Akamai
Experience the Edge

DNS Encryption: Operational Experience and Insights

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Agenda / Topics

- Common question from Network Operators
- Observations
- Analysis
- Testing

Network Operator Question:

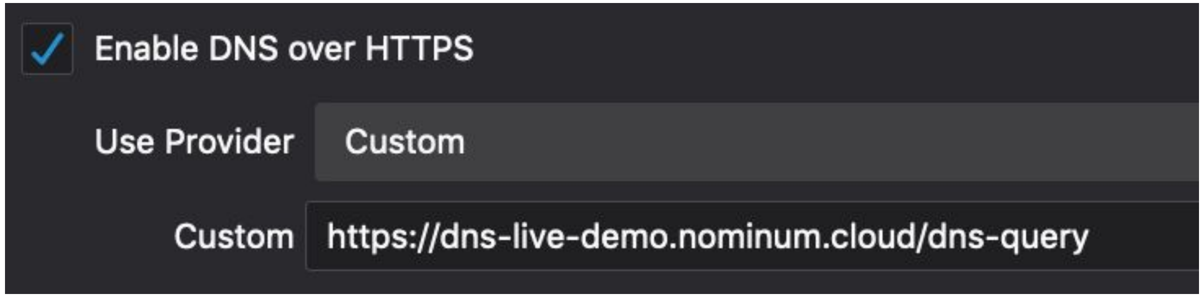
“How does DoT/DoH change our DNS infrastructure capacity model?”

🤔 *.. well.. that depends on what the clients are doing..*

Available sample data sources

- ○ Firefox DoH: Multiple clients/roaming locations
- ○ Residential CPE’s with DoT forwarding capabilities
  - ■ pfSense on ALIX apu4b4 (~35 devices)
  - ■ Stubby on a Raspberry PI (~15 devices)
  - ■ AVM Fritz! Box 7590 (~10 devices)

Client 1: Firefox DoH



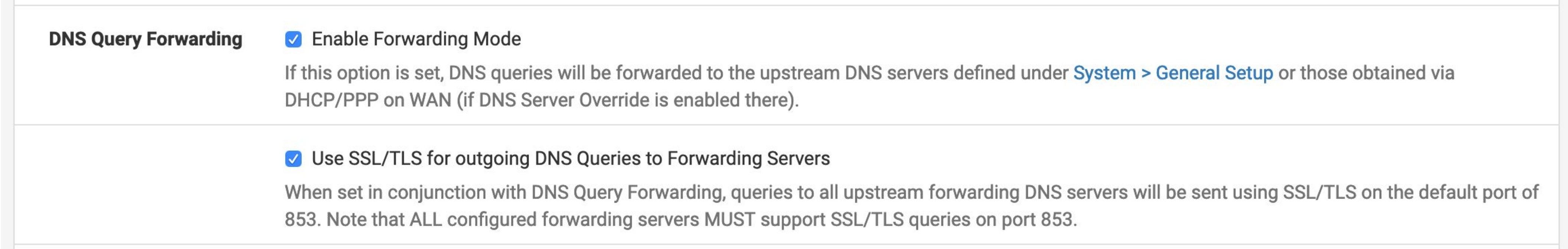
☑ Enable DNS over HTTPS

Use Provider: Custom

Custom: https://dns-live-demo.nominum.cloud/dns-query

- Session reuse:
    - Total queries 268485
    - Total connections 62177
    - Avg queries per unique connection 4.32
- Observations:
    - Generally well behaved
    - Pro: Server side snafu (expired cert) did not cause any interruption of user experience
    - Con: .. cert validation failure not noticeable to end user

Client 2: Residential CPE (pfsense) DoT



DNS Query Forwarding

☑ Enable Forwarding Mode

If this option is set, DNS queries will be forwarded to the upstream DNS servers defined under System > General Setup or those obtained via DHCP/PPP on WAN (if DNS Server Override is enabled there).

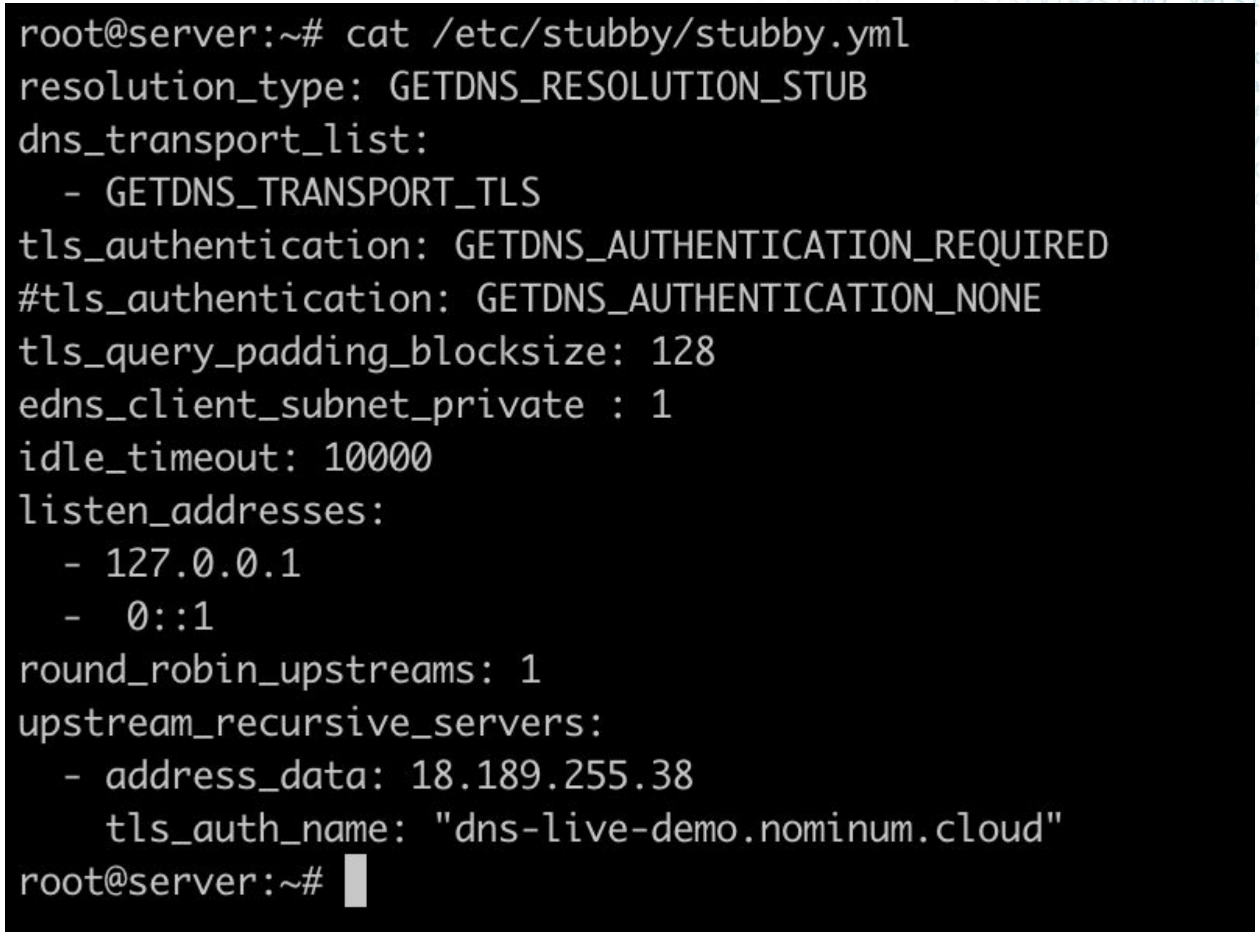
☑ Use SSL/TLS for outgoing DNS Queries to Forwarding Servers

When set in conjunction with DNS Query Forwarding, queries to all upstream forwarding DNS servers will be sent using SSL/TLS on the default port of 853. Note that ALL configured forwarding servers MUST support SSL/TLS queries on port 853.

- Session reuse:
  - None - new TLS session per query
  - Min 0.29 / Max 1.22 second conversation duration seen (on server side packet captures)
- Observations: Some unexpected results
  - ~2% of all queries (70851 of 3472626) timed out
  - Timeouts represented “mostly” unnoticeable user impact
  - Specifying different/multiple upstream forwarders and upgrading to latest in repo version of resolver did not fix issue
  - Typically between 30-120 TCP states in TIME_WAIT (on CPE)

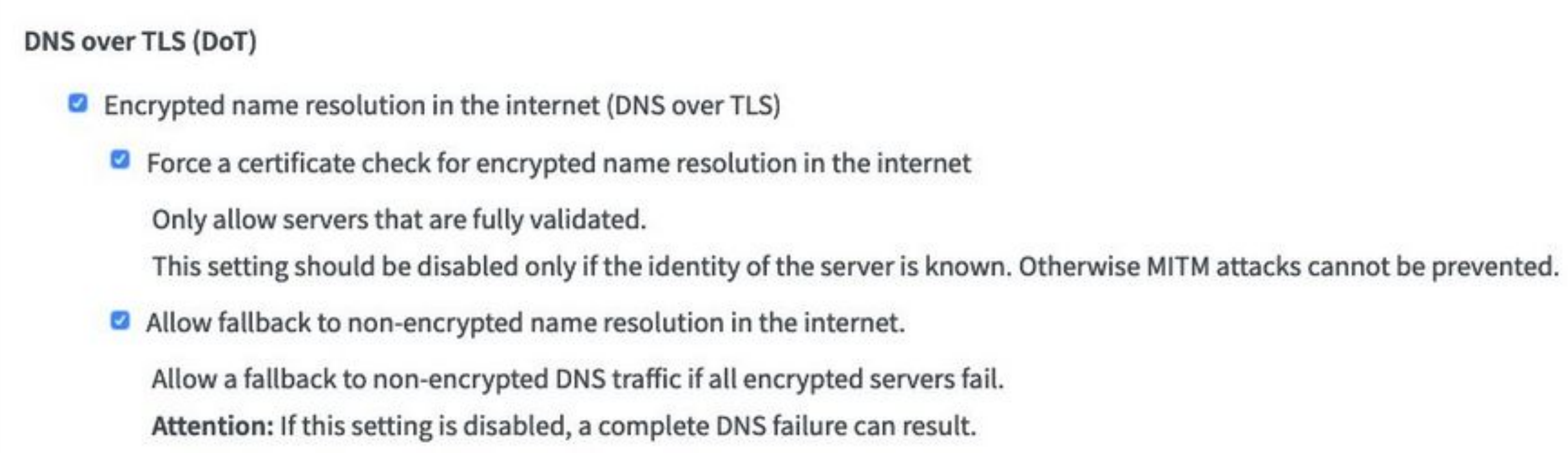
Client 3: Residential CPE (Stubby) DoT

- Session reuse:
  - ○ Total queries 182772
  - ○ Total connections 50594
  - ○ Avg queries per unique connection 3.61
- Observations
  - ○ No issues
  - ○ Not necessarily representative of average user setup
  - ○ By default, stricter default configuration than other clients (fail closed)



```
root@server:~# cat /etc/stubby/stubby.yml
resolution_type: GETDNS_RESOLUTION_STUB
dns_transport_list:
  - GETDNS_TRANSPORT_TLS
tls_authentication: GETDNS_AUTHENTICATION_REQUIRED
#tls_authentication: GETDNS_AUTHENTICATION_NONE
tls_query_padding_blocksize: 128
edns_client_subnet_private : 1
idle_timeout: 10000
listen_addresses:
  - 127.0.0.1
  -  0::1
round_robin_upstreams: 1
upstream_recursive_servers:
  - address_data: 18.189.255.38
    tls_auth_name: "dns-live-demo.nominum.cloud"
root@server:~# 
```

Client 4: Residential CPE (AVM Fritz!Box) DoT



DNS over TLS (DoT)

☑ Encrypted name resolution in the internet (DNS over TLS)

☑ Force a certificate check for encrypted name resolution in the internet

Only allow servers that are fully validated.

This setting should be disabled only if the identity of the server is known. Otherwise MITM attacks cannot be prevented.

☑ Allow fallback to non-encrypted name resolution in the internet.

Allow a fallback to non-encrypted DNS traffic if all encrypted servers fail.

Attention: If this setting is disabled, a complete DNS failure can result.

- Session reuse:
  - Total queries 286811
  - Total connections 53500
  - Avg queries per unique connection 5.36
- Observations
  - No issues
  - Fallback options clearly exposed on UI

Client Behaviours - Cert validation failures

New operational workflows to consider

- Certs: Obtain, rotate/automate, oops?
- Troubleshooting this is hard

Client	Version tested	Failure Mode (default)
Firefox (DoH)	72.0.2	Fail Open
Chrome (DoH)	X	Fail Open
kdig / curl / getdns	2.6.5 / 0.1 / 1.6.0	Opportunistic mode: Fail Open Strict mode: Fail Closed
Android 9 Private DNS	G950WVLS7CSK1	Automatic mode: Fail Open Private DNS hostname: Fail Closed
CPE (pfsense)	2.4.4	Fail closed until CPE restart
CPE (AVM Fritzbox)	7.19-74093	Fail open*
Stubby on Raspberry PI	0.2.2	Fail closed (Dependent on “tls_authentication” param)

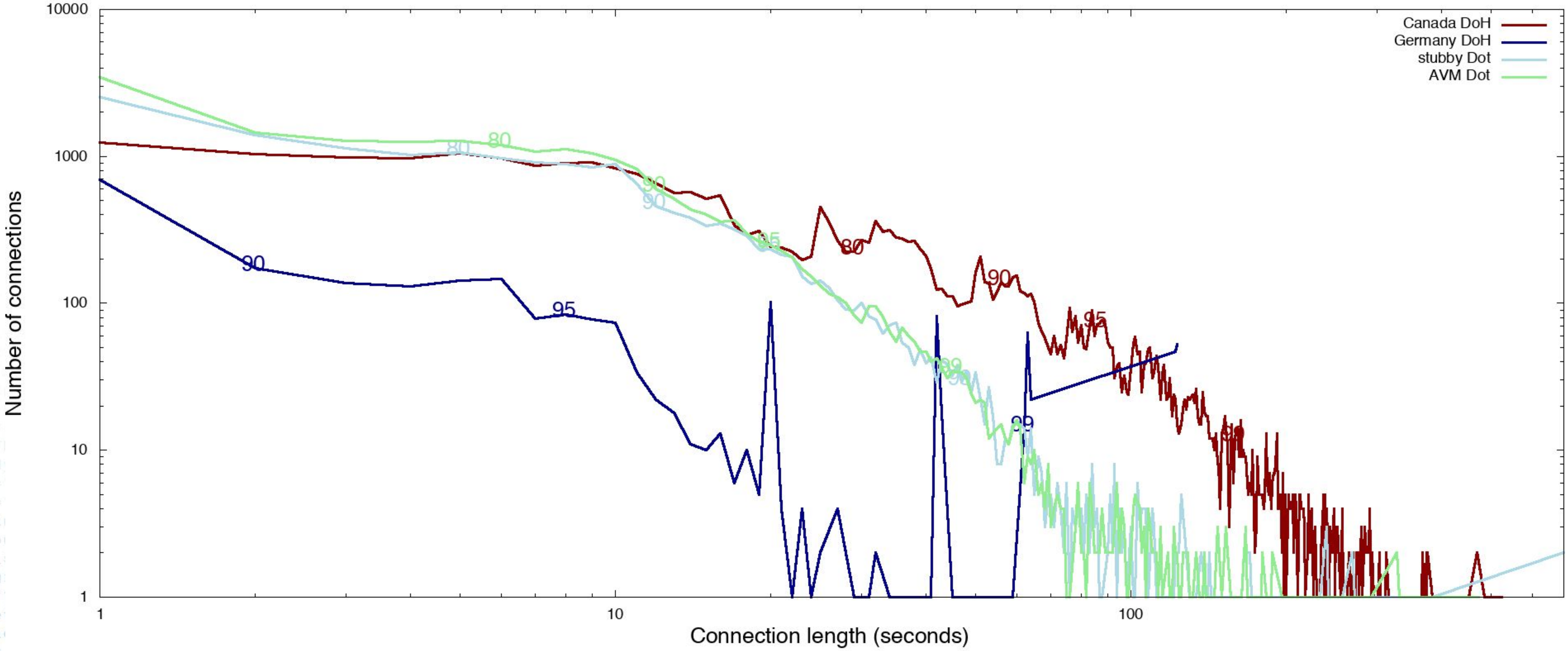
Other observations - Server idle timeouts

Provider	DoT idle timeout (seconds)	DoH idle timeout (seconds)
CloudFlare	1.1	15
Google	60	240
Quad9	10	10
NextDNS	5	5
British Telecom	X	10
Comcast	10	618-655
Cox	10	10
Deutsche Telekom	600	10

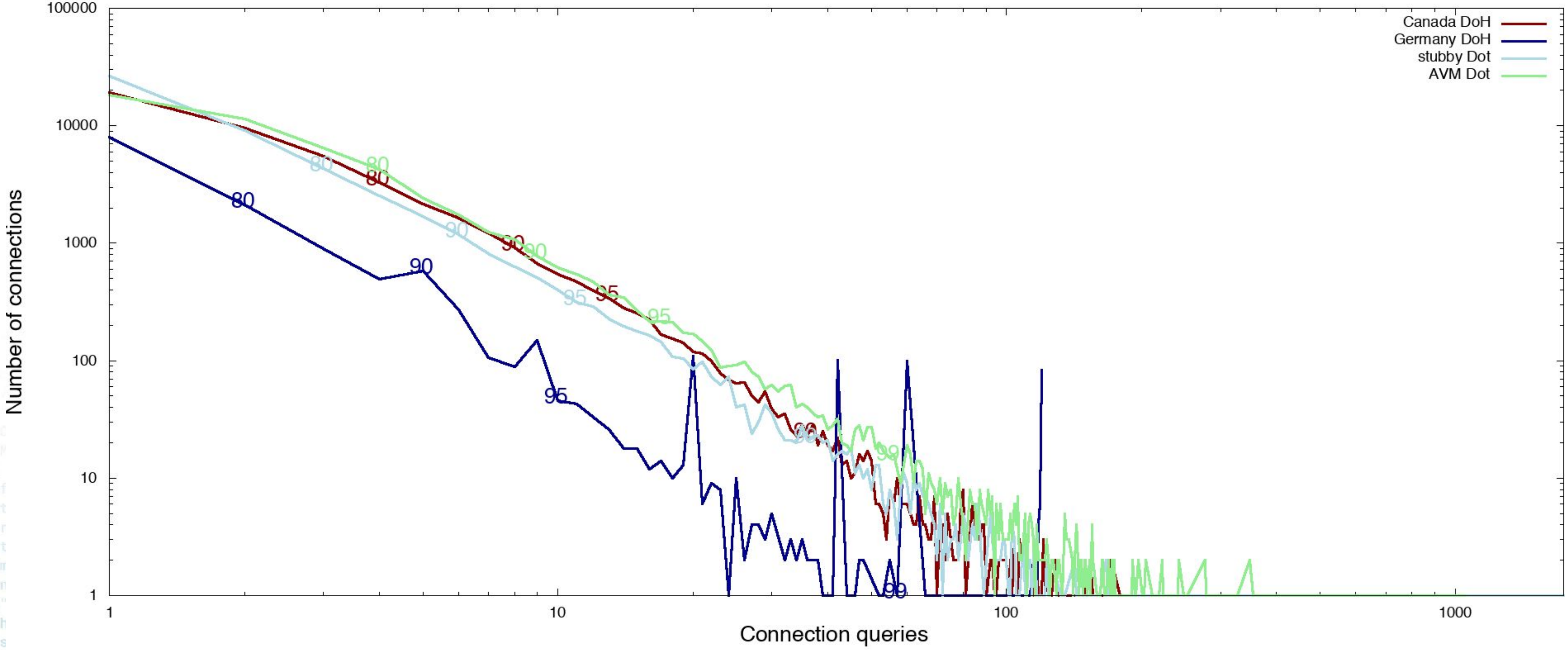
DNS Log Analysis

- Methodology
  - Logged queries include timestamp and unique IP/port combination
  - Server timeout is 10 seconds
  - If there is more than 10 seconds (I actually used 60 to be save) between two queries with same source IP/Port it is counted as a new connection
  - As clients don’t seem to drop connections the actual connections length is 10 seconds after the last packet (not shown in graphs)
- Graphs
  - Log scale (to show the area where most data is)
  - Numbers show percentage of connections

Connection time distribution



Query count distribution



Off to the races

- DNS over 53 sizing is simple
  - Primarily about throughput
  - Understood values. Fixed ~0.25 qps per subscriber, Mobile ~0.15 qps (both rising)
- TCP/DoT/DoH has more variables
  - How many connections?
  - How long is connection lifetime?
  - How many queries per connection?
  - How CPU intensive is connection setup vs established state queries
- Have to do some assumptions here for a lab test

Test Setup

- Hardware
    - Real Hardware – 40 core Intel(R) Xeon(R) CPU E5-2690 v2 @ 3.00GHz
    - 64GB of memory (not enough ;-)
    - Intel 10GB NIC
    - One similar machine as client for UDP testing
    - 12 machines I could borrow from QA (Thanks guys) as DoH clients
- Tools
    - Dnsperf for UDP
    - Python3 (to write my own test scripts)

DNS over UDP/53 tuning and testing

- On the server

```
sysctl -w net.core.rmem_max=524288
sysctl -w net.core.wmem_max=524288
/sbin/ethtool -N eth0 rx-flow-hash udp4 sdfn
```

- On the client run dnsperf

```
dnsperf -s dohtest -d one.q -l 5  -T 8 -c 8 -S 1 -q 200
DNS Performance Testing Tool
Nominum Version 2.1.1.0.d

[Status] Command line: dnsperf -s dohtest -d one.q -l 5 -T 8 -c 8 -S 1 -q 200
[Status] Sending queries (to dohtest) over UDP
[Status] Started at: Sat Feb  8 03:57:29 2020
[Status] Stopping after 5.000000 seconds
1581134250.831940: 604876.413248
1581134251.832960: 621347.225830
1581134252.833940: 650431.577054
1581134253.834939: 623151.471680
[Status] Testing complete (time limit)
```

DNS over HTTPS testing

- Python script
  - Use python multithreading to open a HTTPs connection and send a query every 4 seconds
    - 0.25 qps
    - 5 packets across a 20 second connection
  - Works reliably for ~1000 concurrent threads
  - Add more instances for more connections
  - Did not really work (at least not for the 5 to 6 digit numbers I was aiming for)
  - What is up

DNS over HTTPS (TCP really) tuning

- TCP connections
  - Each connection requires a source port
    - Per default there are only 30k allowed
    - 65536 / 64512 is the maximum you can have
    - For reliability only do 50k connections per machine
      - Need more client machines – QA to the rescue!
  - Each connection requires a filehandle
    - Couldn’t push above 1048576 in /etc/security/limits.conf
      - Have another root terminal open when you change this file

Detailed TCP tuning

- Client
  - sysctl net.ipv4.ip_local_port_range="1025 65535”
- Server
  - sysctl net.ipv4.tcp_fin_timeout = 20
  - sysctl net.ipv4.tcp_tw_reuse = 1
  - sysctl fs.file-max=4194304
  - /etc/security/limits.conf

```
*       soft nofile     1048576
*       hard     nofile     1048576
```

Can we crash the test setup?

- Stuff to figure out
  - How fast can we create new connections
  - How many active connections can we serve
  - What will be the CPU load
  - When will it break

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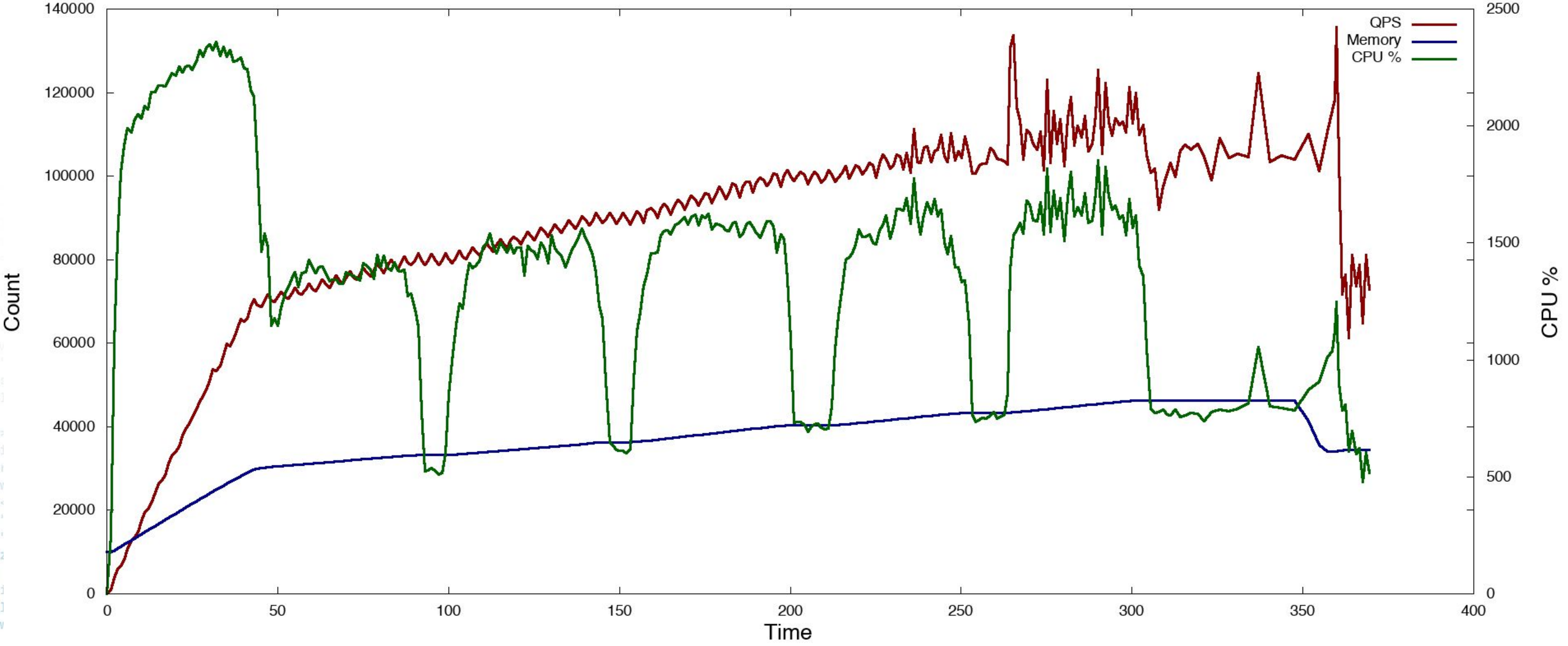
Connection stress diagram



Crashtest takeaways

- It didn’t crash
- Connection setup is far more CPU intensive then just answering
- It had limits
  - ~7000 new DoH connections per second
  - 460000 active connections on a 64GB machine
- It scaled well
  - Could push additional 100k UDP without any other impact to the above

Closing thoughts

- Well behaved clients critical to successfully scaling server side operations
- Early days. Ecosystem is still evolving
- DNS servers now also need to tune for TCP workloads
- Lots of active connections needs lots of memory
- Server side multithreading important
  - UDP and TLS workloads are cumulative
  - Ensure there are sufficient CPU cores to handle the combined workload