

DNS Privacy in Practice and Preparation

BY

Casey Deccio and **Jacob Davis**

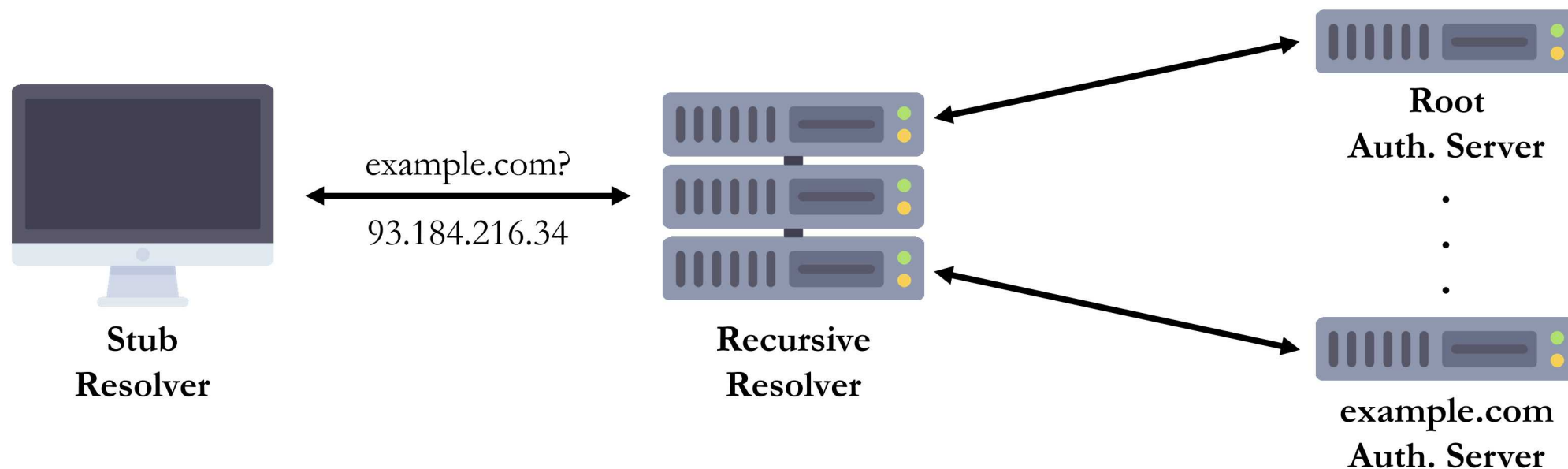


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Domain Name System (DNS) Review



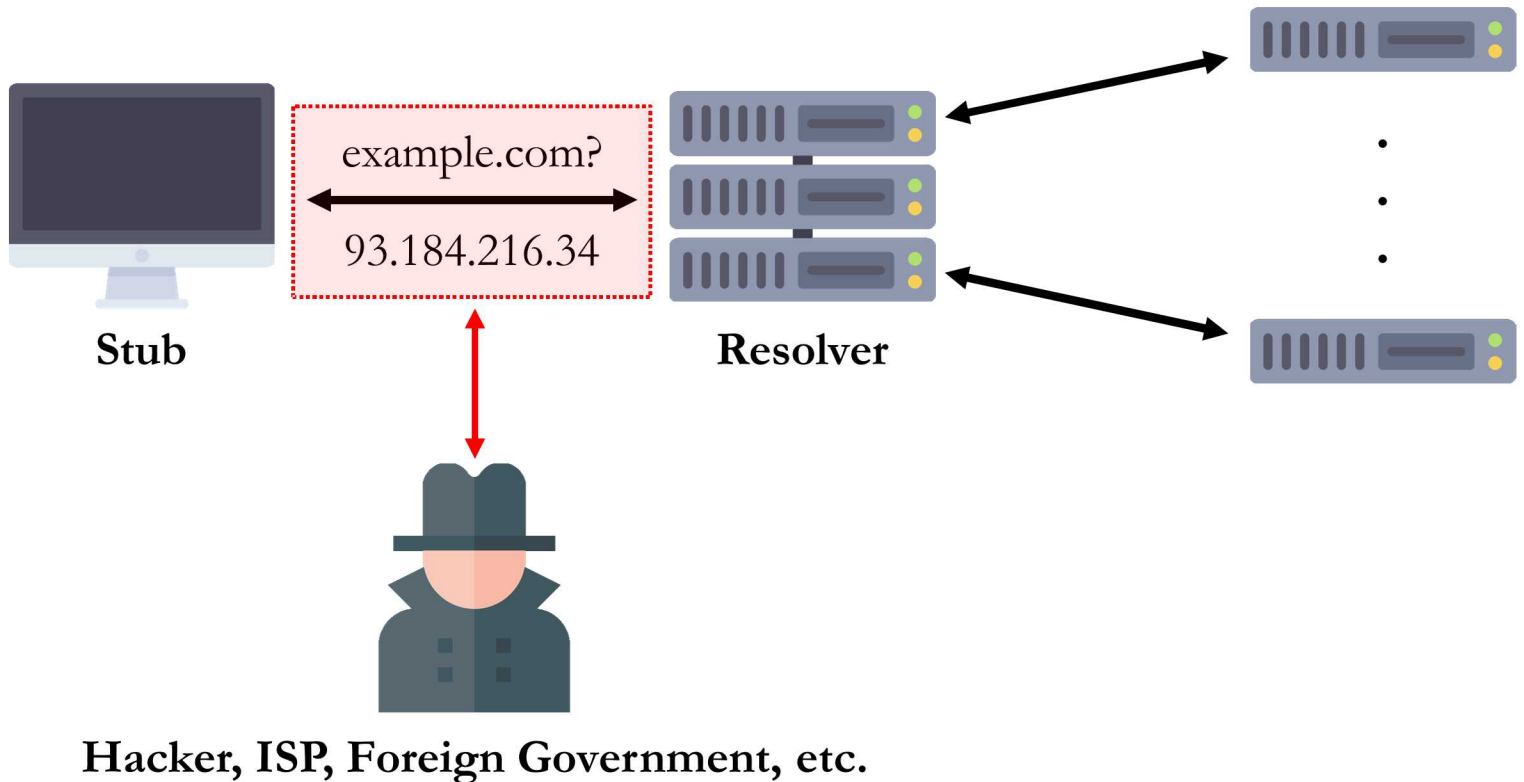
- DNS typically runs over UDP (original standard)
- Recursive resolver follows answers from Authoritative servers



DNS Dangers



- UDP has no security measures
- Vulnerable to eavesdropping, modifications, spoofing (DDoS), etc.
- Easy to use for filtering and logging



DNS Security Measures



Authenticity – Ensuring answer is correct

- DNSSEC

Confidentiality – Ensuring a connection is private

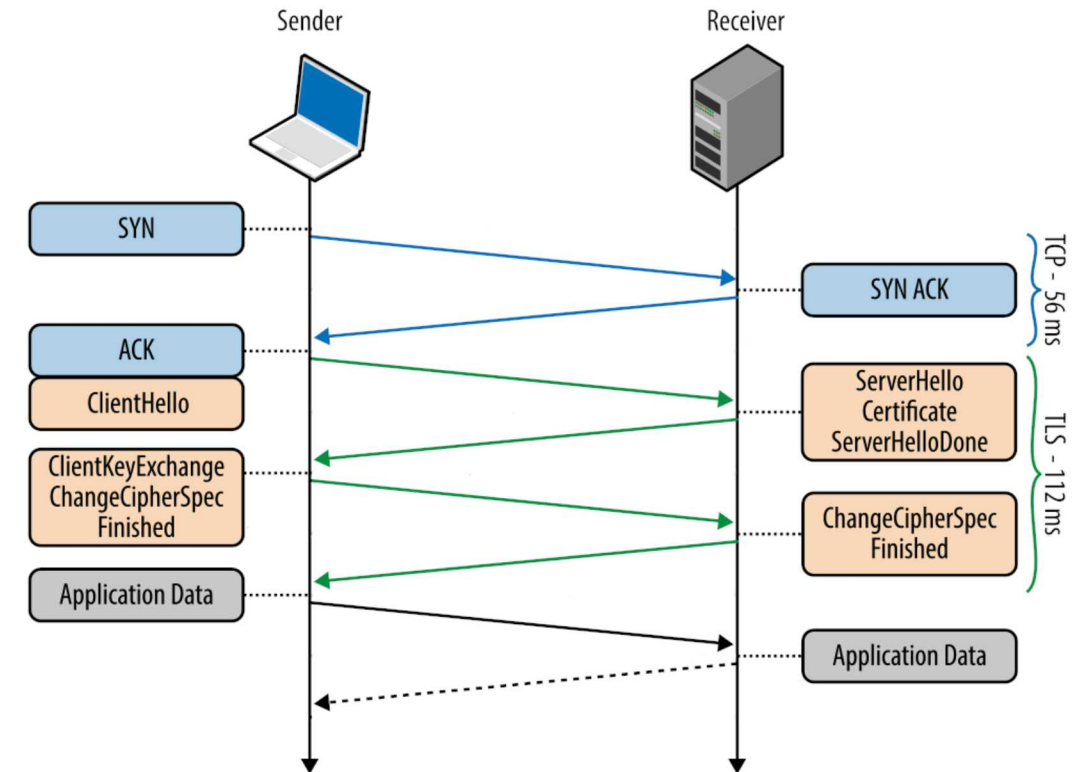
- DNS over TLS (DoT)
- DNS over HTTPS (DoH)
- DNS over DTLS
- DNS over QUIC
- DNSCrypt



DNS over TLS (2016)



- Transmit DNS queries over TLS
 - Optionally, verify server certificate is trusted
 - After handshake, everything is encrypted with shared session key
- Uses dedicated port 853
- Once handshake is complete, send queries like normal



- Send queries like normal web traffic (port 443)
 - Harder to block/detect as a result
 - Easier to implement for applications
- Use either GET or POST requests
 - POST: include wire format message in body
 - GET: include wire format message encoded in Base64url as a URL parameter

```
:method = POST
:scheme = https
:authority = dnsserver.example.net
:path = /dns-query
accept = application/dns-message
content-type = application/dns-message
content-length = 33
```

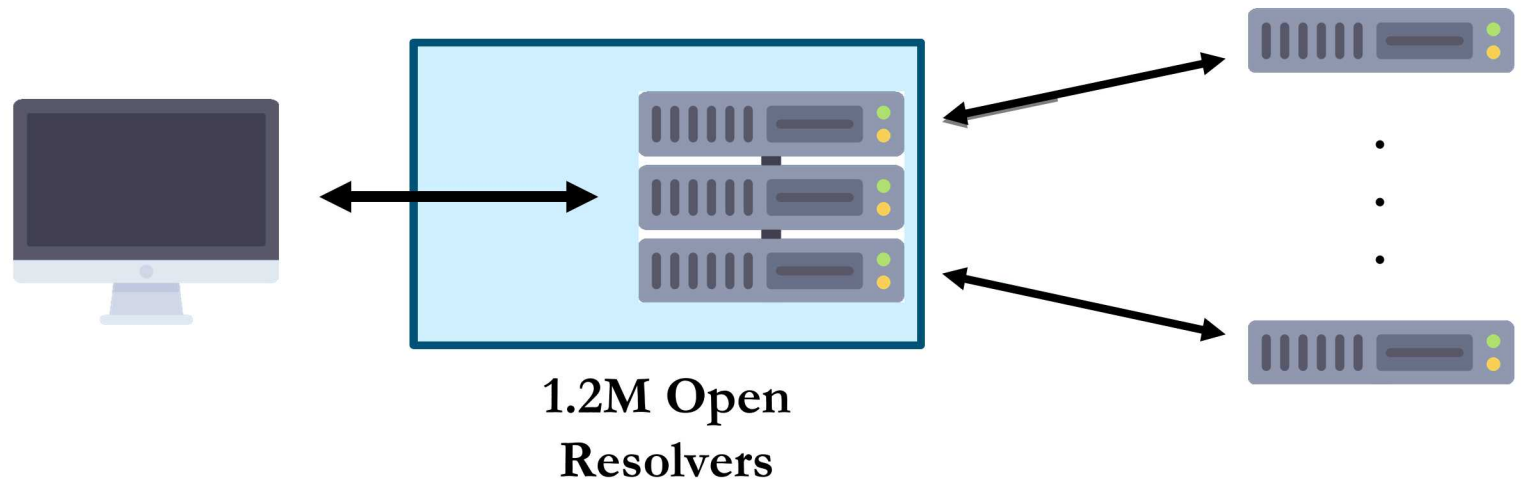
<33 bytes represented by the following hex encoding>
00 00 01 00 00 01 00 00 00 00 00 00 03 77 77 77
07 65 78 61 6d 70 6c 65 03 63 6f 6d 00 00 01 00
01

```
:method = GET
:scheme = https
:authority = dnsserver.example.net
:path = /dns-query?
    dns=AAABAAABAAAAAAAAAA3d3dwdleGFtcGx1A2NvbQAAQAB
accept = application/dns-message
```

DoT and DoH Resolver Results



- **1,197,794** open resolvers
- **1,747** (0.15%) IPs responded to DoT
 - 1,529 of those from a single entity, CleanBrowsing
 - 87 unique autonomous systems
- **9** IPs responded over DoH
 - All owned by Quad9 or Cloudflare
 - More up-to-date sources list 35 public DoH resolvers



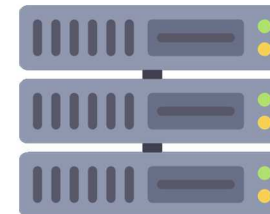
- **22** unique certificate signers were observed
 - GoDaddy and Let's Encrypt were most popular
- **11** certificates were self-signed (Issuer matched Subject)
- **79** (4.5%) IPs supported TLS 1.3
 - Important for reduced RTT (2→1) and potential for 0-RTT
- **1,701** (97%) IPs supported TLS 1.2
- **80** IPs did not support TLS 1 or TLS 1.1



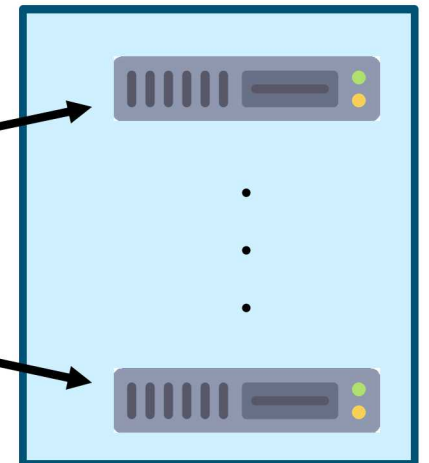
DoT Authoritative Results



- Limited scope to nameservers for top 5K Alexa sites and all TLDS (1,530)
 - **6,817** unique IP addresses for TLDS
 - **10,214** unique IP addresses for Alexa Sites
- No TLD responded over DoT
- **12** Alexa IPs responded over DoT
 - All IPs that responded were owned by Facebook
 - Corroborates with Cloudflare blog experimenting with DoT to Facebook



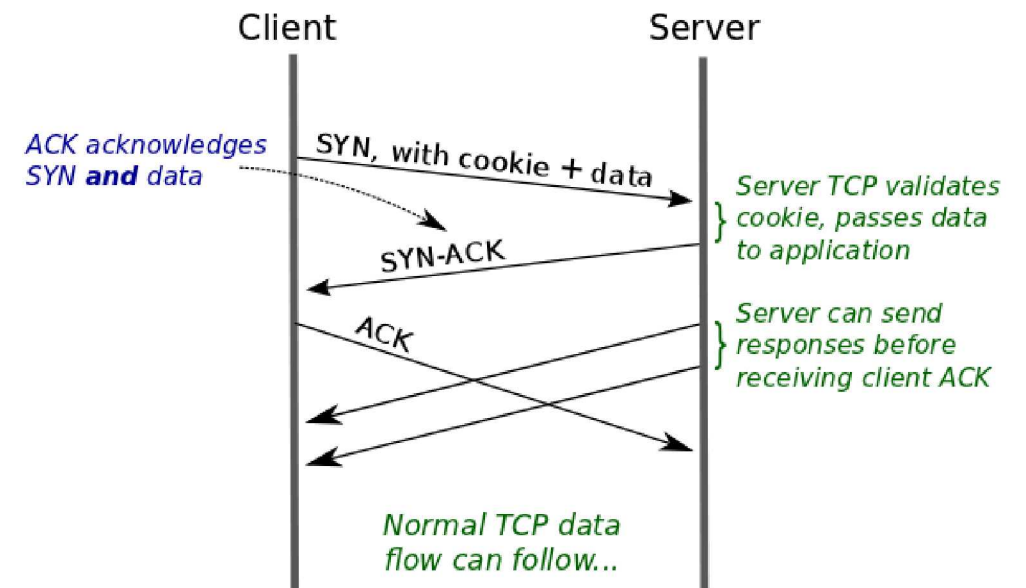
**7K TLD & 10K Alexa
Authoritative Servers**



TCP Fast Open Overview (2014)



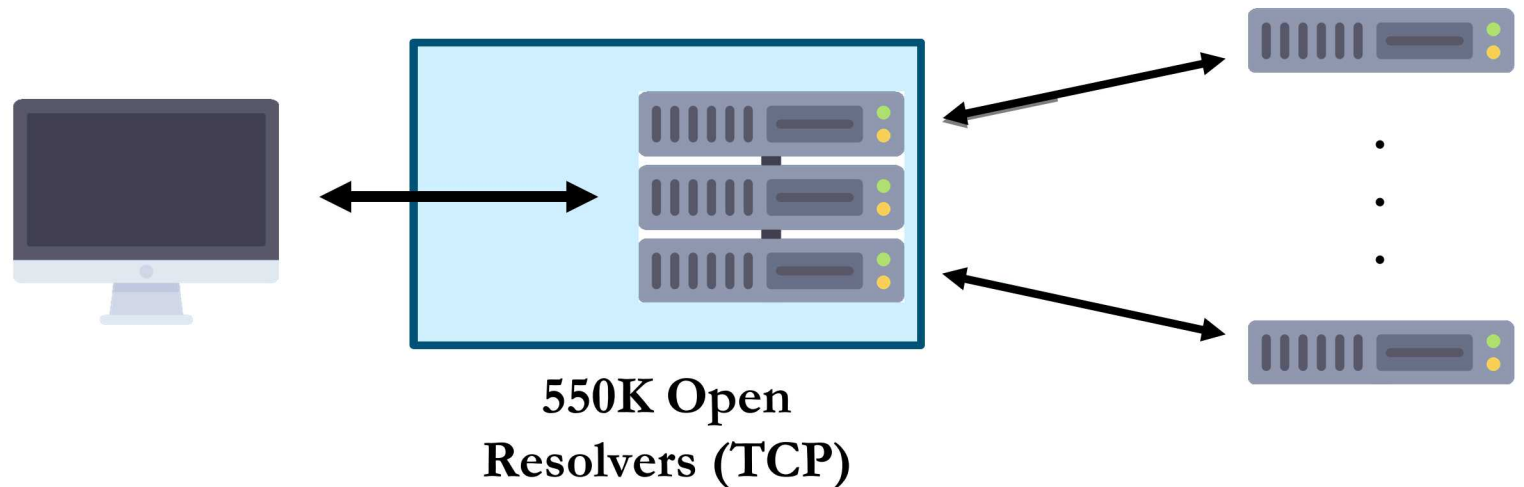
- A major drawback of security is increased delay
- TFO fixes this in subsequent connections
 - Server gives client cookie in first connection
 - Client can reconnect with cookie + data in SYN



TFO Results for Resolvers



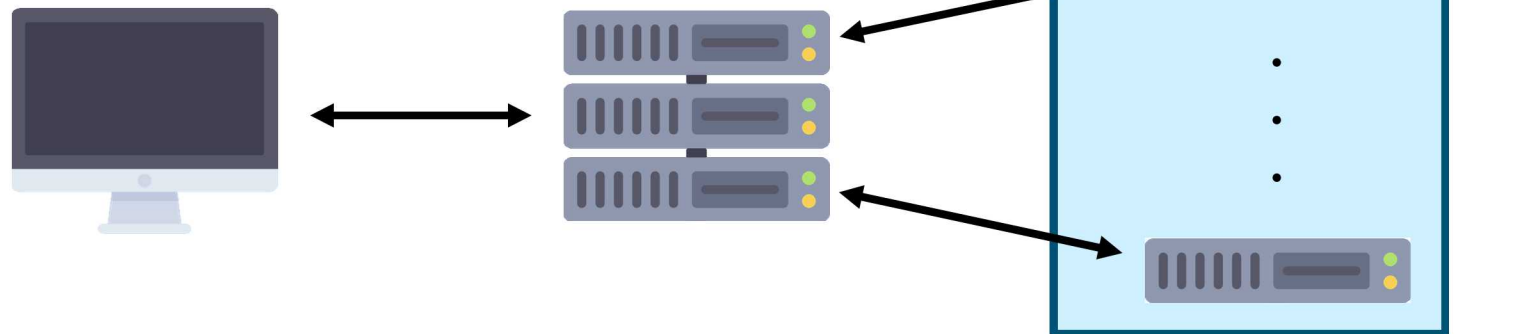
- **557,969** resolvers supported TCP
 - **10,851** (1.9%) responded with the TFO option
 - **1,257** (0.23%) acknowledged data sent in SYN
 - Google sent TFO option, but did not ACK data, likely due to load balancing
- **25** of 1,747 (1.4%) resolvers that responded over DoT included TFO option
 - All also correctly ACKed data



TFO Results for Authoritative Servers



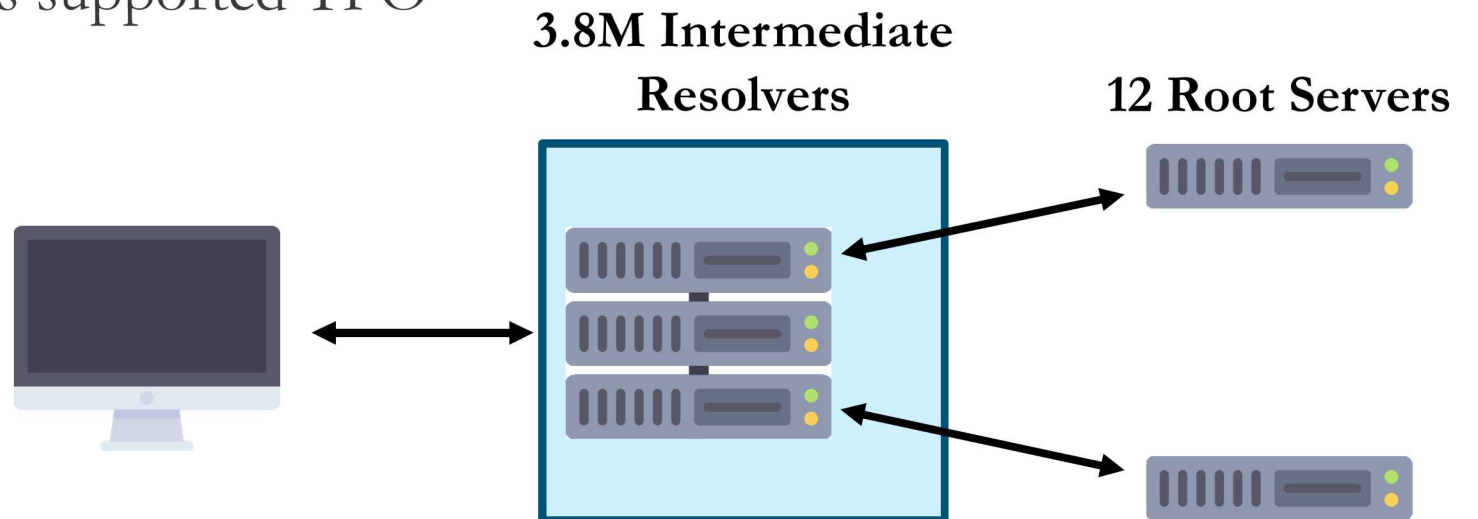
- Like DoT work, used nameservers for top 5K Alexa sites and all TLDS (1,530)
 - **6,743** unique IP addresses for TLDS
 - **9,558** unique IP addresses for Alexa Sites
- **11** TLD IPs included TFO option
 - 10 of these were Google's
- **5** ACKed data
- **726** (7.1%) Alexa IPs sent TFO option
- **18** (0.19%) ACKed data



TFO Client Results at Root Servers



- Analyzed 48 hours of queries sent to root server (minus g-root)
- **3,769,471** unique IPs queried roots
- **89** IPs included TFO option
- **32** included cookie, but didn't send data in SYN
- Needs to be studied further
- Does not appear the root servers supported TFO



Conclusion



- Both DoT and DoH offer security to the DNS
 - DoT adoption is limited, but includes most well-known resolvers
 - DoH is newer, but will likely surpass DoT in adoption
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- TFO can help reduce delay of DoT and DoH but support is very limited
 - Many IPs are sending TFO option, but not ACKing data



Questions

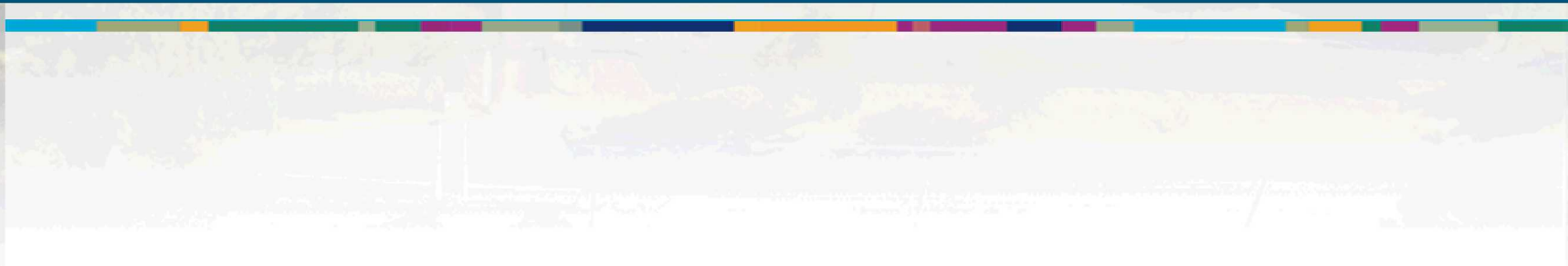
Contact:

jacdavi@sandia.gov

casey@byu.edu



Extra Slides



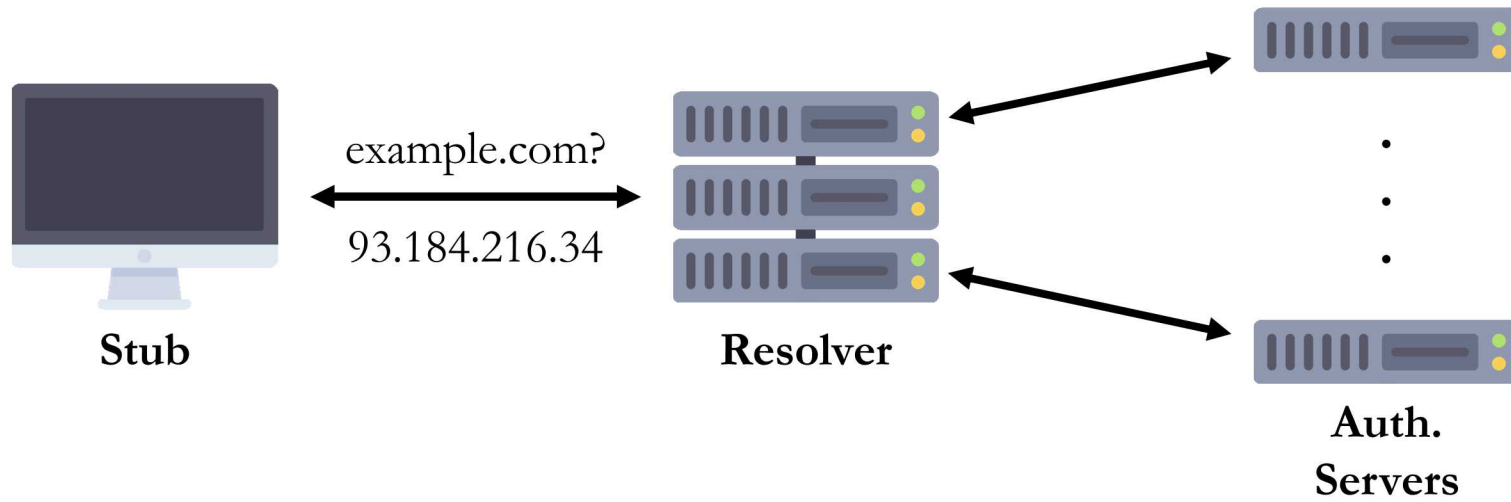
Google and TFO



- Google always included TFO option, but did not ACK data in SYN
 - However, over DoT they did correctly ACK data
- Issued 1,000 queries to Google from a single client IP
- Received **80** distinct TFO cookies, distributed uniformly
- It appears Google uses load balancing of TCP connections to 8.8.8.8
 - Selection does not seem to depend on previous connections

Future Work

- Study TFO usage at root servers in more depth
 - Compare 2018 and 2019 data
- Map out Google's backends through TFO cookies and other methods
 - DNS cookies, EDNS Client Subnet, etc.



80% ^
100% ->

