Factors Affecting Performance of Web Flows in Cellular Networks

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September 25, 2018 - RIPE NCC Regional Meeting , Almaty

Introduction

Introduction — Motivation

- $\sim$ 99% of the Internet traffic flows are short ($<$100 KB).

[Brownlee and claffy **SIGMETRICS'02** , Ramachandran **Google'10**]

- $>$ 95% traffic generated by smartphones consists short-lived TCP flows.

[Huang et al. **SIGCOMM'13**]

Performance of short web flows driven by latency than network throughput:

- DNS lookup time
- TCP connect time

Introduction — Research Question

Few studies that quantify the factors that are responsible for DNS lookup & TCP connect times in cellular network. [Xu et al. **SIGMETRICS'11**, Rula and Bustamante, **SIGCOMM'14**]

We want to know:

- What are factors affecting DNS lookup and TCP connect time?
- How much DNS cached entries and TCP proxies improve latency?
- Distribution of packet loss and DNS look up failure.

Introduction — Contribution

1. DNS lookup failure & packet loss
   - $\sim$ 2% DNS lookup test experience failures
   - $\sim$ 14.98% of have lost at least one packet
2. Radio technology & device model:
   - TCP connect times to popular websites are reduced by $\sim$80% on LTE compared to legacy networks.
   - Device model has an impact on DNS lookup time.
3. ISP caches & DNS server's proximity:
   - ISP caches improve TCP connect times towards some websites.
   - DNS server's proximity to the subscriber has an impact on DNS lookup time.

Methodology

Measured Websites

DNS lookup and TCP Connect time towards 4 websites:

- `www.google.fi`
- `www.youtube.com`
- `www.facebook.com`
- `www.elisa.net`

Ping Test towards:

- `www.google.fi`

Measurement —DNS Lookup Time — TCP Connect Time — Ping Test

DNS Lookup Time:

- DNS lookup time (in milliseconds)
- IPv4 address of DNS server
- Radio technology, device model
- Response error code

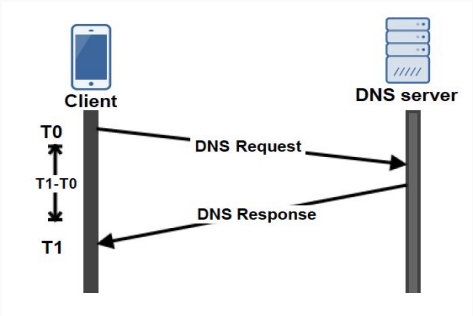
TCP Connect Time

- Starting time of the test
- FQDN of the destination host
- Radio technology, device model

Ping Test:

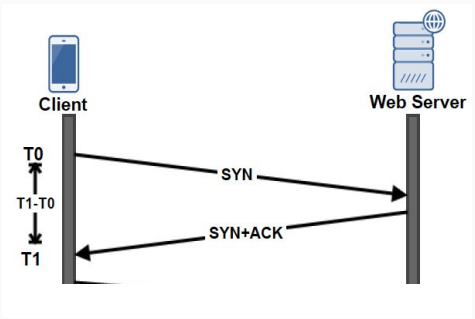
- ICMP echo request towards `www.google.fi`
- RTT and packet loss
- five to nine ICMP Echo requests
- payload size of request is 16 bytes

DNS lookup test



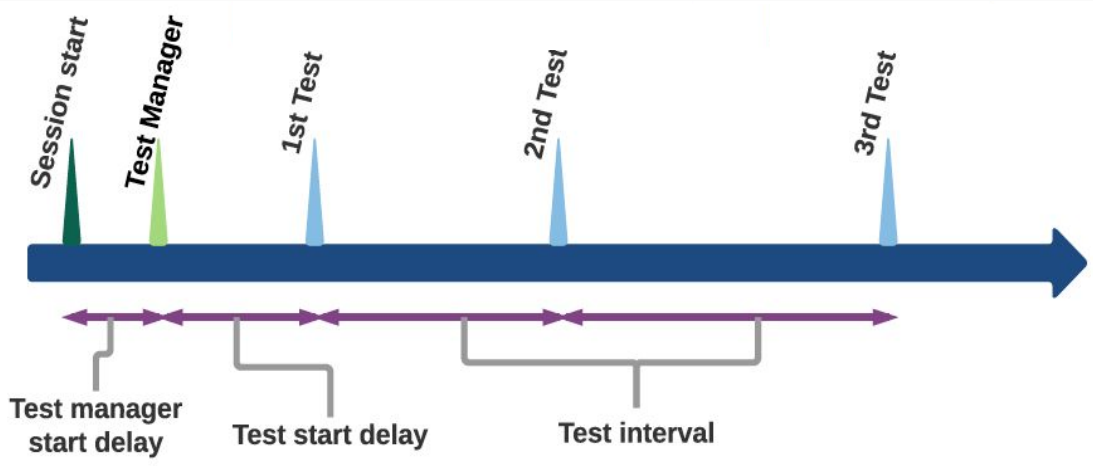
Measures the time it takes to look up a FQDN from a DNS server

TCP connect time



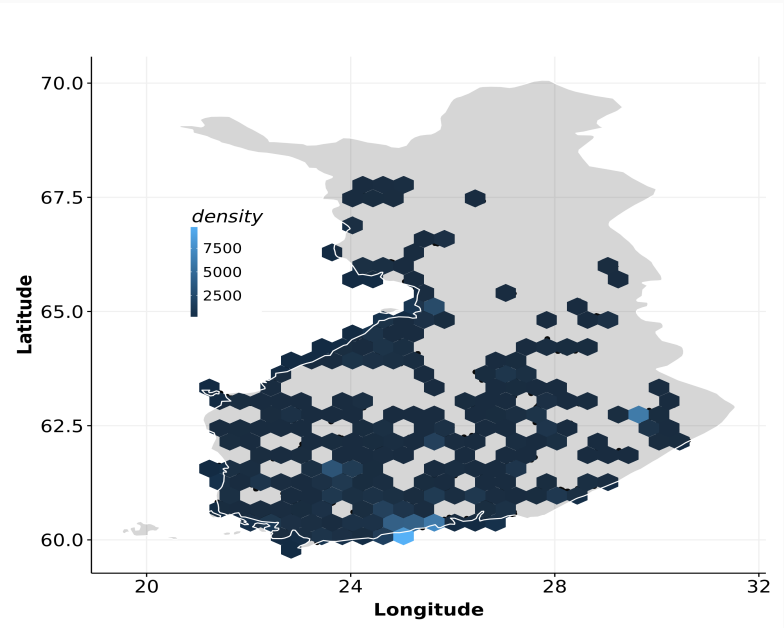
Measures the time to connect to a target website (IPv4 ,80) from the client

Measurement Setup



- Measurements tests are executed inside sessions.
- A session starts when a network interface becomes available or best interface changes.
- It is not periodic, but they are repeated when network conditions changes

Data Set and Measurement Trials



The geographical distribution of ∼25K subscribers in Finland.

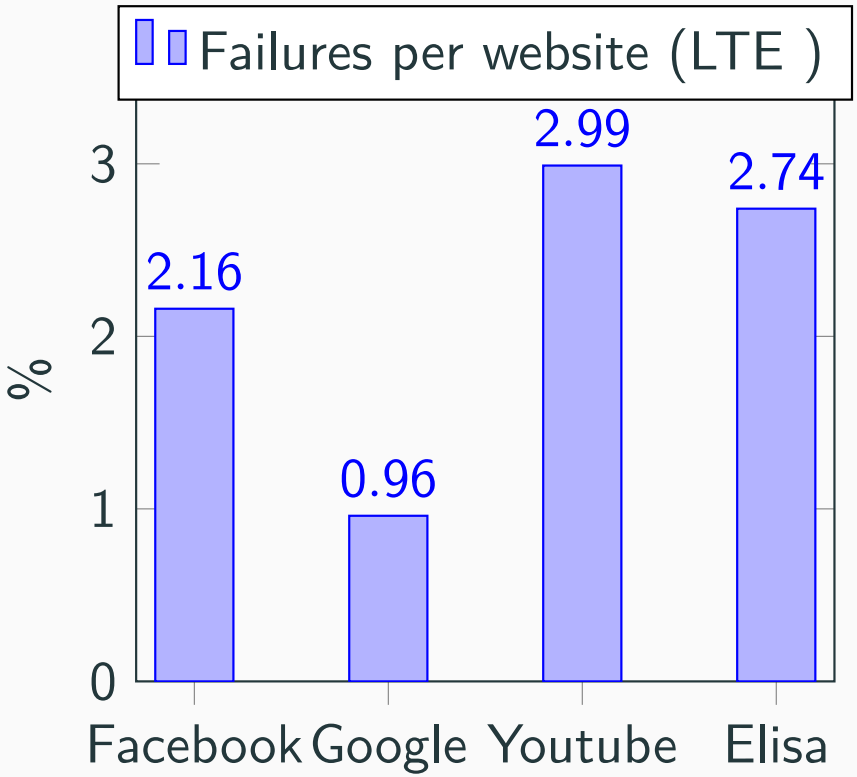
Website	DNS (#)	TCP (#)	ping (#)
www.facebook.com	3.4M	4.6M	-
www.google.fi	6.9M	4.9M	2.1M
www.youtube.com	1.6M	4.1M	-
www.elisa.net	1.8M	5.3M	-

DNS, TCP and ping measurements by website.

A month-long dataset collected through a mobile operator in Finland (Elisa)

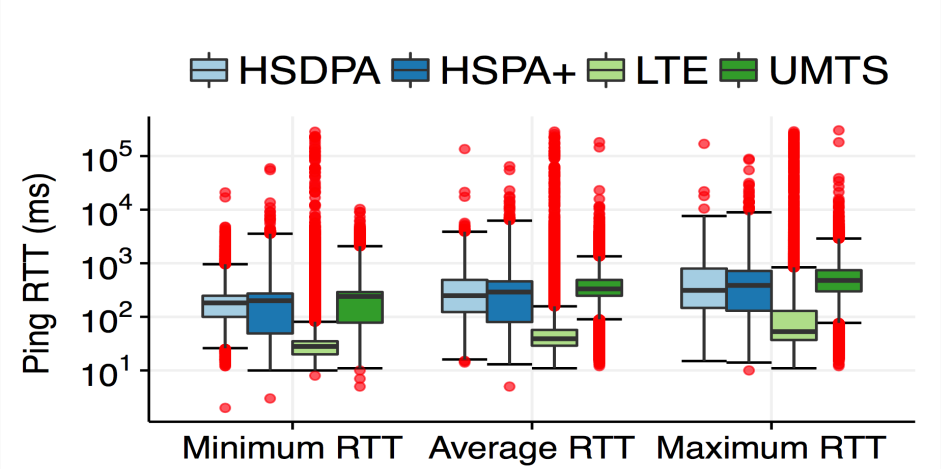
Data Analysis & Results

DNS Lookup Failures



- $\sim$ 2% of the total DNS lookup show failure
  - $\sim$ 86% of the DNS failures indicating that a responder does not implement the version level of the request
  - LTE (1.9%) , UMTS (3.4%) , HSPA (3.9%) and HSPA+ (2.7%)

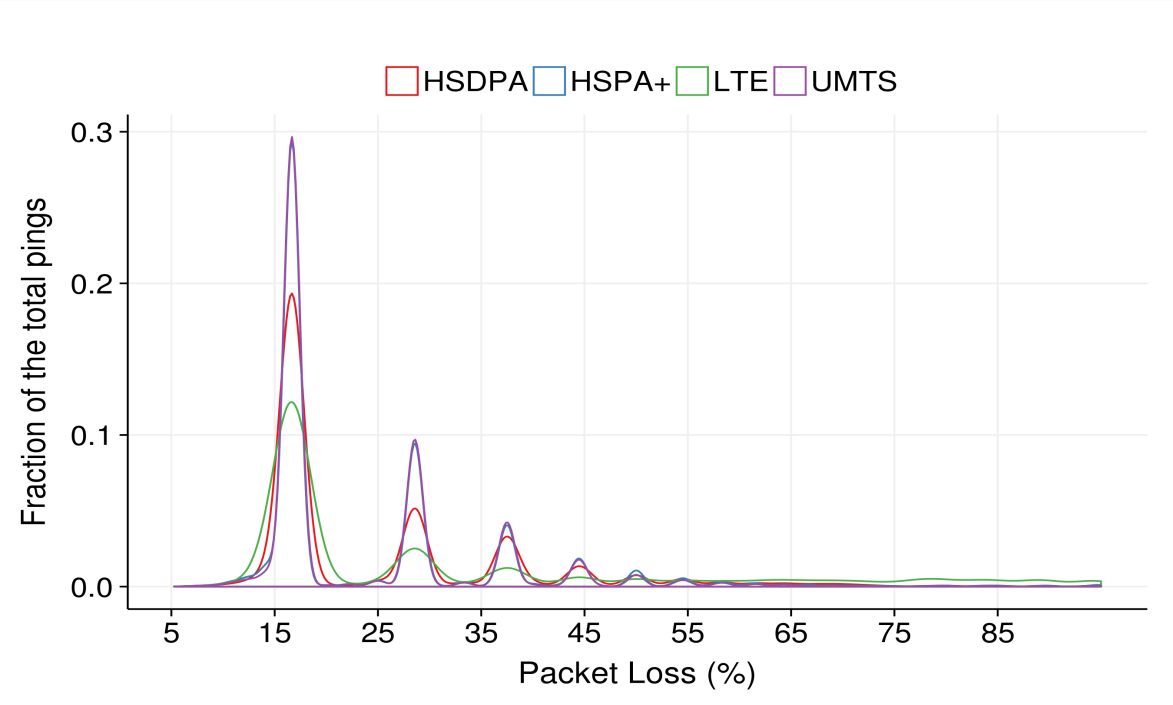
Latency — Using `Ping` Test



Min, Avg & Max RTT values split by radio technology for a `ping` towards `www.google.fi`

- $\sim$ 90% of the average `ping` test towards `www.google.fi` using LTE have a RTT $<$ 100 ms.
- Legacy 3G technologies are quite slow with more than 200 ms RTT.

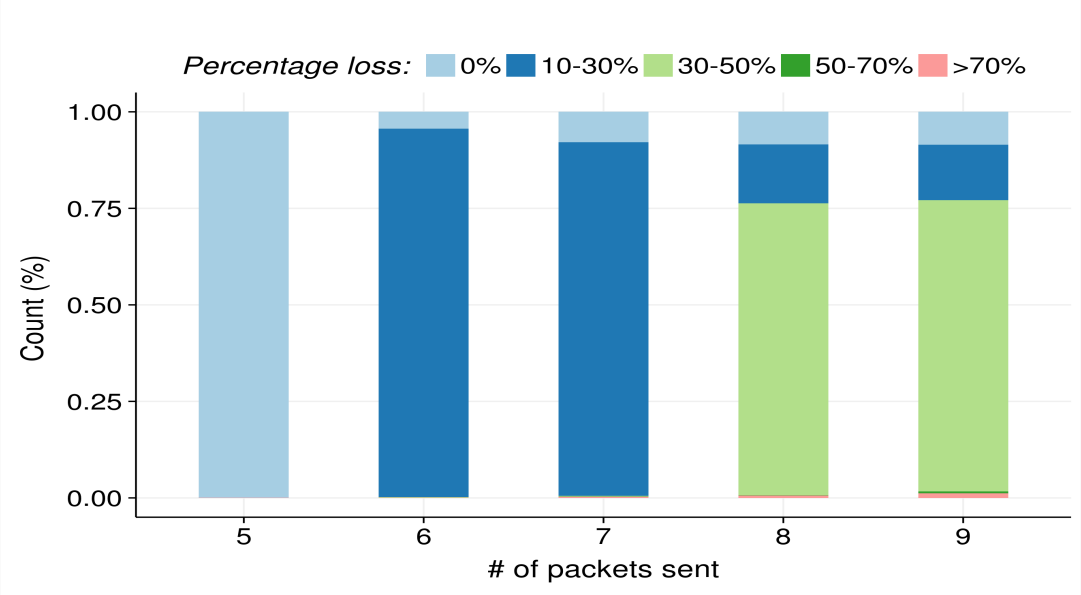
Ping Test — packet loss by radio technology



Distribution of packet loss as the fraction total ping by radio technology type.

- Of all ping tests over LTE , 2.4% of them lost at least a single packet.
- ping test over UMTS network experience highest packet loss ($\sim$ 65%).

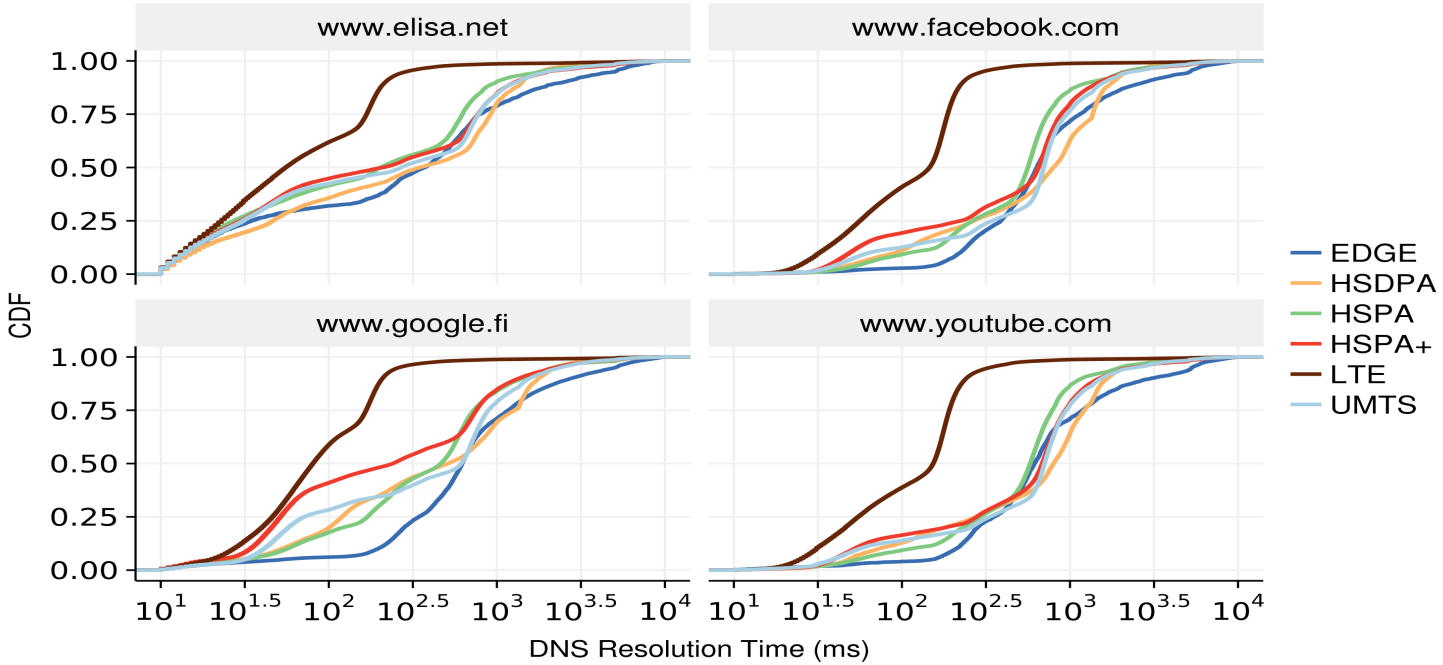
Ping Test — packet loss by # packets sent at every ping test instance



Percentage of packets loss across the number of packets sent.

- ∼14.98% of tests in ping measurement have at least one packet loss.
- Packet loss happens, if the number of packets sent at every `ping` test instance $>$ 5 Echo Requests.

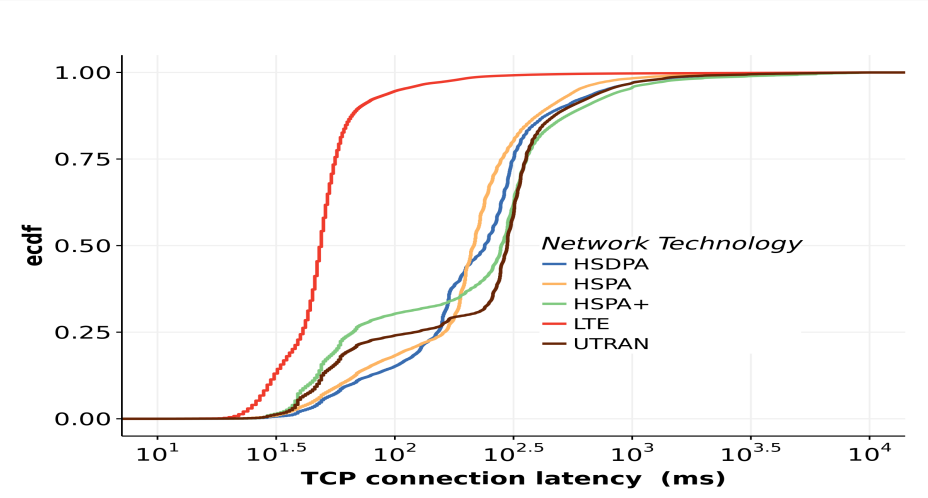
DNS lookup time — by radio technology

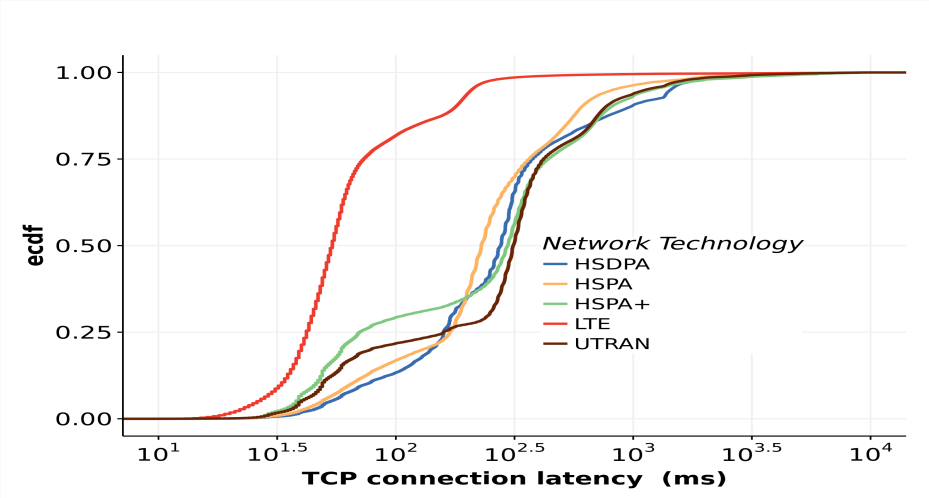


LTE exhibits significantly lower latency.

- 75% www.youtube.com $<$ 200ms [LTE]
- 25% www.youtube.com $<$ 200ms [3G]

TCP connect time — by radio technology





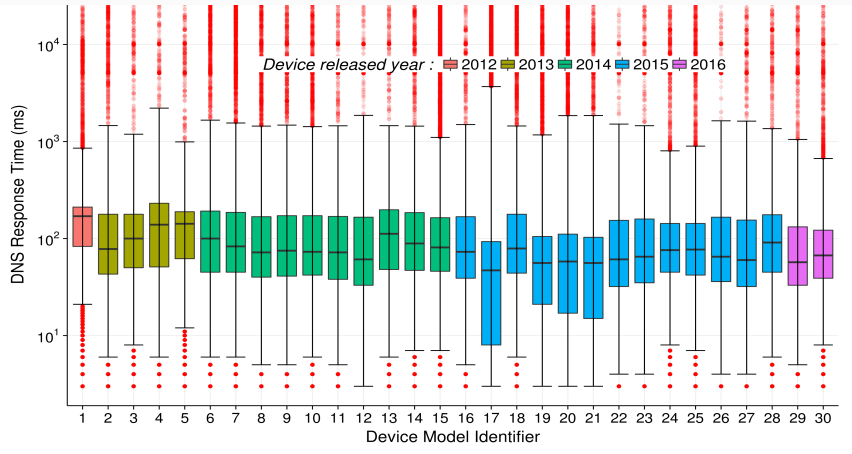
TCP connect time towards `www.youtube.com` (L) & `www.google.fi` (R)

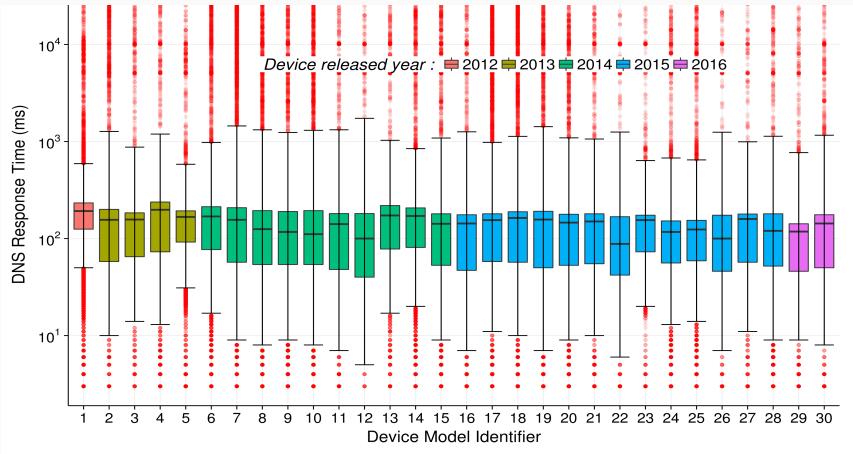
TCP Connect time towards `www.youtube.com`

- 92% of TCP test using LTE finished $<$ 100ms
- only 28% of 3G based TCP test finished $<$ 100ms

The distribution exhibits similar pattern for `www.elisa.net` & `www.facebook.com`.

DNS lookup time — Device models



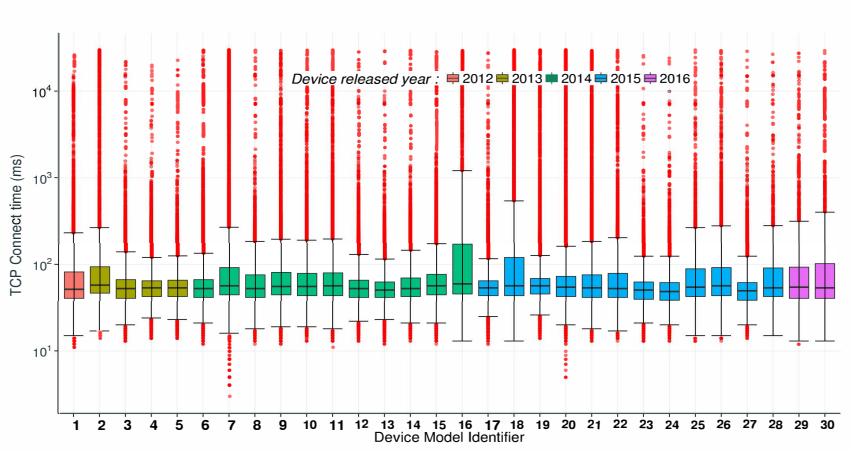


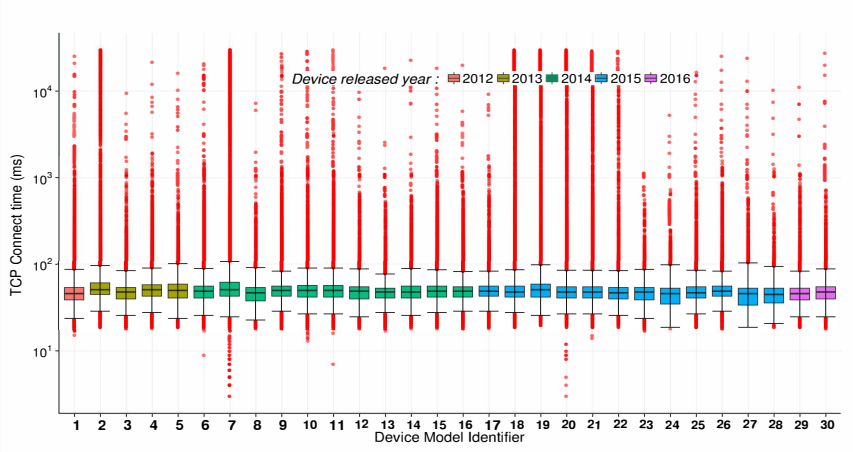
DNS response time of `www.google.fi` (L) and `www.facebook.com` (R) across device models as measured over LTE – order by device models' release year.

No clear pattern between DNS lookup time & device models year of release

- Variation in DNS resolution time among device models is very high
- Google has faster resolution time in most devices than Facebook (median case)

TCP connect time — Device models



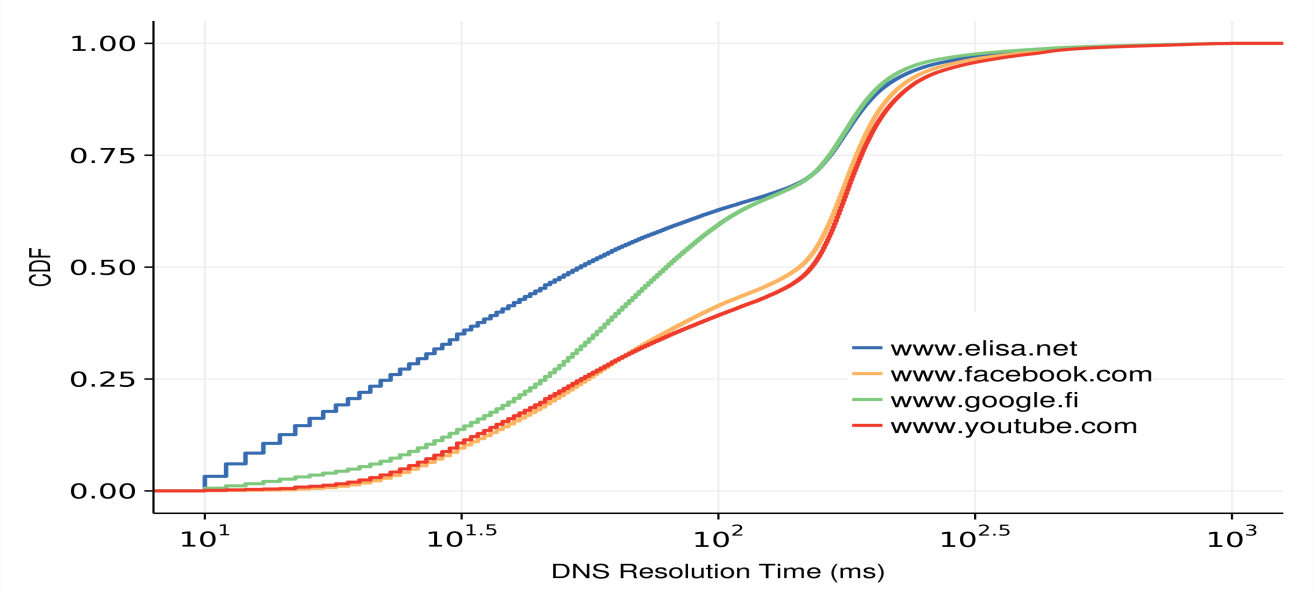


TCP connect time for `www.google.fi` (L) and `www.facebook.com` (R) across device models as measured over LTE – order by device models' release year.

Device type has smaller impact to TCP connect time

- Both Google and Facebook have similar TCP Connect time for most of device models

DNS lookup time — Websites

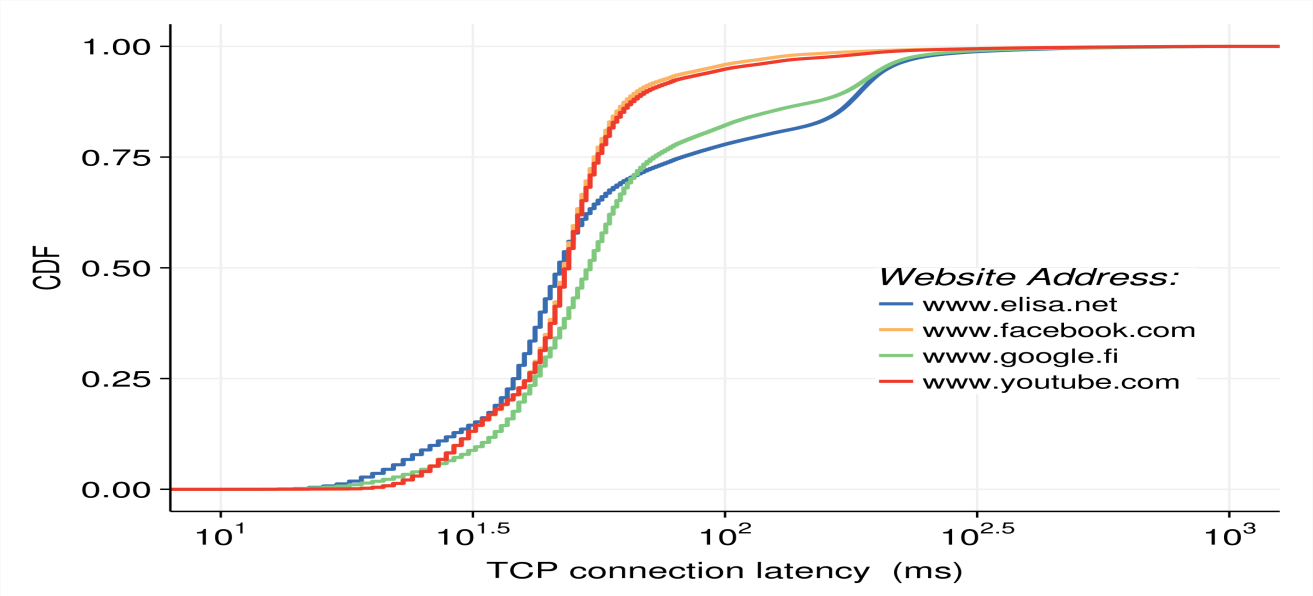


DNS response time towards websites using LTE – towards different DNS resolvers.

DNS server's proximity to the subscriber has an impact on DNS lookup time.

- `www.youtube.com` and `www.facebook.com` are slower than `www.google.fi` (likely cached by DNS resolvers) & `www.elisa.net` (ISP's website).

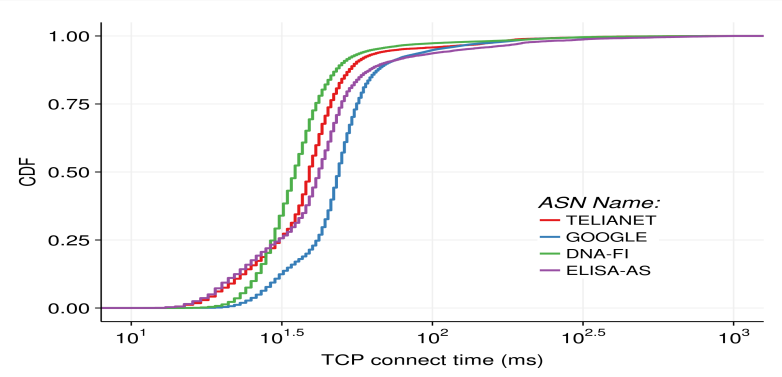
TCP connect time — Websites

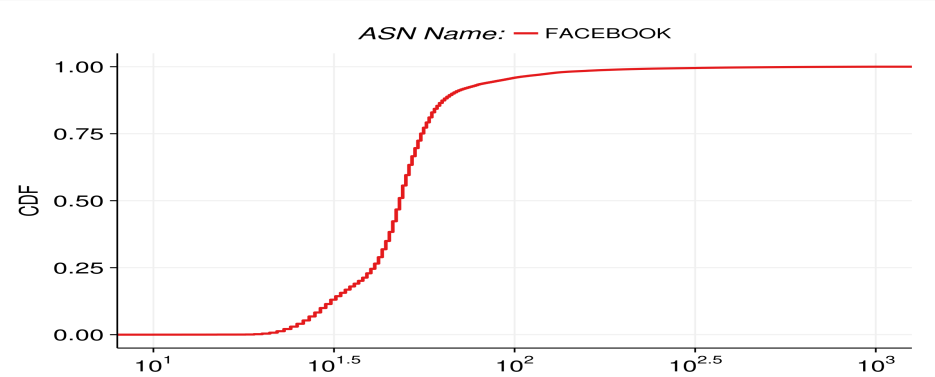


TCP connect time towards websites under LTE.

- $\sim$ 90% of the time, `www.facebook.com` and `www.youtube.com` can be reached in less than 100 ms from a client's device.
- for `www.google.fi` and `www.elisa.net`, only 80% and 76% of the TCP connection test are below 100 ms, respectively.

TCP Connect time — by destination ASN from LTE networks





- Requests towards `www.youtube.com` served by the ISPs cache are faster than those served by Google CDN.
- `www.facebook.com` does not hit any caches in the ISP network —
  - slower TCP connect time than `www.youtube.com` and `www.google.fi`

Caching can improves the fetch time of small files

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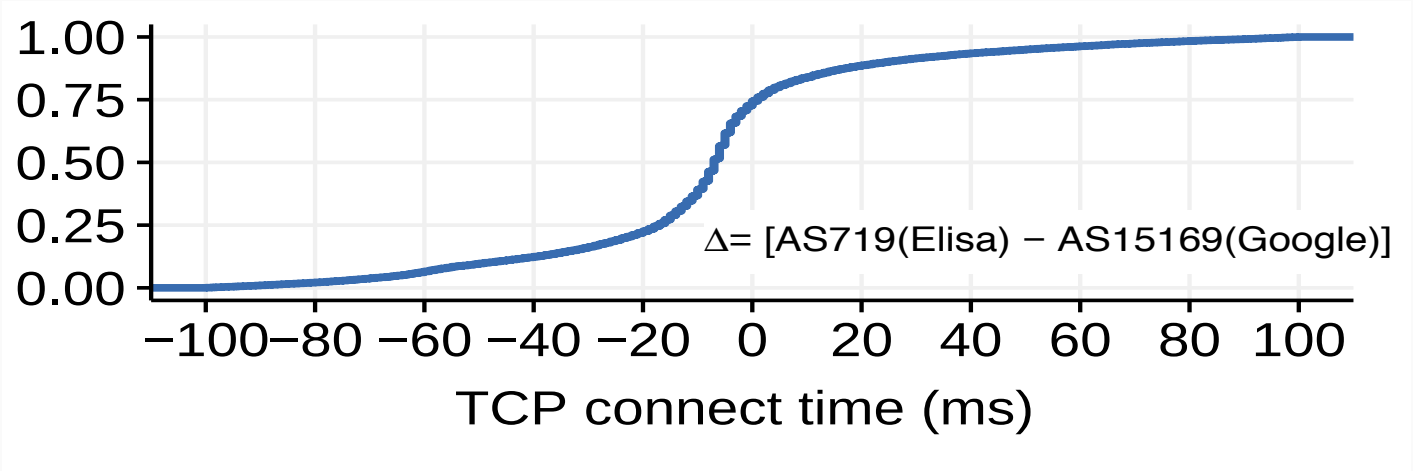

TCP connect time towards `www.google.fi` showing the latency difference between ISP cache - Elisa (AS719) and CDN - Google (AS15169) using LTE.

Values on the negative scale indicate that ISP cache is faster

- $\sim$ 70% of TCP connect time towards `www.google.fi` achieve lower latency when they hit ISP cache.

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   - e.g., if # of packets to be sent per `ping`test instance < 5.
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