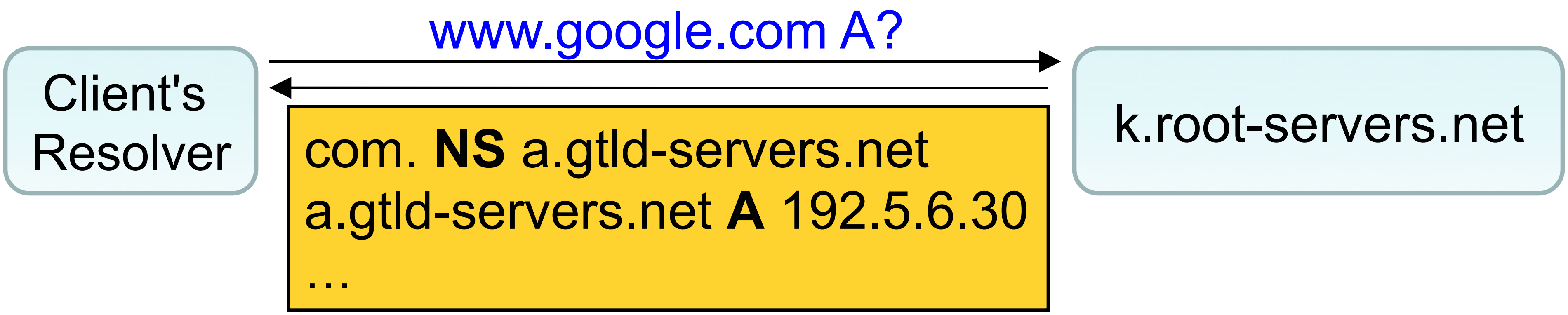
Ordinary DNS:



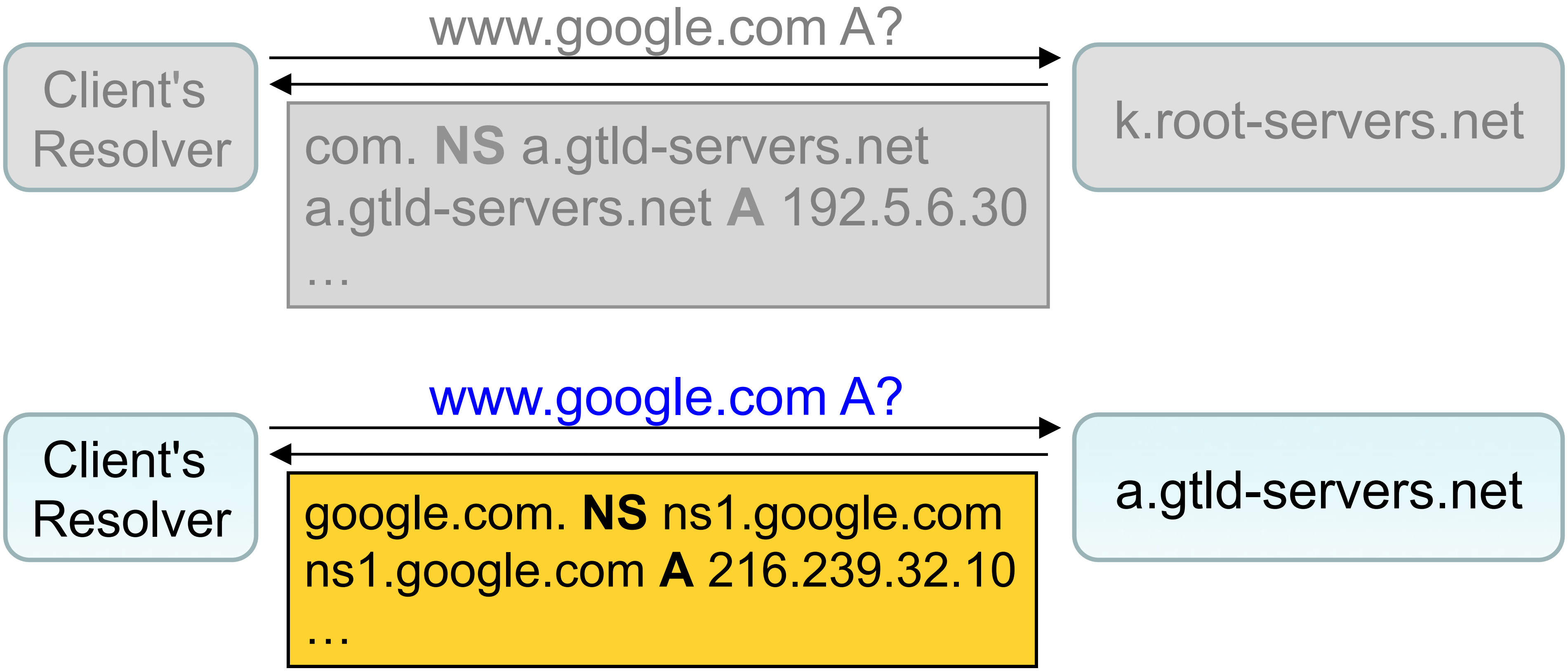
Client's Resolver

www.google.com A?

k.root-servers.net

com. **NS** a.gtld-servers.net
a.gtld-servers.net **A** 192.5.6.30
…

Ordinary DNS:



www.google.com A?

Client's Resolver

k.root-servers.net

com. **NS** a.gtld-servers.net
a.gtld-servers.net **A** 192.5.6.30
…

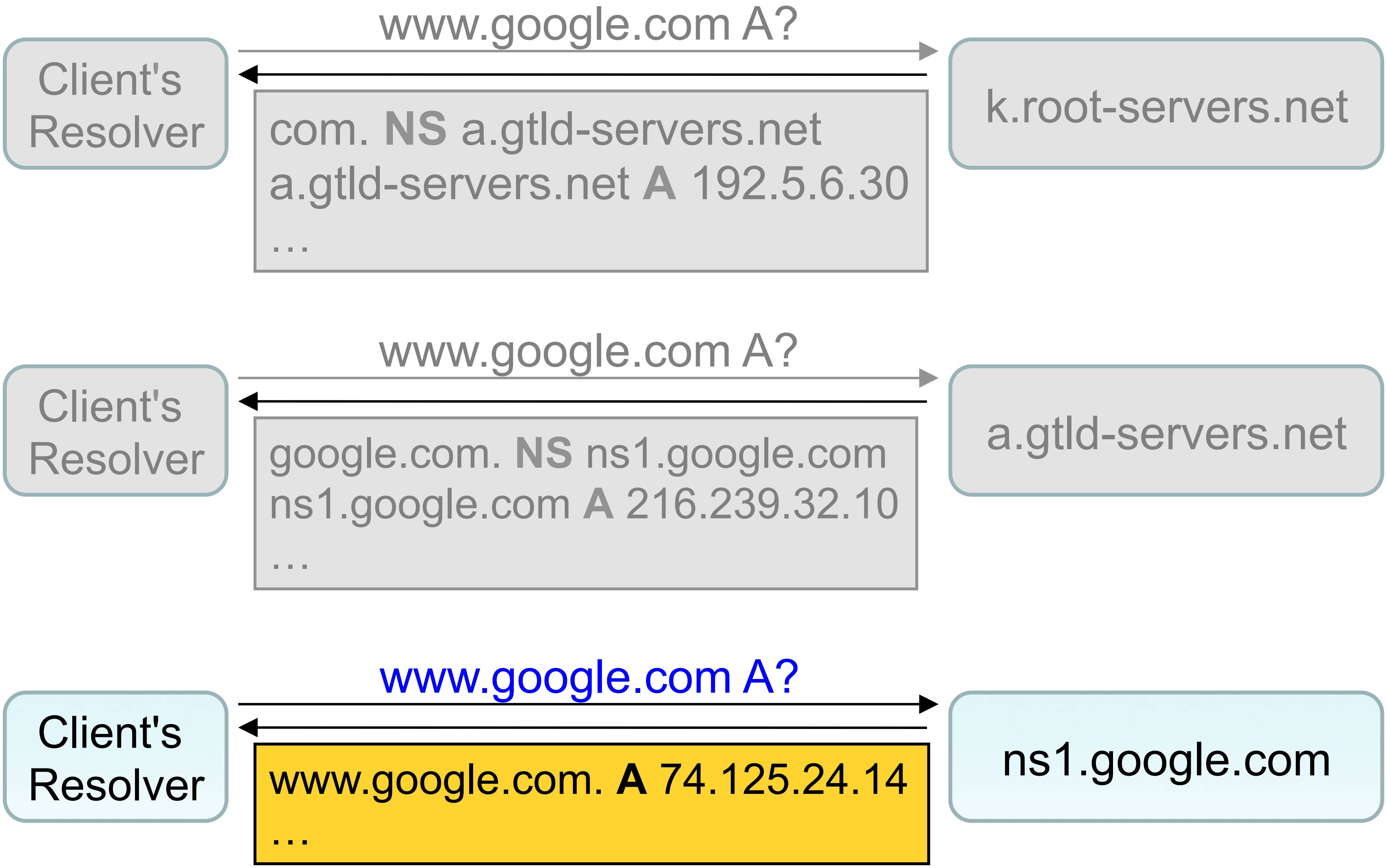
www.google.com A?

Client's Resolver

a.gtld-servers.net

google.com. **NS** ns1.google.com
ns1.google.com **A** 216.239.32.10
…

Ordinary DNS:



Client's Resolver

www.google.com A?

k.root-servers.net

com. **NS** a.gtld-servers.net
a.gtld-servers.net **A** 192.5.6.30
…

Client's Resolver

www.google.com A?

a.gtld-servers.net

google.com. **NS** ns1.google.com
ns1.google.com **A** 216.239.32.10
…

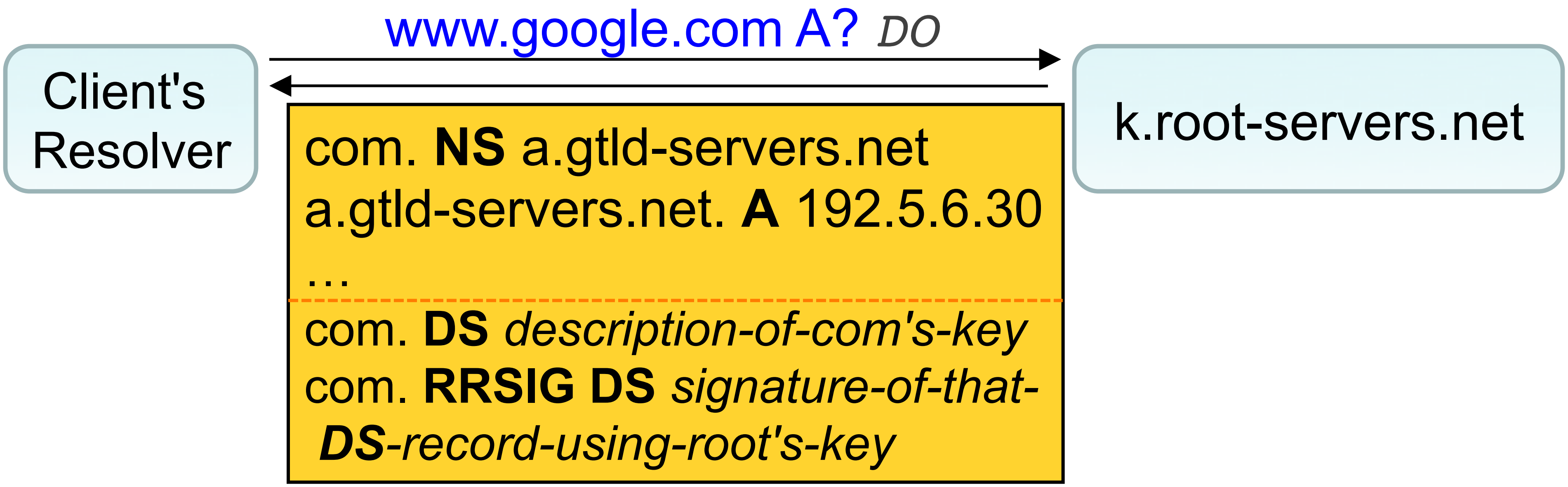
Client's Resolver

www.google.com A?

ns1.google.com

www.google.com. **A** 74.125.24.14
…

DNSSEC (with simplifications):



Client's Resolver

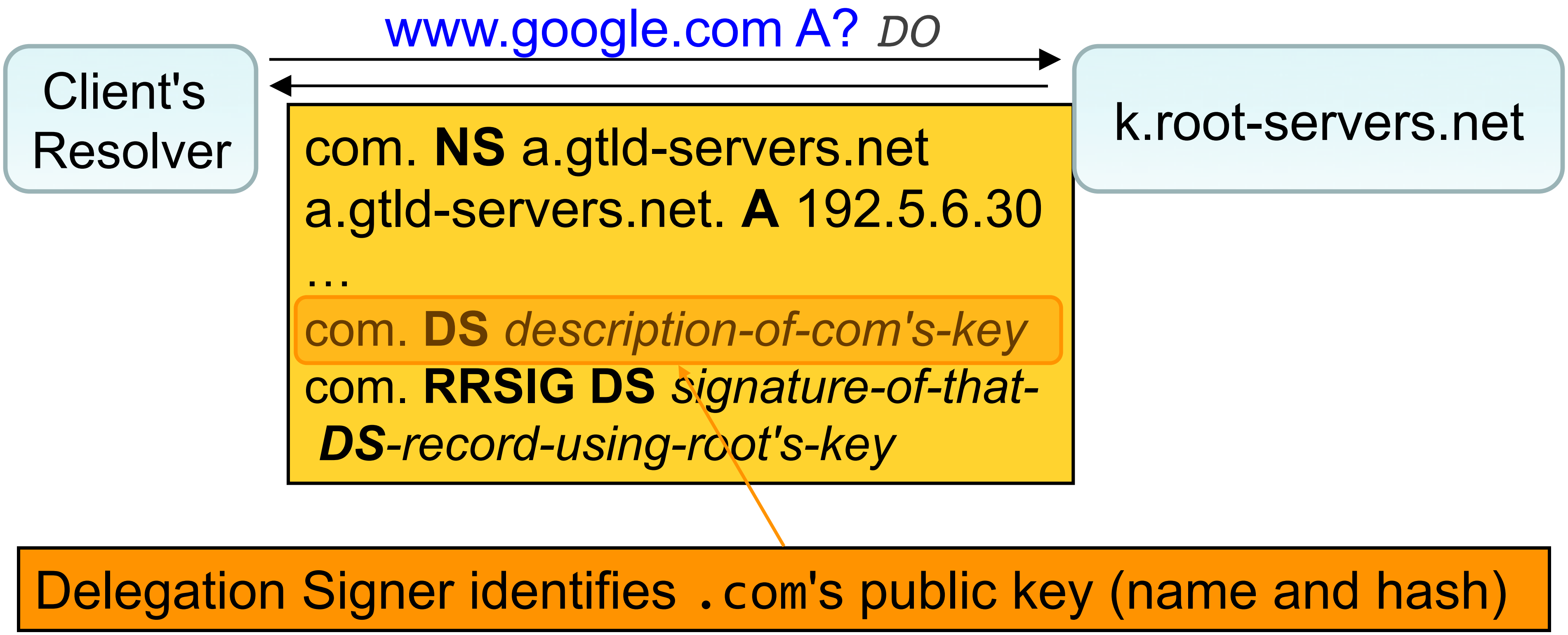
www.google.com A? *DO*

k.root-servers.net

com. **NS** a.gtld-servers.net
a.gtld-servers.net. **A** 192.5.6.30
…

com. **DS** *description-of-com's-key*
com. **RRSIG DS** *signature-of-that-* ***DS****-record-using-root's-key*

DNSSEC (with simplifications):



Client's Resolver

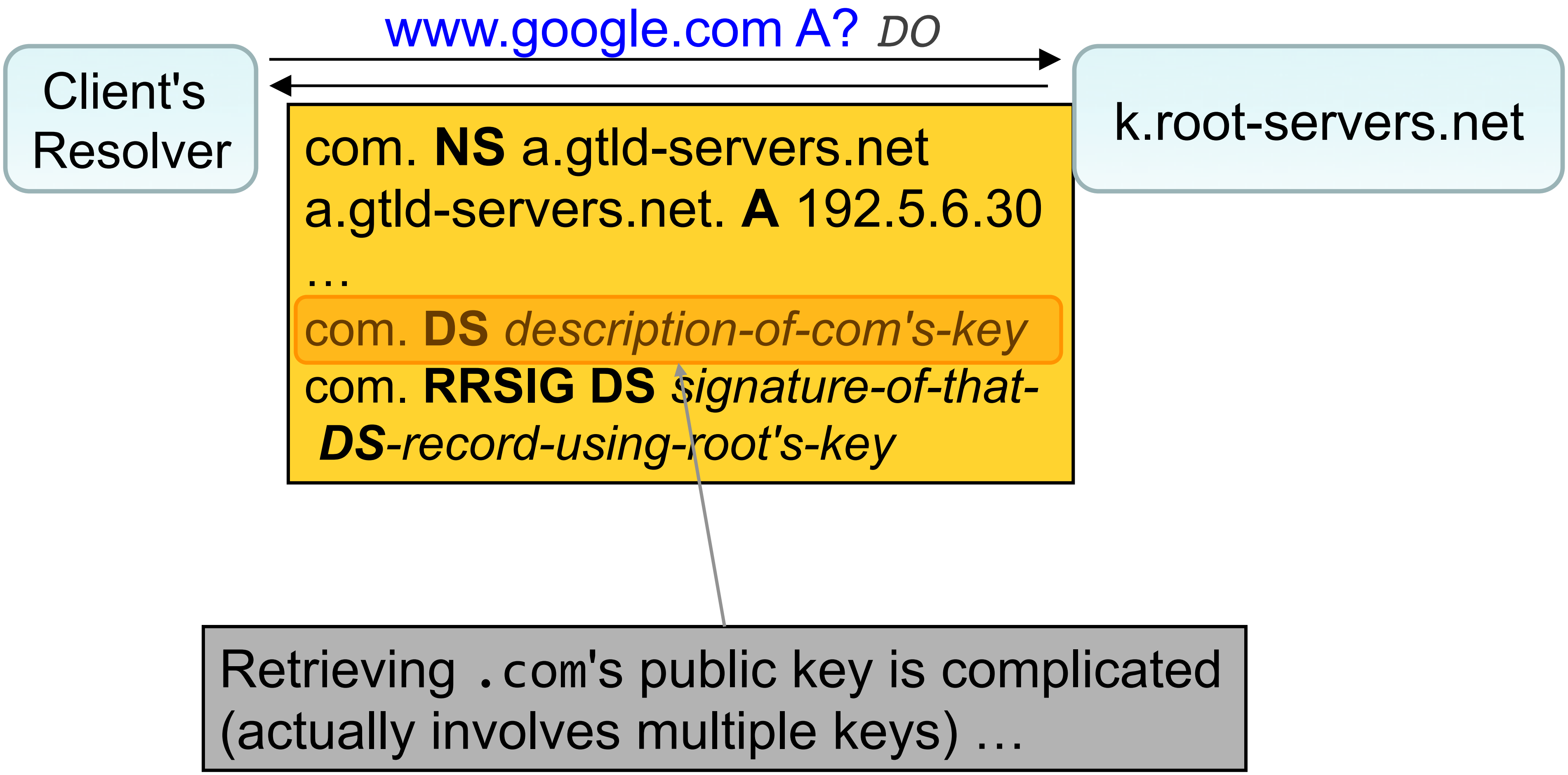
www.google.com A? *DO*

k.root-servers.net

com. **NS** a.gtld-servers.net
a.gtld-servers.net. **A** 192.5.6.30
…
com. **DS** *description-of-com's-key*
com. **RRSIG DS** *signature-of-that-*
DS*-record-using-root's-key*

Delegation Signer identifies `.com`'s public key (name and hash)

DNSSEC (with simplifications):



Client's Resolver

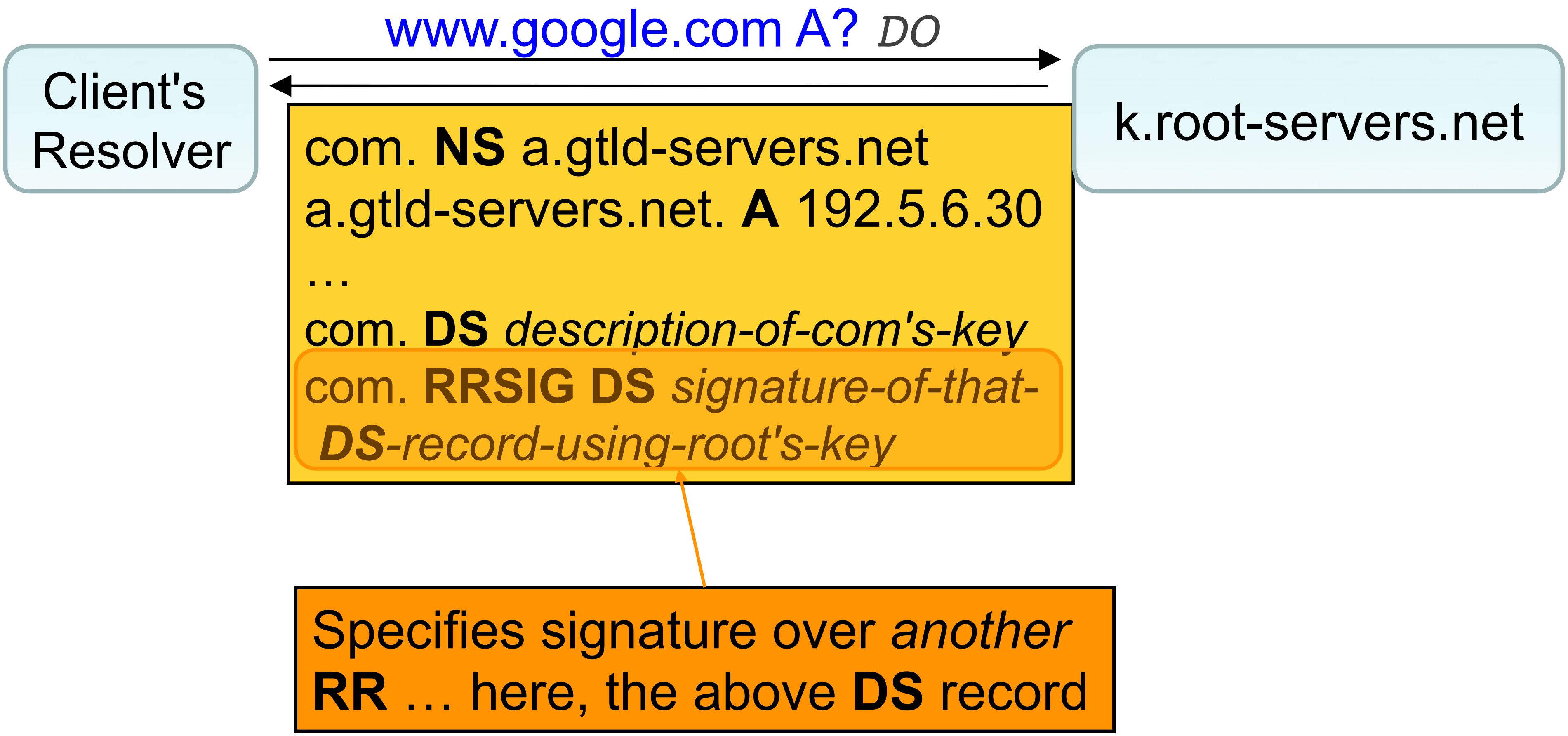
www.google.com A? *DO*

k.root-servers.net

com. **NS** a.gtld-servers.net
a.gtld-servers.net. **A** 192.5.6.30
…
com. **DS** *description-of-com's-key*
com. **RRSIG DS** *signature-of-that-* ***DS****-record-using-root's-key*

Retrieving `.com`'s public key is complicated (actually involves multiple keys) …

DNSSEC (with simplifications):



www.google.com A? *DO*

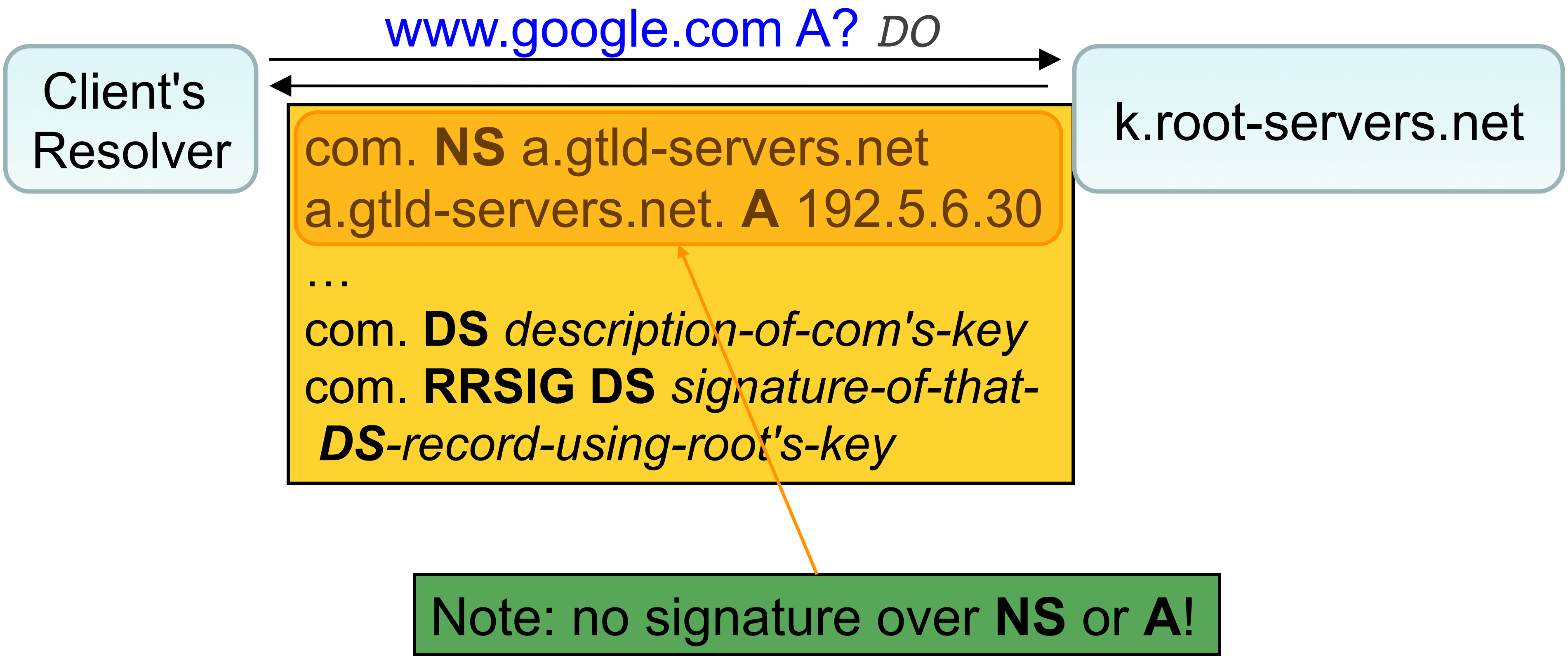
Client's Resolver

k.root-servers.net

com. **NS** a.gtld-servers.net
a.gtld-servers.net. **A** 192.5.6.30
…
com. **DS** *description-of-com's-key*
com. **RRSIG DS** *signature-of-that-* ***DS****-record-using-root's-key*

Specifies signature over *another* **RR** … here, the above **DS** record

DNSSEC (with simplifications):



Client's Resolver

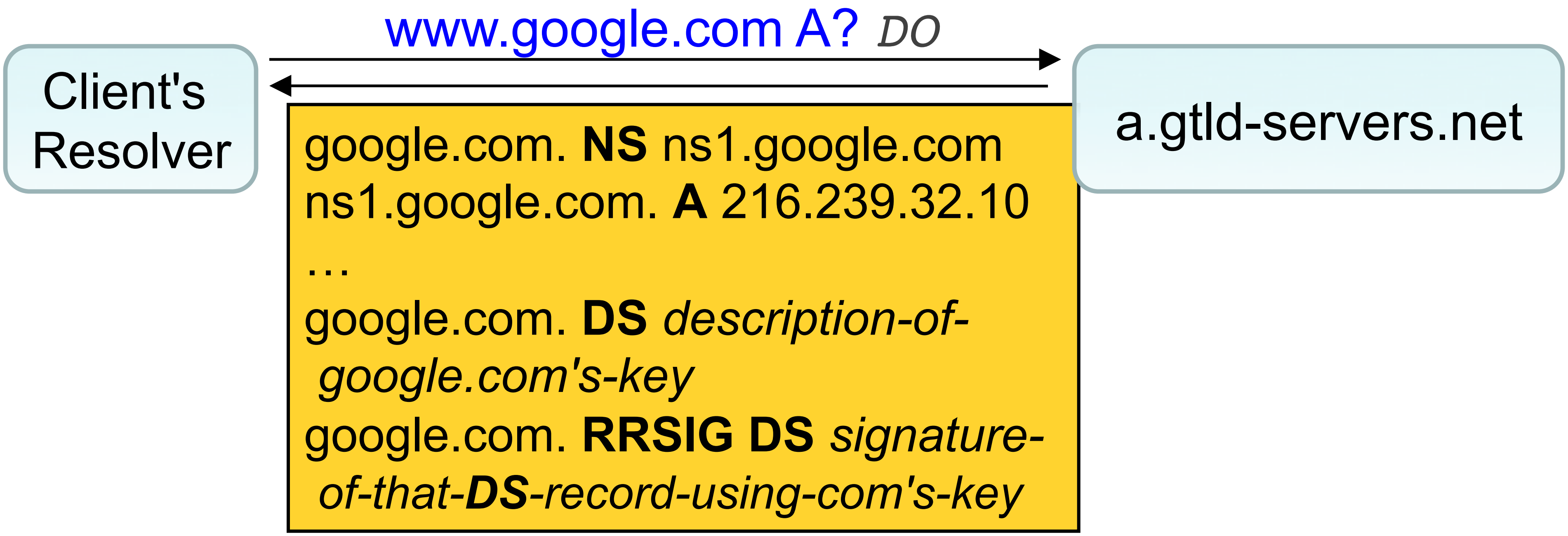
www.google.com A? *DO*

k.root-servers.net

com. **NS** a.gtld-servers.net
a.gtld-servers.net. **A** 192.5.6.30
…
com. **DS** *description-of-com's-key*
com. **RRSIG DS** *signature-of-that-* ***DS****-record-using-root's-key*

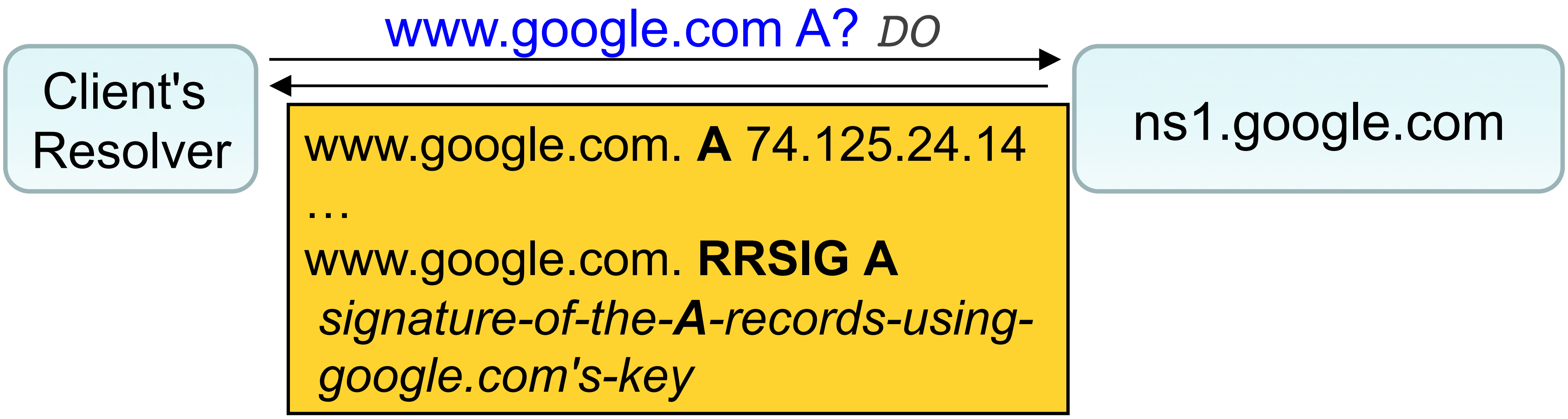
Note: no signature over **NS** or **A**!

DNSSEC (with simplifications):



google.com. **NS** ns1.google.com
ns1.google.com. **A** 216.239.32.10
…
google.com. **DS** *description-of-google.com's-key*
google.com. **RRSIG DS** *signature-of-that-**DS**-record-using-com's-key*

DNSSEC (with simplifications):



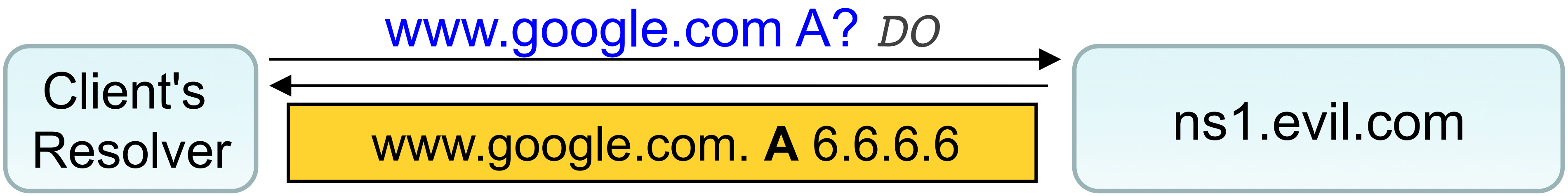
www.google.com. **A** 74.125.24.14

…

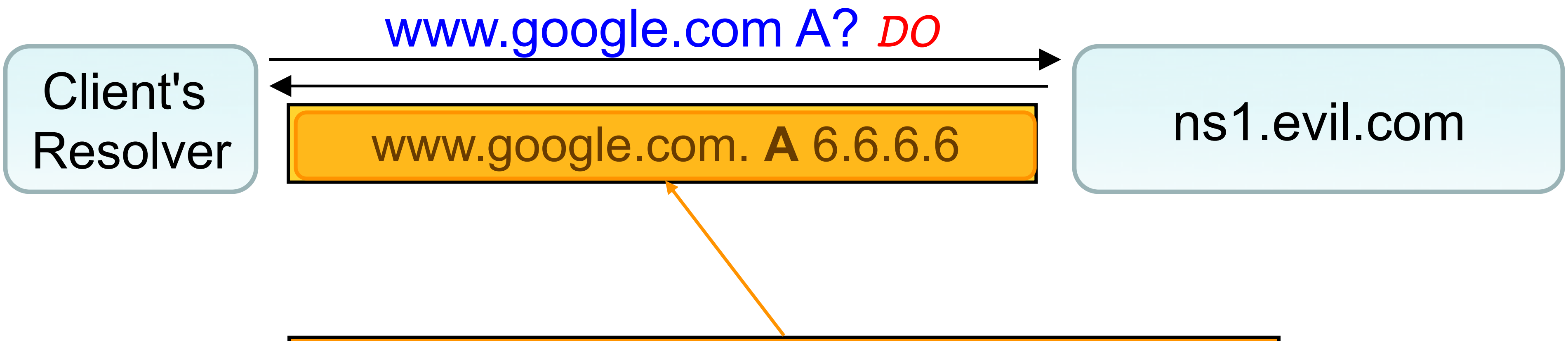
www.google.com. **RRSIG A**

*signature-of-the-**A**-records-using-google.com's-key*

DNSSEC - Mallory attacks!



DNSSEC - Mallory attacks!



www.google.com A? *DO*

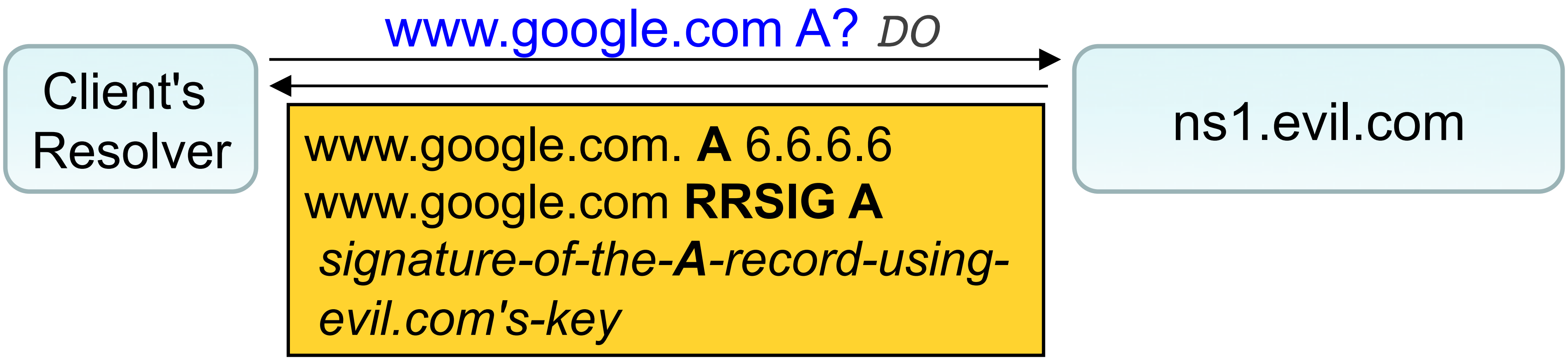
Client's Resolver

ns1.evil.com

www.google.com. **A** 6.6.6.6

Resolver observes that the reply didn't include a signature, rejects it as insecure

DNSSEC - Mallory attacks!



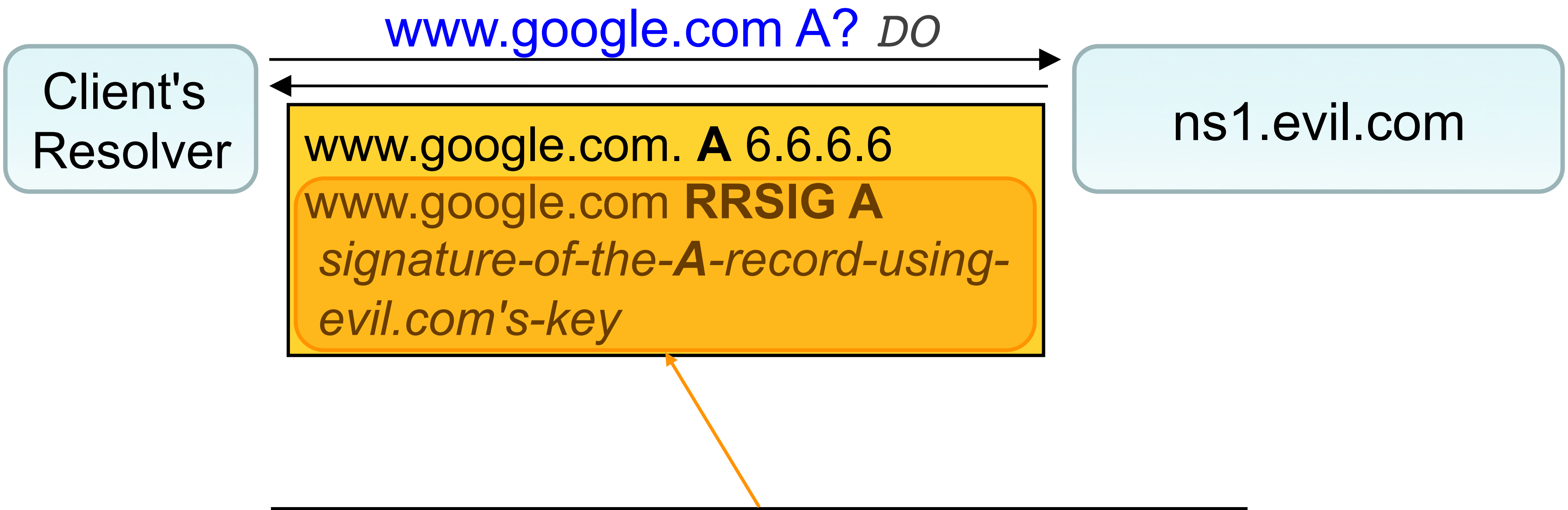
www.google.com A? *DO*

Client's Resolver

ns1.evil.com

www.google.com. **A** 6.6.6.6
www.google.com **RRSIG A**
*signature-of-the-**A**-record-using-evil.com's-key*

DNSSEC - Mallory attacks!



Client's Resolver

www.google.com A? *DO*

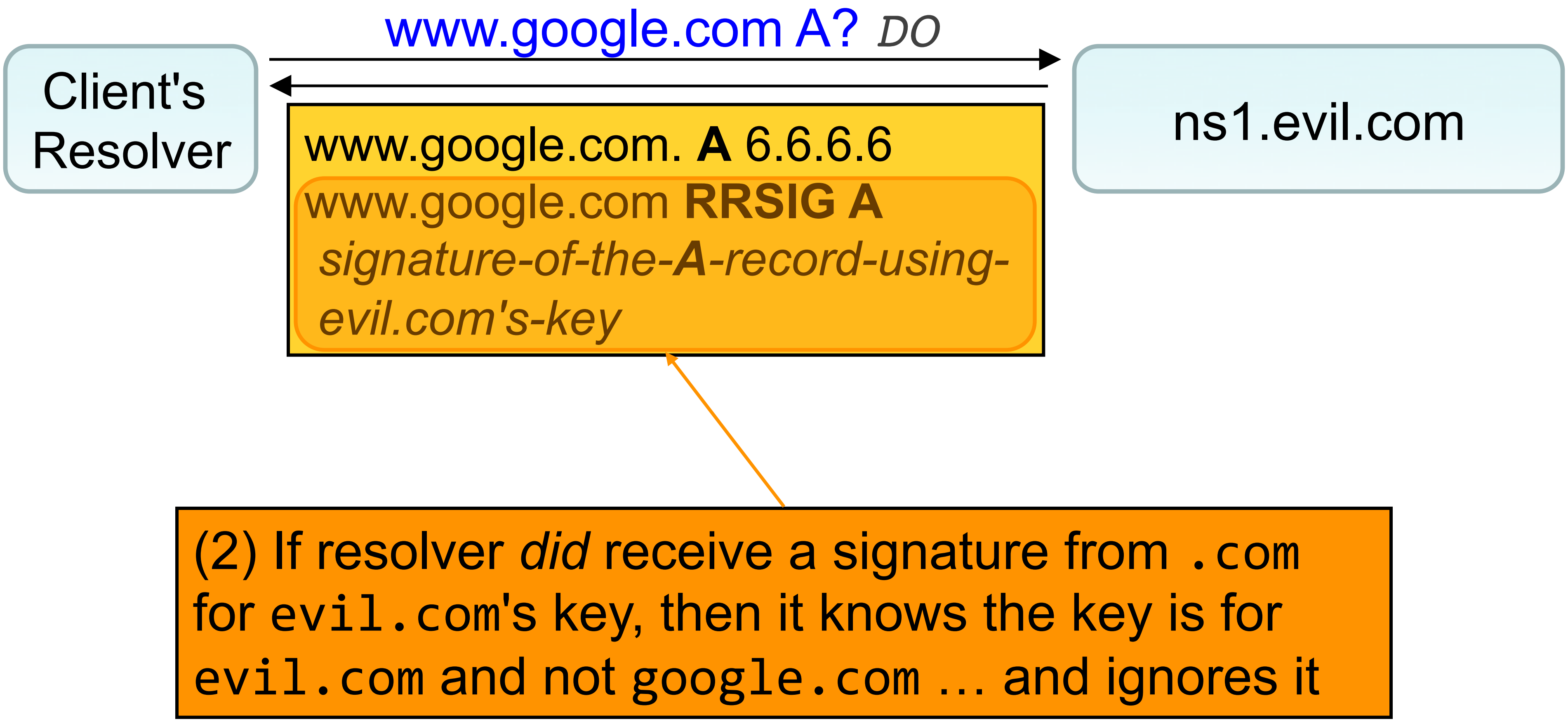
ns1.evil.com

www.google.com. **A** 6.6.6.6

www.google.com **RRSIG A** *signature-of-the-**A**-record-using-evil.com's-key*

(1) If resolver didn't receive a signature from `.com` for `evil.com`'s key, then it can't validate this signature & ignores reply since it's not properly signed …

DNSSEC - Mallory attacks!



Client's Resolver

www.google.com A? *DO*

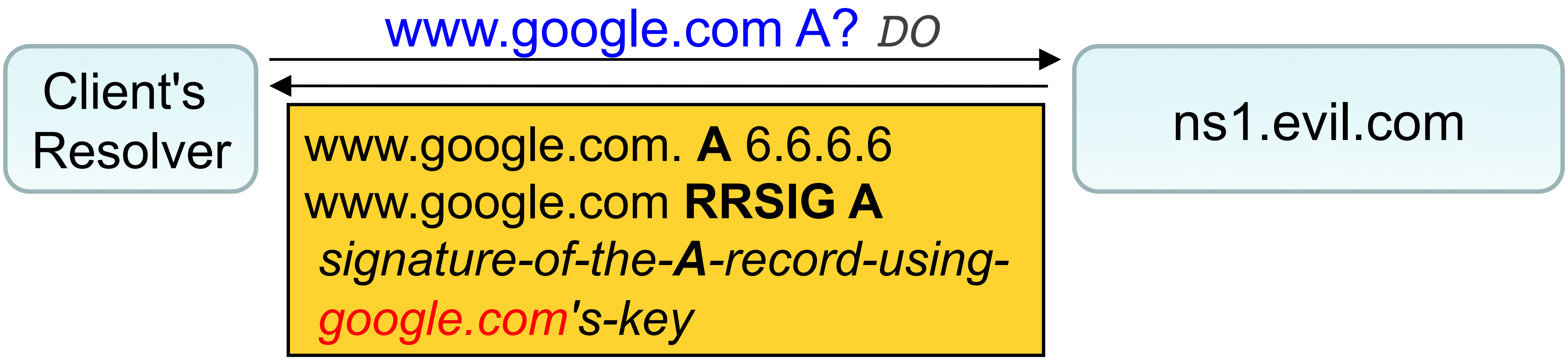
ns1.evil.com

www.google.com. **A** 6.6.6.6

www.google.com **RRSIG A** *signature-of-the-**A**-record-using-evil.com's-key*

(2) If resolver *did* receive a signature from `.com` for `evil.com`'s key, then it knows the key is for `evil.com` and not `google.com` … and ignores it

DNSSEC - Mallory attacks!



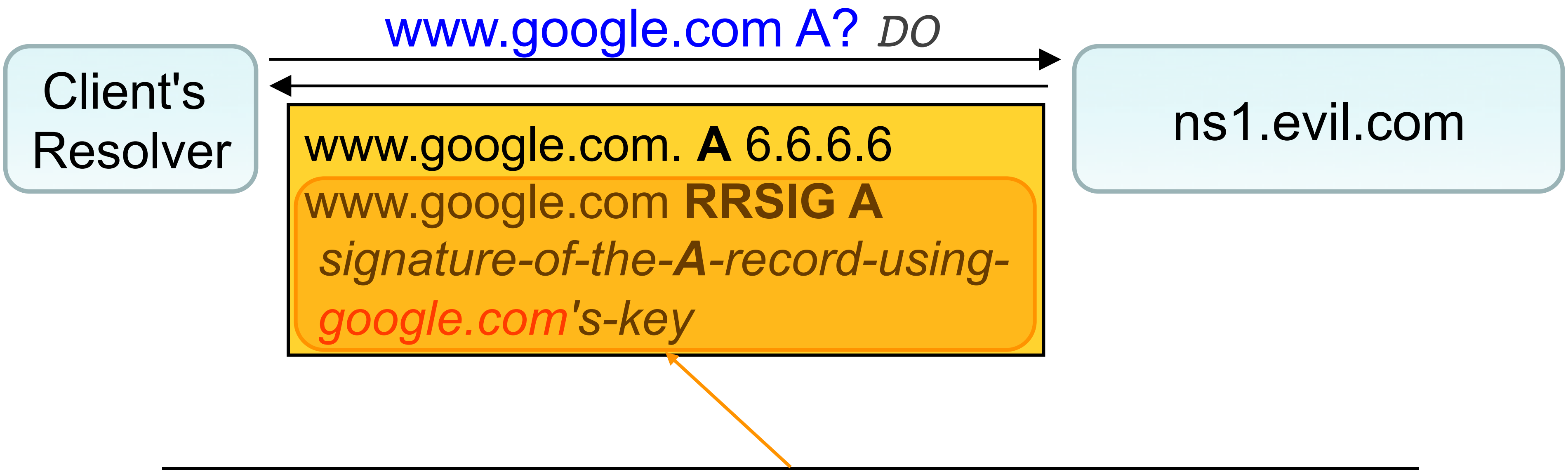
Client's Resolver

www.google.com A? *DO*

ns1.evil.com

www.google.com. **A** 6.6.6.6
www.google.com **RRSIG A**
*signature-of-the-**A**-record-using-google.com's-key*

DNSSEC - Mallory attacks!



Client's Resolver

www.google.com A? *DO*

ns1.evil.com

www.google.com. **A** 6.6.6.6

www.google.com **RRSIG A**

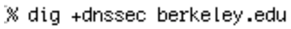
*signature-of-the-**A**-record-using-google.com's-key*

If signature **actually** comes from `google.com`'s key, resolver will believe it …

… but no such signature should exist unless either:

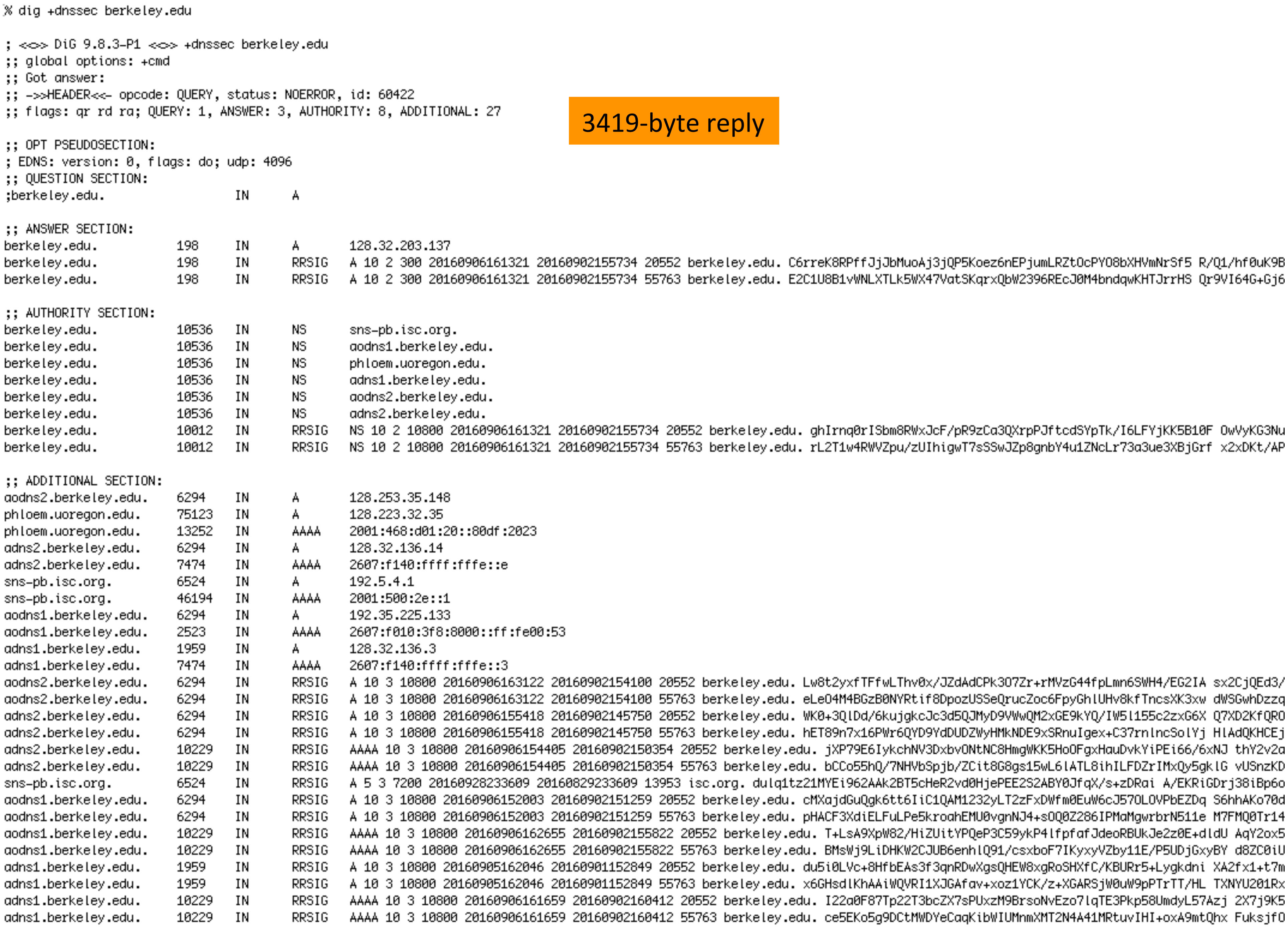
(1) `google.com` *intended* to sign the RR, or

(2) `google.com`'s private key was compromised



```
% dig +dnssec berkeley.edu
```

69-byte query



```
% dig +dnssec berkeley.edu

; <<>> DiG 9.8.3-P1 <<>> +dnssec berkeley.edu
;; global options: +cmd
;; Got answer:
;; ->>HEADER<<- opcode: QUERY, status: NOERROR, id: 60422
;; flags: qr rd ra; QUERY: 1, ANSWER: 3, AUTHORITY: 8, ADDITIONAL: 27

;; OPT PSEUDOSECTION:
; EDNS: version: 0, flags: do; udp: 4096
;; QUESTION SECTION:
;berkeley.edu.                  IN      A

;; ANSWER SECTION:
berkeley.edu.           198     IN      A       128.32.203.137
berkeley.edu.           198     IN      RRSIG   A 10 2 300 20160906161321 20160902155734 20552 berkeley.edu. C6rreK8RPffJjJbMuoAj3jQP5Koez6nEPjumLRZtOcPYO8bXHVmNrSf5 R/Q1/hf0uK9B
berkeley.edu.           198     IN      RRSIG   A 10 2 300 20160906161321 20160902155734 55763 berkeley.edu. E2C1U8B1vWNLXTLk5WX47VatSKqrxQbW2396REcJ0M4bndqwKHTJrrHS Qr9VI64G+Gj6

;; AUTHORITY SECTION:
berkeley.edu.           10536   IN      NS      sns-pb.isc.org.
berkeley.edu.           10536   IN      NS      aodns1.berkeley.edu.
berkeley.edu.           10536   IN      NS      phloem.uoregon.edu.
berkeley.edu.           10536   IN      NS      adns1.berkeley.edu.
berkeley.edu.           10536   IN      NS      aodns2.berkeley.edu.
berkeley.edu.           10536   IN      NS      adns2.berkeley.edu.
berkeley.edu.           10012   IN      RRSIG   NS 10 2 10800 20160906161321 20160902155734 20552 berkeley.edu. ghIrnq0rISbm8RWxJcF/pR9zCa3QXrpPJftcdSYpTk/I6LFYjKK5B10F OwVyKG3Nu
berkeley.edu.           10012   IN      RRSIG   NS 10 2 10800 20160906161321 20160902155734 55763 berkeley.edu. rL2T1w4RWVZpu/zUIhigwT7sSSwJZp8gnbY4u1ZNcLr73a3ue3XBjGrf x2xDKt/AP

;; ADDITIONAL SECTION:
aodns2.berkeley.edu.    6294    IN      A       128.253.35.148
phloem.uoregon.edu.     75123   IN      A       128.223.32.35
phloem.uoregon.edu.     13252   IN      AAAA    2001:468:d01:20::80df:2023
adns2.berkeley.edu.     6294    IN      A       128.32.136.14
adns2.berkeley.edu.     7474    IN      AAAA    2607:f140:ffff:fffe::e
sns-pb.isc.org.         6524    IN      A       192.5.4.1
sns-pb.isc.org.         46194   IN      AAAA    2001:500:2e::1
aodns1.berkeley.edu.    6294    IN      A       192.35.225.133
aodns1.berkeley.edu.    2523    IN      AAAA    2607:f010:3f8:8000::ff:fe00:53
adns1.berkeley.edu.     1959    IN      A       128.32.136.3
adns1.berkeley.edu.     7474    IN      AAAA    2607:f140:ffff:fffe::3
aodns2.berkeley.edu.    6294    IN      RRSIG   A 10 3 10800 20160906163122 20160902154100 20552 berkeley.edu. Lw8t2yxfTFfwLThv0x/JZdAdCPk3O7Zr+rMVzG44fpLmn6SWH4/EG2IA sx2CjQEd3/
aodns2.berkeley.edu.    6294    IN      RRSIG   A 10 3 10800 20160906163122 20160902154100 55763 berkeley.edu. eLeO4M4BGzB0NYRtif8DpozUSSeQrucZoc6FpyGhlUHv8kfTncsXK3xw dWSGwhDzzq
adns2.berkeley.edu.     6294    IN      RRSIG   A 10 3 10800 20160906155418 20160902145750 20552 berkeley.edu. WK0+3QlDd/6kujgkcJc3d5QJMyD9VWwQM2xGE9kYQ/IW5l155c2zxG6X Q7XD2KfQRO
adns2.berkeley.edu.     6294    IN      RRSIG   A 10 3 10800 20160906155418 20160902145750 55763 berkeley.edu. hET89n7x16PWr6QYD9YdDUDZWyHMkNDE9xSRnuIgex+C37rnlncSolYj HlAdQKHCEj
adns2.berkeley.edu.     10229   IN      RRSIG   AAAA 10 3 10800 20160906154405 20160902150354 20552 berkeley.edu. jXP79E6IykchNV3DxbvONtNC8HmgWKK5HoOFgxHauDvkYiPEi66/6xNJ thY2v2a
adns2.berkeley.edu.     10229   IN      RRSIG   AAAA 10 3 10800 20160906154405 20160902150354 55763 berkeley.edu. bCCo55hQ/7NHVbSpjb/ZCit8G8gs15wL6lATL8ihILFDZrIMxQy5gklG vUSnzKD
sns-pb.isc.org.         6524    IN      RRSIG   A 5 3 7200 20160928233609 20160829233609 13953 isc.org. dulq1tz21MYEi962AAk2BT5cHeR2vd0HjePEE2S2ABY0JfqX/s+zDRai A/EKRiGDrj38iBp6o
aodns1.berkeley.edu.    6294    IN      RRSIG   A 10 3 10800 20160906152003 20160902151259 20552 berkeley.edu. cMXajdGuQgk6tt6IiC1QAM1232yLT2zFxDWfm0EuW6cJ57OLOVPbEZDq S6hhAKo70d
aodns1.berkeley.edu.    6294    IN      RRSIG   A 10 3 10800 20160906152003 20160902151259 55763 berkeley.edu. pHACF3XdiELFuLPe5kroahEMU0vgnNJ4+sOQ0Z286IPMaMgwrbrN511e M7FMQ0Tr14
aodns1.berkeley.edu.    10229   IN      RRSIG   AAAA 10 3 10800 20160906162655 20160902155822 20552 berkeley.edu. T+LsA9XpW82/HiZUitYPQeP3C59ykP4lfpfafJdeoRBUkJe2z0E+dldU AqY2ox5
aodns1.berkeley.edu.    10229   IN      RRSIG   AAAA 10 3 10800 20160906162655 20160902155822 55763 berkeley.edu. BMsWj9LiDHKW2CJUB6enhlQ91/csxboF7IKyxyVZby11E/P5UDjGxyBY d8ZC0iU
adns1.berkeley.edu.     1959    IN      RRSIG   A 10 3 10800 20160905162046 20160901152849 20552 berkeley.edu. du5i0LVc+8HfbEAs3f3qnRDwXgsQHEW8xgRoSHXfC/KBURr5+Lygkdni XA2fx1+t7m
adns1.berkeley.edu.     1959    IN      RRSIG   A 10 3 10800 20160905162046 20160901152849 55763 berkeley.edu. x6GHsdlKhAAiWQVRI1XJGAfav+xoz1YCK/z+XGARSjW0uW9pPTrTT/HL TXNYU201Rx
adns1.berkeley.edu.     10229   IN      RRSIG   AAAA 10 3 10800 20160906161659 20160902160412 20552 berkeley.edu. I22a0F87Tp22T3bcZX7sPUxzM9BrsoNvEzo7lqTE3Pkp58UmdyL57Azj 2X7j9K5
adns1.berkeley.edu.     10229   IN      RRSIG   AAAA 10 3 10800 20160906161659 20160902160412 55763 berkeley.edu. ce5EKo5g9DCtMWDYeCaqKibWIUMnmXMT2N4A41MRtuvIHI+oxA9mtQhx FuksjfO
```

3419-byte reply