Passive and Active
Measurement Conference 2023

Measuring the Performance of iCloud Private Relay

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ENS DE LYON

Context

Context: a more private web

At the beginning of the Internet everything was **in clear**

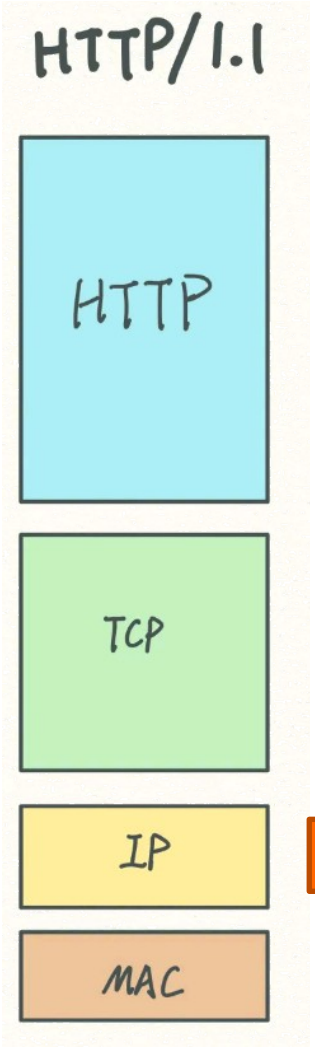
In clear traffic has **problems**

- For Security: Passwords, Credit Cards Numbers, etc.
- For Privacy: An Eavesdropper can observe your traffic, your websites, your interests

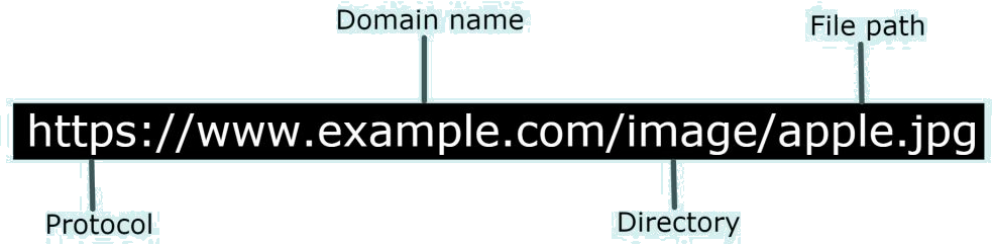
Since 2010, we observe a trend towards **encryption**

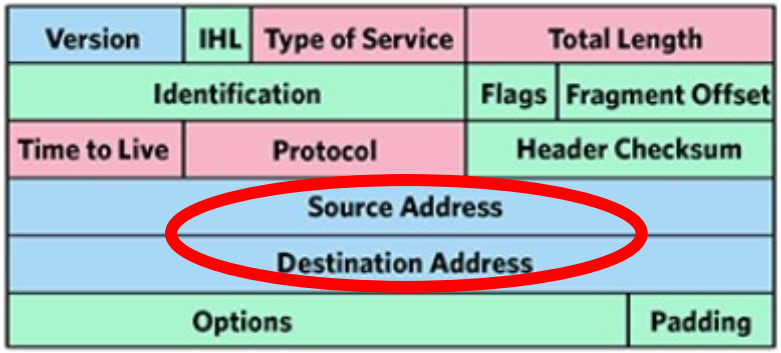
- More and more protocol fields get encrypted

Context: a more private web



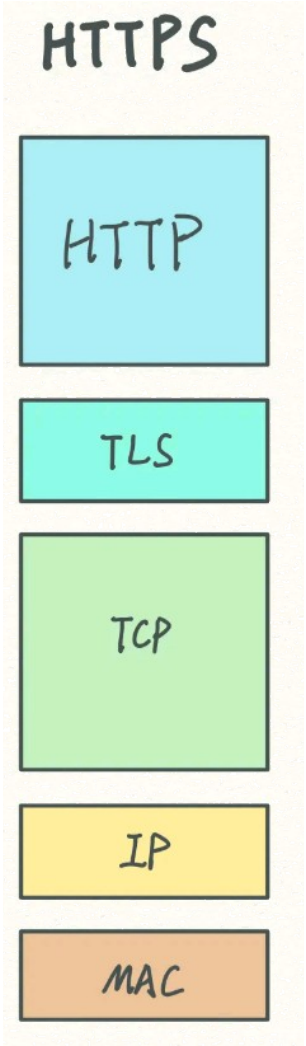
In clear URL





In clear Client and Server IP addresses

Context: a more private web



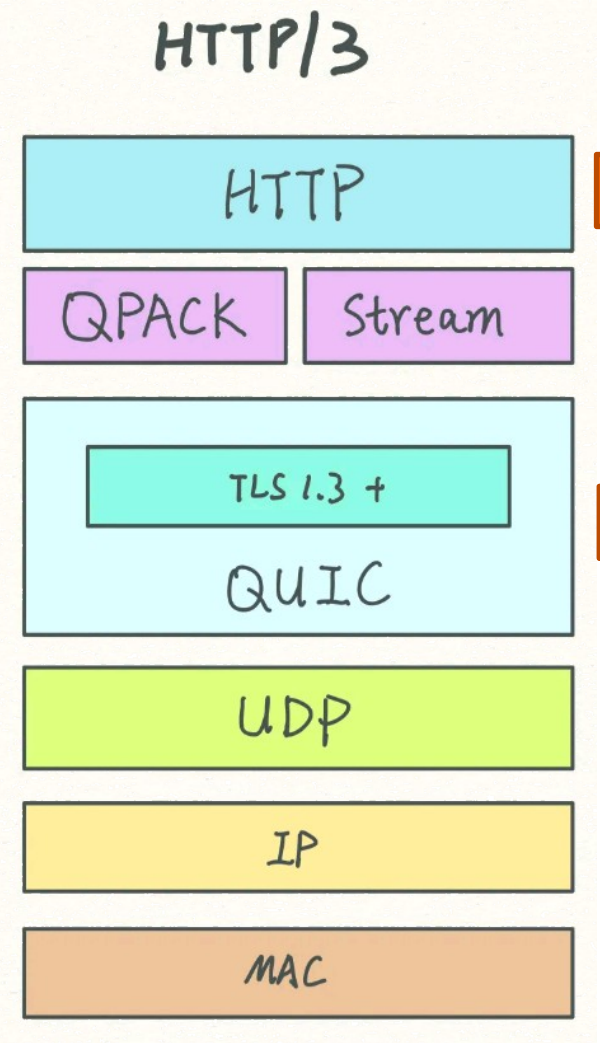
Encrypted

In clear Domain Name

```
Extension: server_name
    Type: server_name (0x0000)
    Length: 31
  Server Name Indication extension
      Server Name list length: 29
      Server Name Type: host_name (0)
      Server Name length: 26
      Server Name: tiles.services.mozilla.com
```

In clear Client and Server IP addresses

Context: a more private web



Encrypted

Encrypted Domain Name

`draft-ietf-tls-esni`

Workgroup: tls
Internet-Draft: draft-ietf-tls-esni-15
Published: 3 October 2022
Intended Status: Standards Track
Expires: 6 April 2023

E. Rescorla
RTFM, Inc.
K. Oku
Fastly
N. Sullivan
Cloudflare
C. A. Wood
Cloudflare

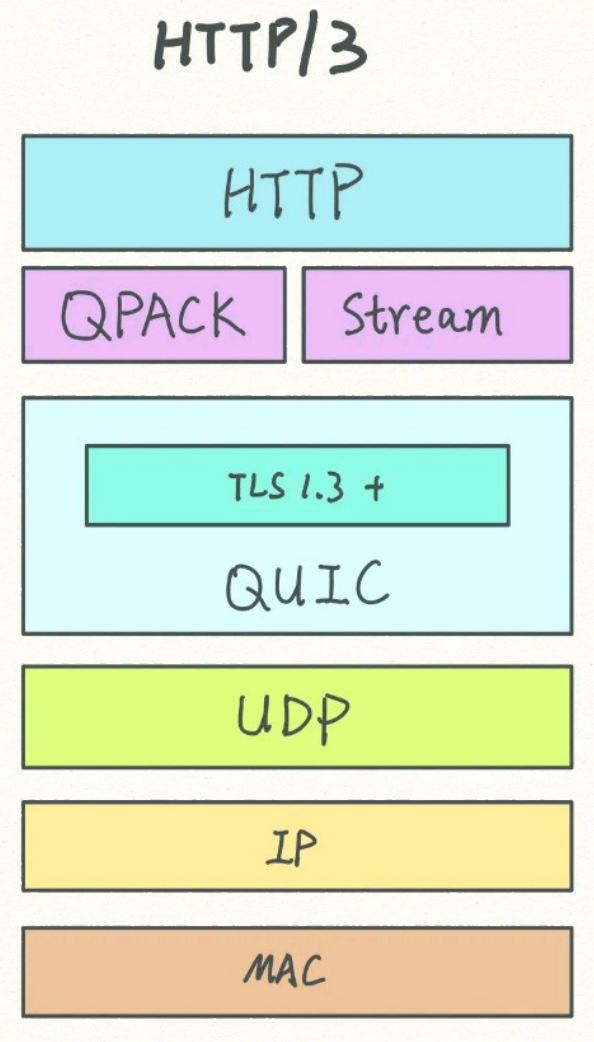
TLS Encrypted Client Hello

Abstract

This document describes a mechanism in Transport Layer Security (TLS) for encrypting a ClientHello message under a server public key.

In clear Client and Server IP addresses

Context: a more private web



The ISP knows visited servers

- And possibly the website

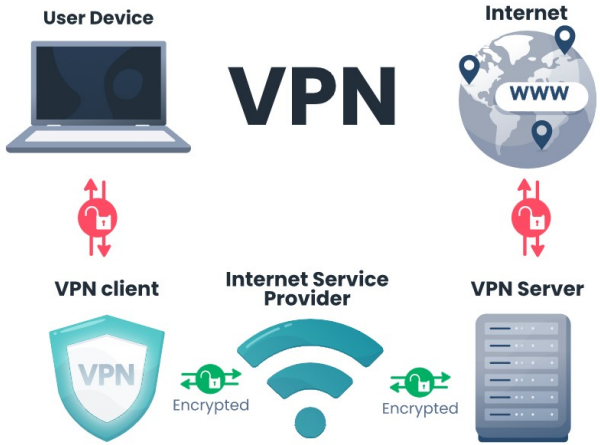
The website knows audience's IP

- Can track them

In clear Client and Server IP addresses

Solution: anonymity services!

- **Virtual Private Networks**



Network Working Group
Request for Comments: 1825
Category: Standards Track

R. Atkinson
Naval Research Laboratory
August 1995

Security Architecture for the Internet Protocol

- **Developed in the mid-1990s by United States Naval Research Laboratory**

IP addresses are encrypted!

iCloud Private Relay

Solution: The Apple Way

iCloud Private Relay

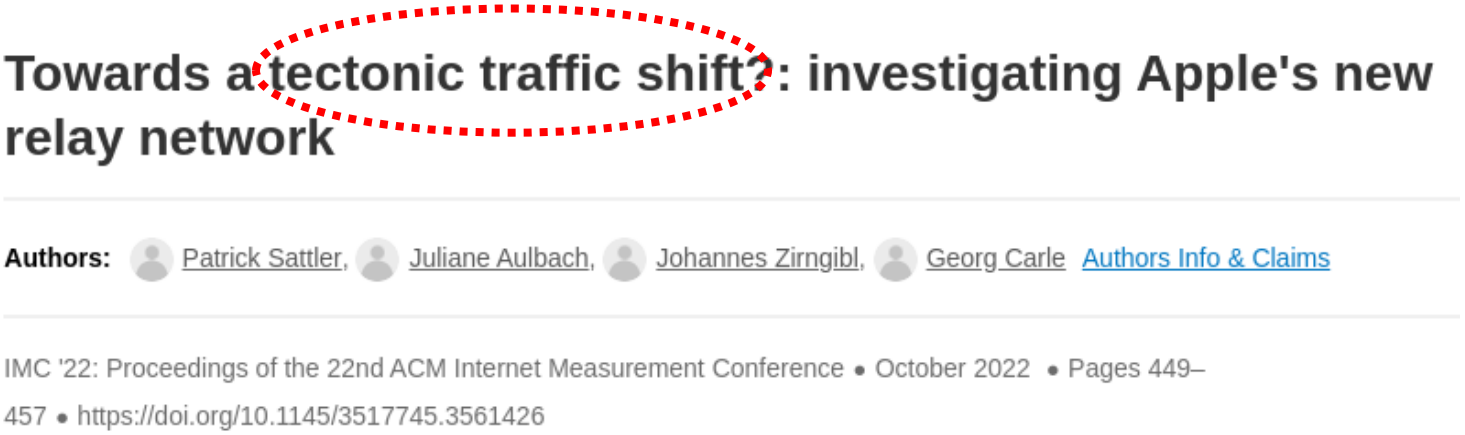
- Launched in 2021
- Included in iCloud+ plan
- VPN-like service
- Integrated in MacOS and iOS
- Easy to use

iCloud

Private Relay: Interesting to study

Can become widely deployed!

- Low entry barriers
- E.g., 25% of smartphones are iPhone!
- ➢ **Implications on the global traffic mixture!**



Towards a tectonic traffic shift?: investigating Apple's new relay network

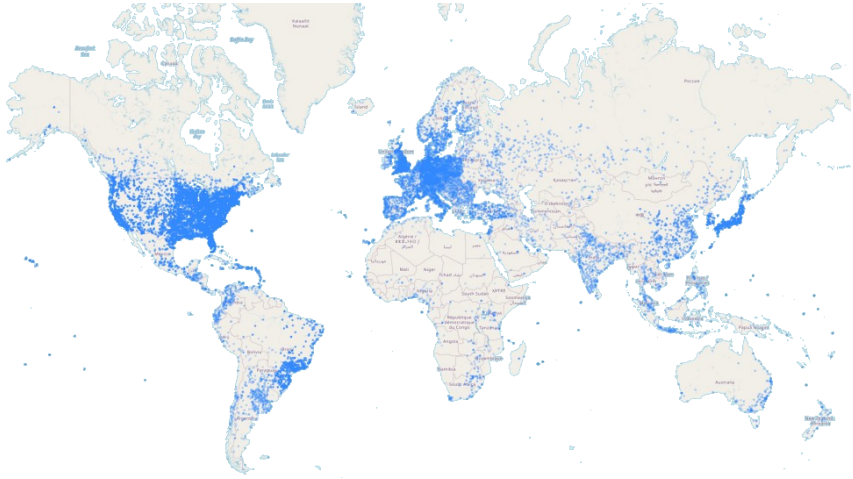
Authors: Patrick Sattler, Juliane Aulbach, Johannes Zirngibl, Georg Carle Authors Info & Claims

IMC '22: Proceedings of the 22nd ACM Internet Measurement Conference • October 2022 • Pages 449–457 • https://doi.org/10.1145/3517745.3561426

Private Relay: Interesting to study

Large infrastructure already deployed

- Based on Akamai, Cloudflare and Fastly
- Apple declares 238 k subnets
- ➢ Complications for **GeoBlocking** services



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Private Relay: Interesting to study

Novel Technical Operation

Two-Hop architecture

- Traffic passes through **two proxies** before reaching the server

Based on QUIC

- Implementes novel features of **QUIC**

Private Relay: Two-Hop Architecture

Multi-Party Relay architecture

Decouples:

- Users' network identity: Client IP
- Internet usage: Server IP

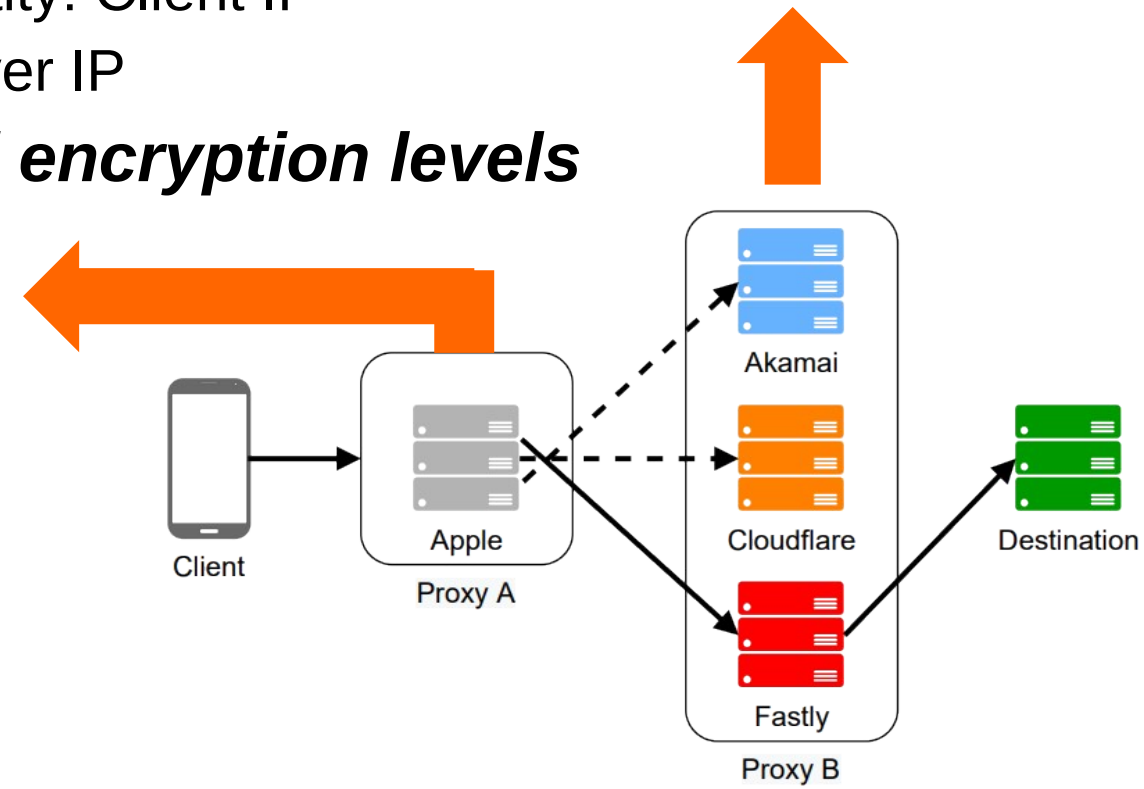
Based on ***2 nested encryption levels***

Does not know *Client* IP

Knows *Server* IP

Knows *Client* IP

Does not know *Server* IP



Private Relay: Based on QUIC

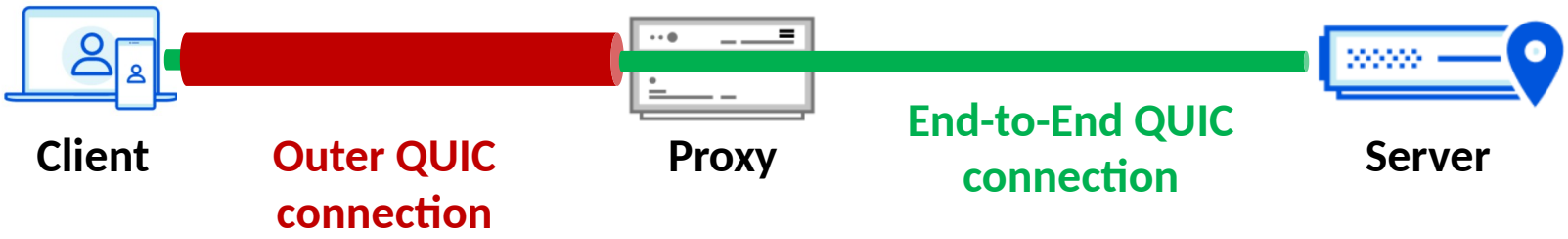
The two nested encryption levels are **QUIC** connections

- With **modifications** to avoid **pitfalls**
  - First commercial use of **two recent RFCs**

- **Issue 1:** two nested instances of **reliable** protocols
- **Issue 2:** must create a **CONNECT** equivalent for QUIC
  - Solution: **RFC9220**: Extended Connect for QUIC

Private Relay: Based on QUIC

- **Issue 1:** two nested instances of reliable protocols:
  - Known to be a bad idea: Long delays and frequent connection aborts are to be expected
  - **Outer QUIC connection**: Client <-> Proxy
  - **End-to-End QUIC connection**: Client <-> Server
- **Solution**: use QUIC's unreliable datagram extension (RFC9221) also called **MASQUE**
  - Disable retransmissions **in Outer QUIC connection** : Client <-> Proxy
    - Useless as provided in **End-to-End QUIC connection**



Goal and Methods

Goal of the paper: Performance

Research Question: is there a performance penalty when using iCloud Private Relay?

- Slower Throughput?
- Downloading files takes more time?
- Web pages load more slowly?

Experimental Setup

Three MacOS PCs

Trieste (IT)

Lyon (FR)

Honolulu (US)

- Connected via **Ethernet** to the Internet
- Payed **Subscription** to iCloud Private Relay

Experimental Setup

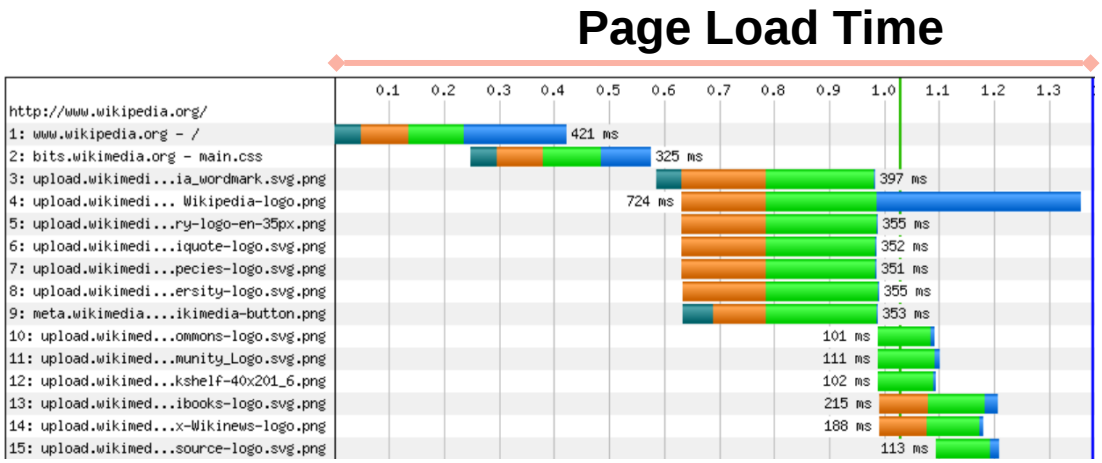
Three set of experiments

1. **Throughput Measurements**: via Ookla Speed Test
   - **KPI**: Download/Upload Throughput

2. **Bulk Download**: of a 1 GB test file on Hetzner CDN
   - **KPI**: Download Speed

Experimental Setup

3. **Web Browsing**: visit top-100 websites per country
   - Using **Safari**
   - **Automated** with BrowserTime testing tools
   - **KPI**: Page Load Time:
     - Time between first and last HTTP request



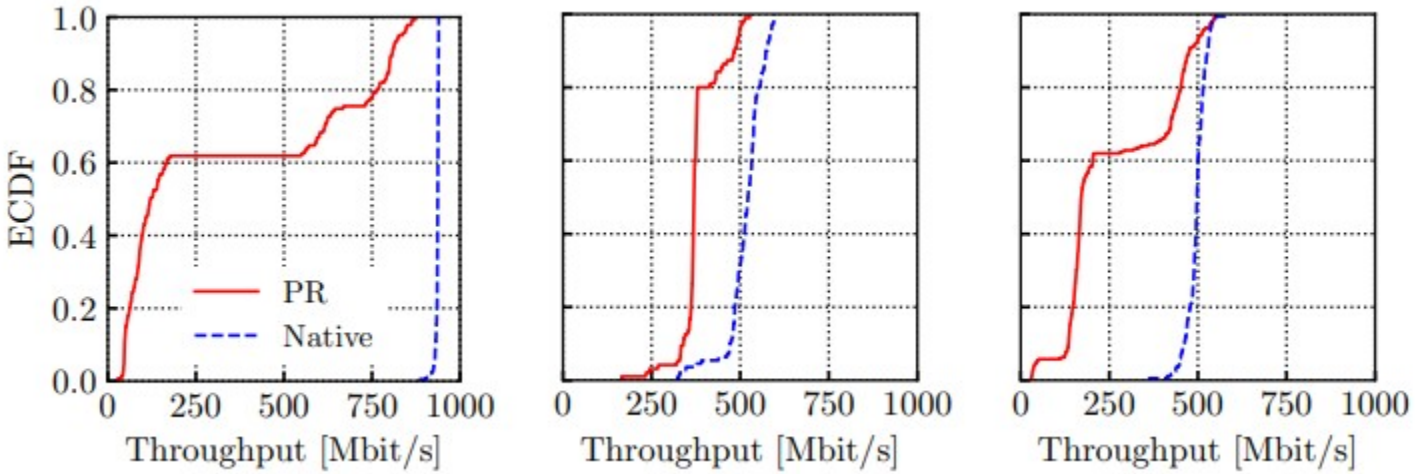
   - Correlated with Users's Quality of Experience

Experimental Results

Results: Throughput

Download:

- PR is not as fast as native network!

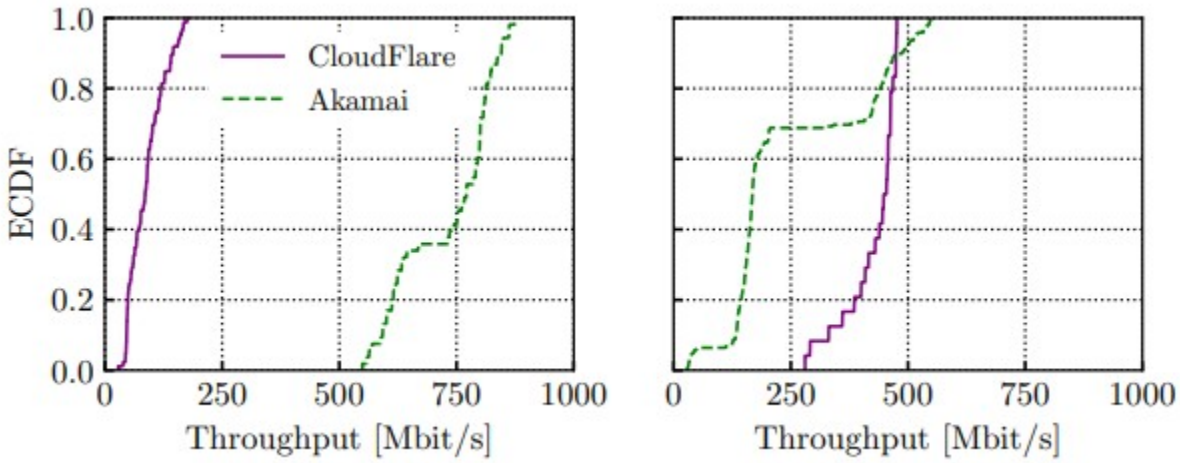


France **Italy** **US**

Results: Throughput

Download:

- Performance varies depending on the Proxy owner!

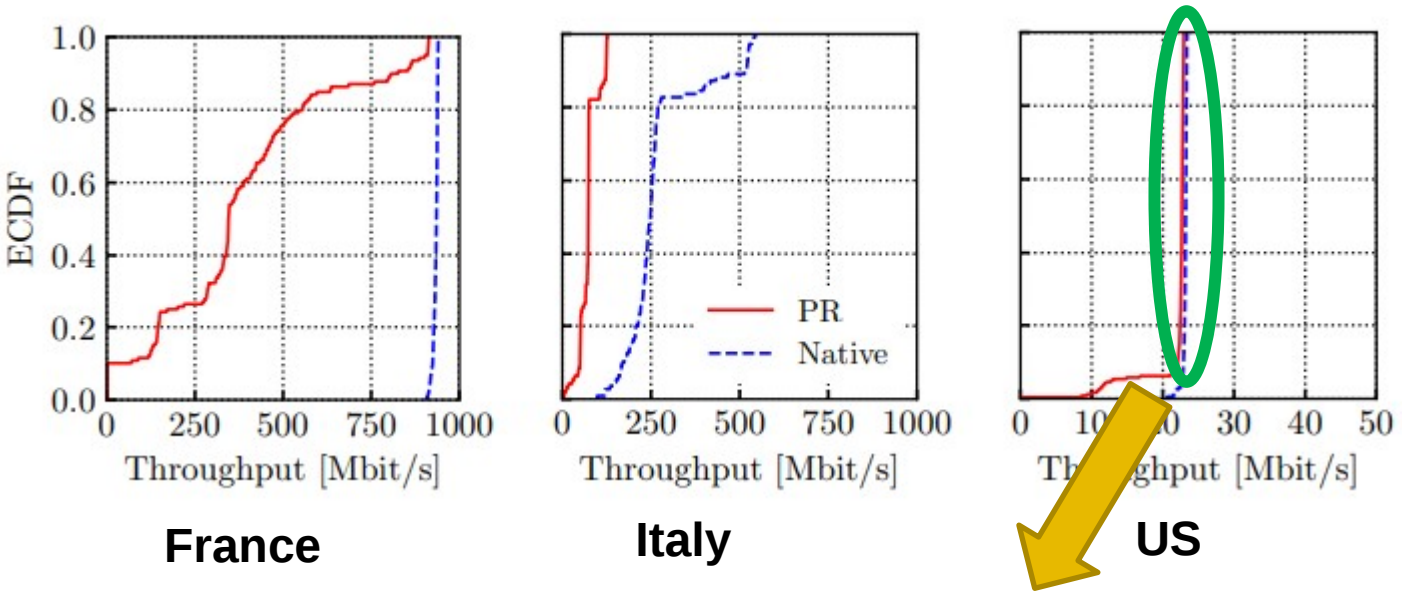


France **US**

Results: Throughput

Upload:

- Again PR is not as fast as native network!

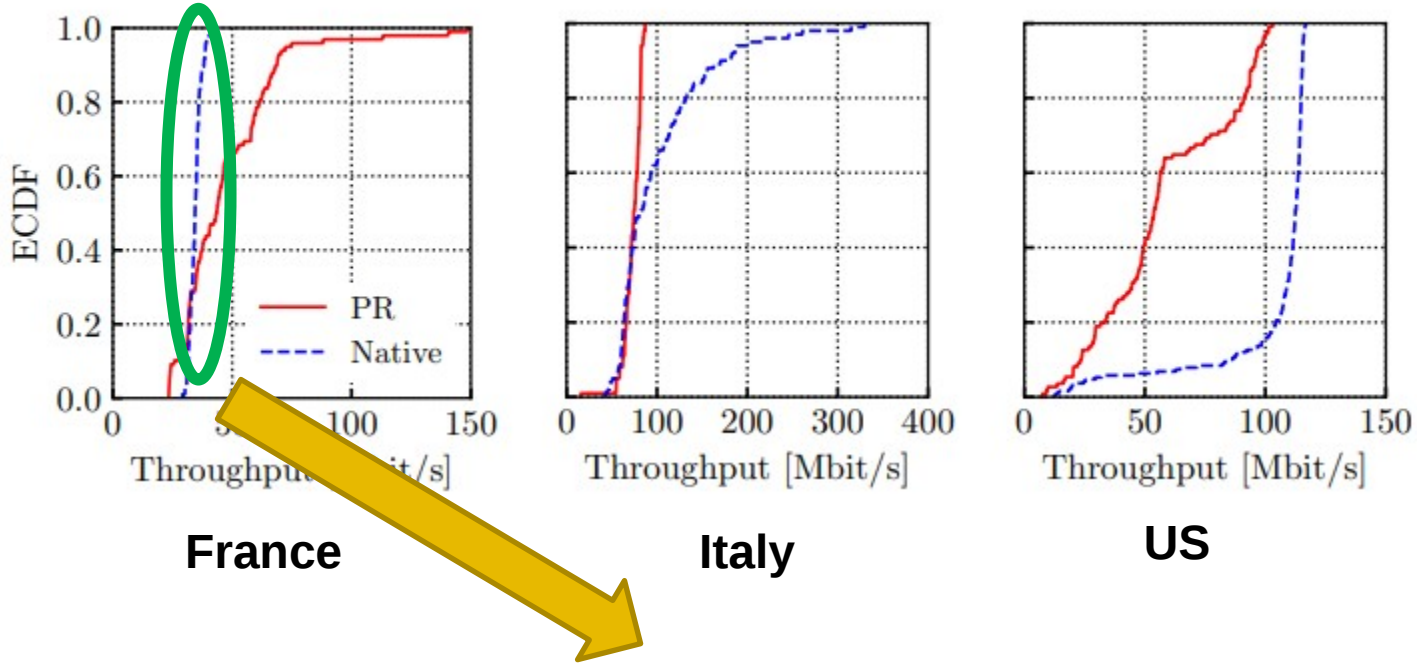


France **Italy** **US**

Slow Uplink is the bottleneck!

Results: Bulk Download

No clear winner

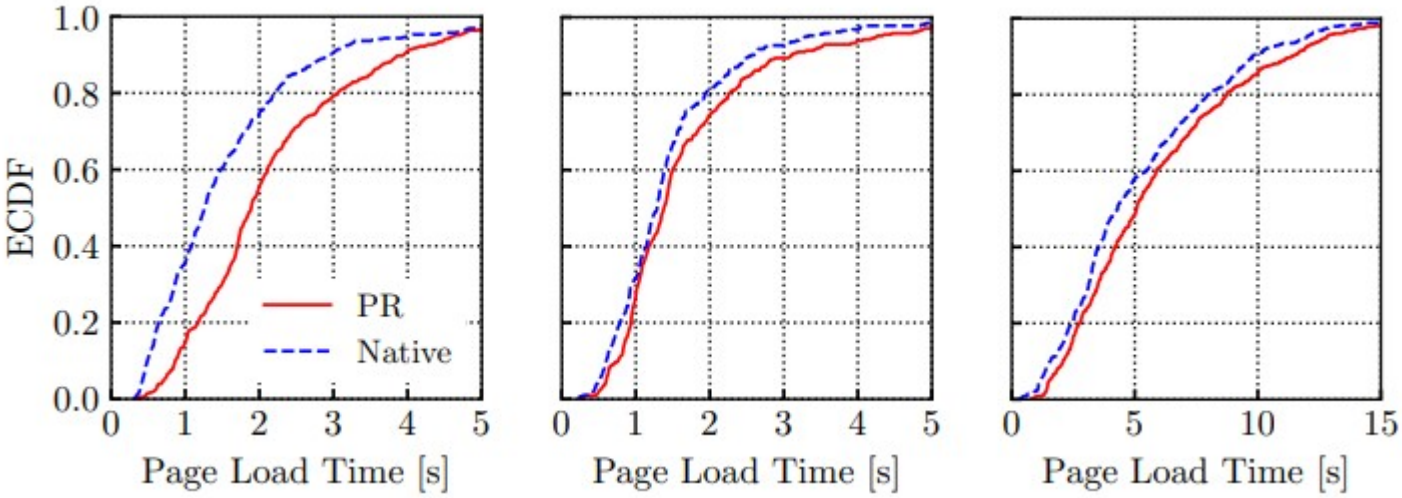


France **Italy** **US**

Cannot find root cause!

Results: Web Browsing

Page Load Time **larger** by 7-60%



France **Italy** **US**

Final Remarks

iCloud Private Relay moderately impairs performance

- First commercial use of new features
  - QUIC Datagrams / MASQUE

Other aspects left to study

- Implications on Localizations / Geo Blocking
- Cost
  - In terms of computing resources
  - Energy (for additional encryption)

Thank you for your attention