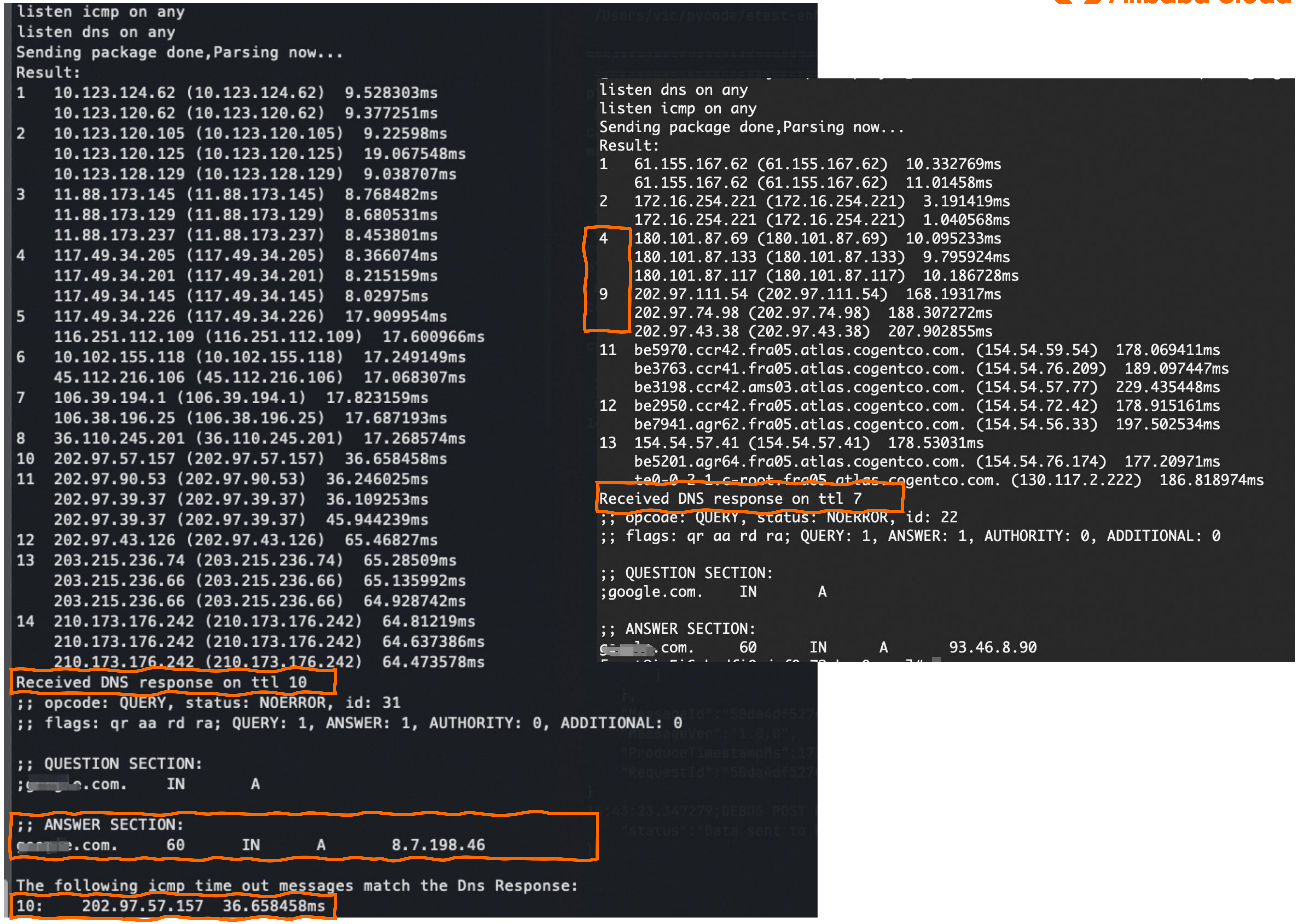


```python

# A Demo to create DNS query with increasing TTL

from scapy.all import *

for i in range(1, DEFAULT_MAX_HOPS + 1): #Send DNS queries for each hop
  for repeat in range(3): # Send 3 identical DNS query packets for each hop

    # Define the IP layer with the destination address and increasing TTL value
    ip_layer = IP(dst=args.dest, ttl=i)
    # Define the UDP layer with the source and destination ports,
    udp_layer = UDP(sport=sport_list[repeat], dport=53)
    # Define the DNS query with the query name and query type
    dns_query = DNSQR(qname=args.qname, qtype=args.qtype)
    # Define the DNS layer, enabling recursion and including the DNS query
    dns_layer = DNS(rd=1, qd=dns_query)
    # Combine the IP, UDP, and DNS layers to construct the complete packet
    p = ip_layer / udp_layer / dns_layer

    #...
```

A simple Demo of creating DNS queries with increasing TTL

On-Path Interception Example

DNS-traceroute one victim’ s name @root server

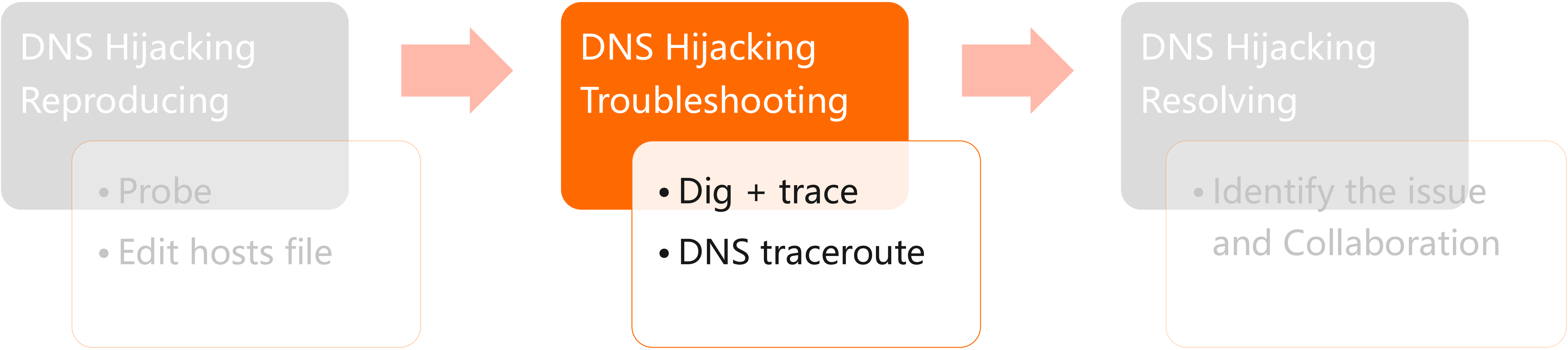


```
listen icmp on any
listen dns on any
Sending package done,Parsing now...
Result:
1    10.123.124.62 (10.123.124.62)  9.528303ms
     10.123.120.62 (10.123.120.62)  9.377251ms
2    10.123.120.105 (10.123.120.105)  9.22598ms
     10.123.120.125 (10.123.120.125)  19.067548ms
     10.123.128.129 (10.123.128.129)  9.038707ms
3    11.88.173.145 (11.88.173.145)  8.768482ms
     11.88.173.129 (11.88.173.129)  8.680531ms
     11.88.173.237 (11.88.173.237)  8.453801ms
4    117.49.34.205 (117.49.34.205)  8.366074ms
     117.49.34.201 (117.49.34.201)  8.215159ms
     117.49.34.145 (117.49.34.145)  8.02975ms
5    117.49.34.226 (117.49.34.226)  17.909954ms
     116.251.112.109 (116.251.112.109)  17.600966ms
6    10.102.155.118 (10.102.155.118)  17.249149ms
     45.112.216.106 (45.112.216.106)  17.068307ms
7    106.39.194.1 (106.39.194.1)  17.823159ms
     106.38.196.25 (106.38.196.25)  17.687193ms
8    36.110.245.201 (36.110.245.201)  17.268574ms
10   202.97.57.157 (202.97.57.157)  36.658458ms
11   202.97.90.53 (202.97.90.53)  36.246025ms
     202.97.39.37 (202.97.39.37)  36.109253ms
     202.97.39.37 (202.97.39.37)  45.944239ms
12   202.97.43.126 (202.97.43.126)  65.46827ms
13   203.215.236.74 (203.215.236.74)  65.28509ms
     203.215.236.66 (203.215.236.66)  65.135992ms
     203.215.236.66 (203.215.236.66)  64.928742ms
14   210.173.176.242 (210.173.176.242)  64.81219ms
     210.173.176.242 (210.173.176.242)  64.637386ms
     210.173.176.242 (210.173.176.242)  64.473578ms
Received DNS response on ttl 10
;; opcode: QUERY, status: NOERROR, id: 31
;; flags: qr aa rd ra; QUERY: 1, ANSWER: 1, AUTHORITY: 0, ADDITIONAL: 0

;; QUESTION SECTION:
;[redacted].com.    IN      A

;; ANSWER SECTION:
[redacted].com.    60      IN      A       8.7.198.46

The following icmp time out messages match the Dns Response:
10:    202.97.57.157  36.658458ms
```

```
listen dns on any
listen icmp on any
Sending package done,Parsing now...
Result:
1    61.155.167.62 (61.155.167.62)  10.332769ms
     61.155.167.62 (61.155.167.62)  11.01458ms
2    172.16.254.221 (172.16.254.221)  3.191419ms
     172.16.254.221 (172.16.254.221)  1.040568ms
4    180.101.87.69 (180.101.87.69)  10.095233ms
     180.101.87.133 (180.101.87.133)  9.795924ms
     180.101.87.117 (180.101.87.117)  10.186728ms
9    202.97.111.54 (202.97.111.54)  168.19317ms
     202.97.74.98 (202.97.74.98)  188.307272ms
     202.97.43.38 (202.97.43.38)  207.902855ms
11   be5970.ccr42.fra05.atlas.cogentco.com. (154.54.59.54)  178.069411ms
     be3763.ccr41.fra05.atlas.cogentco.com. (154.54.76.209)  189.097447ms
     be3198.ccr42.ams03.atlas.cogentco.com. (154.54.57.77)  229.435448ms
12   be2950.ccr42.fra05.atlas.cogentco.com. (154.54.72.42)  178.915161ms
     be7941.agr62.fra05.atlas.cogentco.com. (154.54.56.33)  197.502534ms
13   154.54.57.41 (154.54.57.41)  178.53031ms
     be5201.agr64.fra05.atlas.cogentco.com. (154.54.76.174)  177.20971ms
     te0-0-2-1.c-root.fra05.atlas.cogentco.com. (130.117.2.222)  186.818974ms
Received DNS response on ttl 7
;; opcode: QUERY, status: NOERROR, id: 22
;; flags: qr aa rd ra; QUERY: 1, ANSWER: 1, AUTHORITY: 0, ADDITIONAL: 0

;; QUESTION SECTION:
;google.com.    IN      A

;; ANSWER SECTION:
[redacted].com.    60      IN      A       93.46.8.90
```

Received a forged answer and pinpoint the IP who forged it

Wrap up: Troubleshooting Result



DNS Hijacking Reproducing

- Probe
- Edit hosts file

DNS Hijacking Troubleshooting

- Dig + trace
- DNS traceroute

DNS Hijacking Resolving

- Identify the issue and Collaboration

✓ dig with trace option finds specific DNS query to root/.com servers received random, forged answers which will be cached by resolvers.

✓ The DNS traceroute tool prints **the path of the query forwarded** and pinpoints **IP address who forges the answer**

✓ The DNS traceroute tool also indicates the presence of **on-path interception**. The hijacking device responds with a forged answer preemptively, ahead of the legitimate response.

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