

Measuring Web QoE in Cellular Networks

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PAM 2019

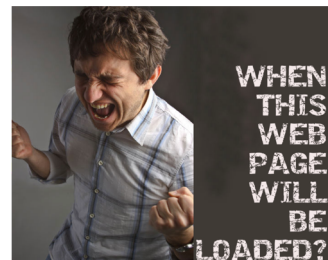
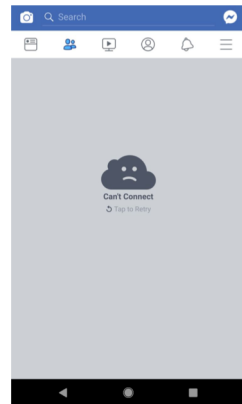
March 28, 2019
Puerto Varas, Chile



5.7b MBB subscriptions in 2018.

[Ericsson mobility report]

Since 2016, users prefer to browse on smart phone than PC. [Jun et. Al., MobiCom'19]



- ISPs and content providers work to give a good browsing experience for mobile users.
- New technologies, new protocols, etc

The effect of bad QoE is beyond personal satisfaction.



100ms latency
cost 1% in sales



0.5sec delay
dropped 20% traffic

How do we measure the user browsing experience in operational cellular networks, at scale?

– SpeedChecker

- Measures the traditional QoE metrics like PLT, TTFB

– Meteor

- Estimate the user QoE for a given app, based on a given network condition
- The methodology is not open

WebLAR

Agenda

- ✓ Web QoE Metrics
- ✓ WebLAR
- ✓ Results & findings
- ✓ Conclusion

Web QoE Metrics

– Mean Opinion Score

- Averaging the subjective user rating

– Time instant metrics

- Time To First Byte
- DOM time
- Time to First Paint
- onLoad time (PLT)
- Above the fold (ATF) time



Traditional / Commonly used metrics

– Time integral metrics

- Speed Index
- Object Index
- Byte Index

WebLAR

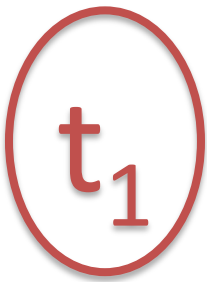
Enables us to measure both web QoS and QoE (time instant) metrics.

- Written in Java and JavaScript
- Utilizes the Chrome resource timing API
- Browses a website; records timing information of the website; record video of the browsing progress; and metadata information about the network
- Extract the traditional QoE metrics from the recorded timing information
- Uses two approaches to approximate the ATF time.
- Runs browsers in a virtualized screen (xvfb)

Two approaches to measure ATF time

1. Pixel-wise comparison approach (ATF_p time)

- Comparing the pixel changes of the ATF area in the browsing session at every 100ms for 30 seconds
- Different threshold for webpage stabilizing (3s, 10s, 14s)
- The ATF time is the time where we see the last pixel change



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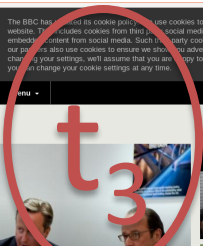
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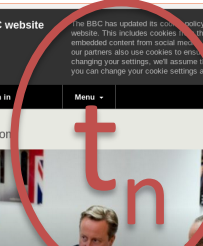
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Two approaches to measure ATF time

2. Browser heuristic approach (ATF_b time)

- Uses the browser timing information API
- Identify the location of images in the page
- ATF_b time = $\max\{T_o | o \in \mathcal{H} \cup J \cup C \cup I_{ATF}\}$, where:

\mathcal{T} : download time

J : JavaScript

C : Cascaded Style sheets

I_{ATF} : Images under the ATF area

The ATF time is 5.37s

The screenshot shows the Amazon homepage with several elements highlighted by red and blue boxes. The Amazon logo and Prime tagline are in a red box. The search bar is in a red box. The 'Off-to-College Deals' banner is in a red box. The 'Cart' icon is in a red box. The main banner for the 'NEW STANDARD' tablet is in a blue box, with the price '\$49.99' and the ATF time '5.37s' also in a blue box. Below the banner, the 'Movies Included with Prime Membership' section is highlighted with a blue box, showing a row of movie posters with their respective ATF times: 2.49s, 2.77s, 3.19s, 3.11s, 3.17s, 3.11s, and 3.6s.

Image objects: 154
Images ATF: 8

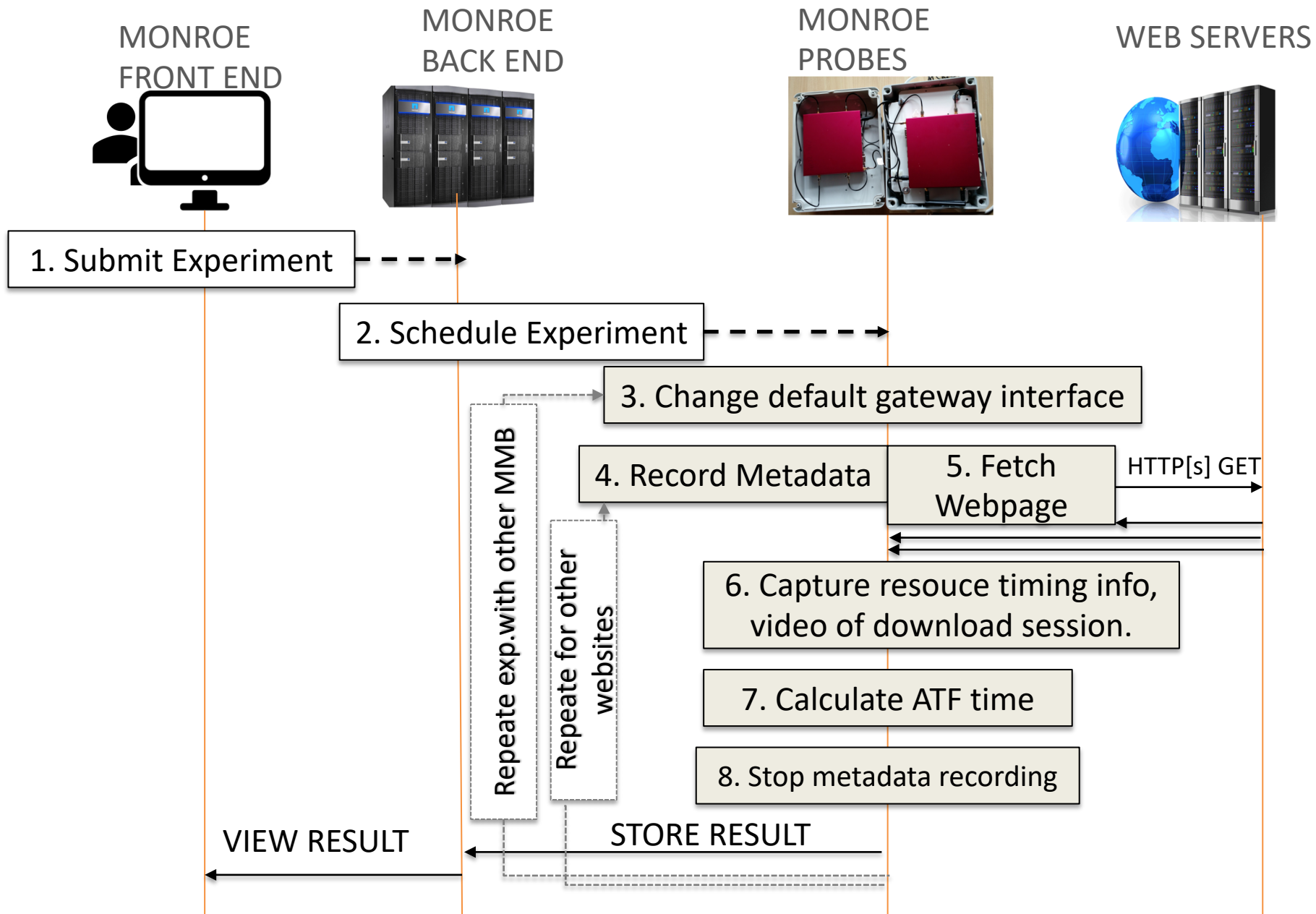
DOM: 2.62s
II^{ATF}: 1.91s
II^{PLT}: 1.99s
OI^{ATF}: 3.83s
BI^{ATF}: 3.85s
OI^{PLT}: 4.31s
BI^{PLT}: 4.49s
ATF: 5.37s
onload: 16.11s

Credit: D. Hora, A. Asrese, et al., Narrowing the gap between QoS metrics and Web QoE using Above-the-fold metrics, PAM 2018



- Experimental platform for mobile measurement
- Measurement probes
 - Located in ES, IT, NO, SE
 - Cellular, WiFi and Ethernet connectivity
 - Stationary (e.g., at volunteers home) or mobile (trains, buses, trucks)
 - Uses docker virtualization technology for running user experiment
- User access and scheduling

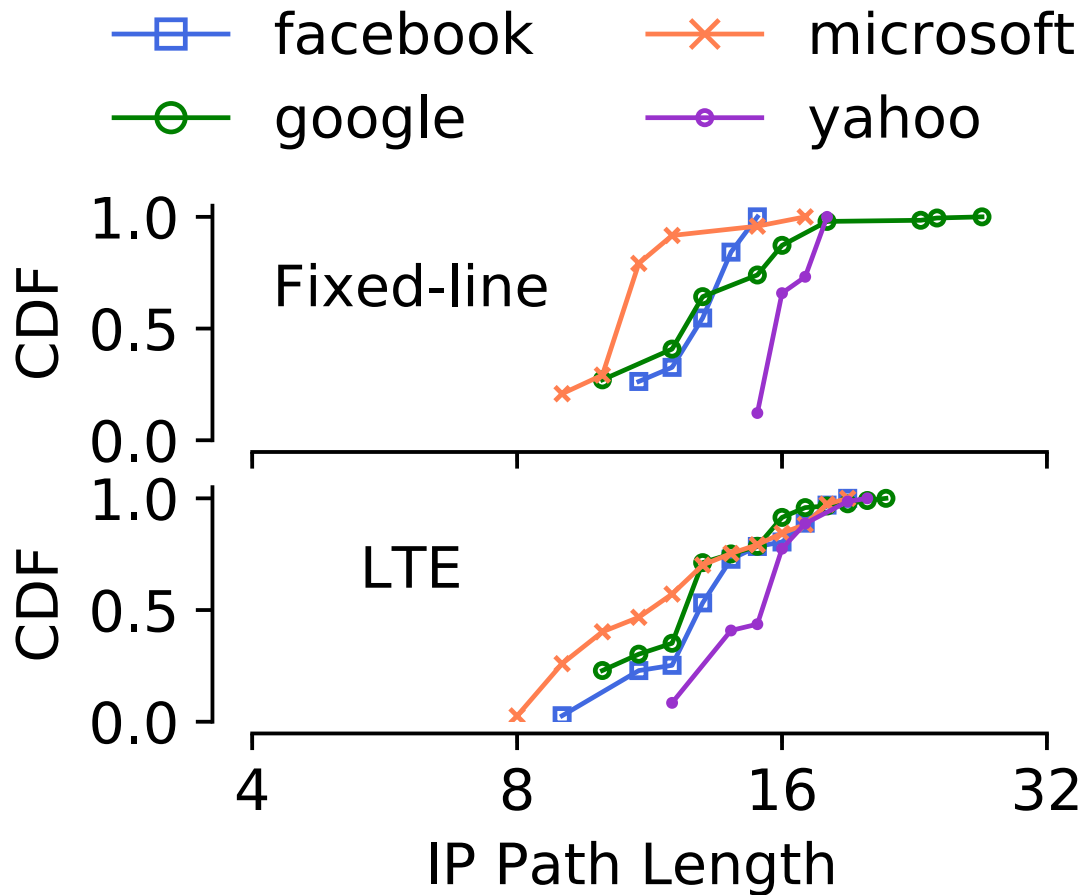
WebLAR Experimental Workflow in MONROE platform



Measurement

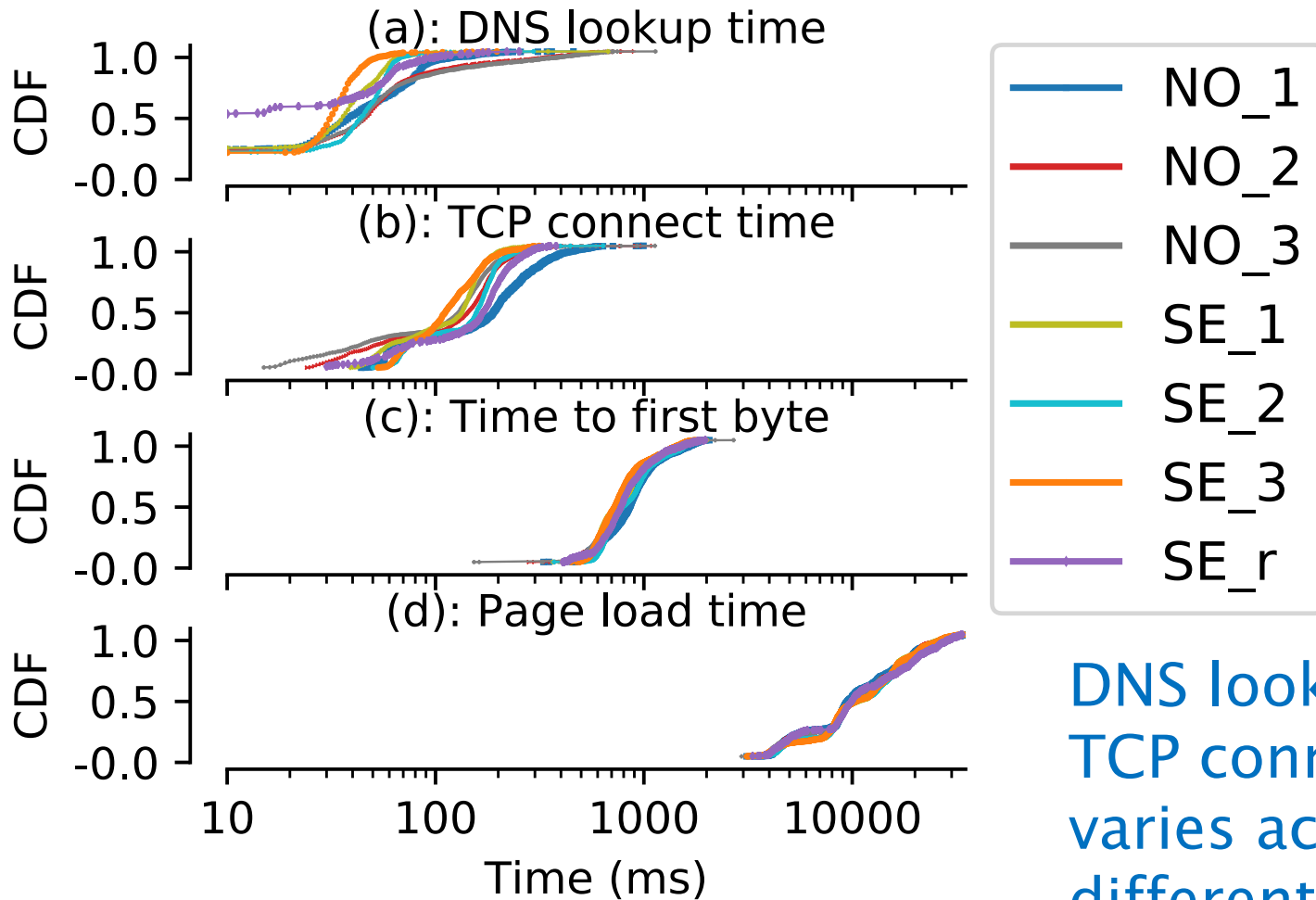
- 2 weeks long measurement (May & Jul'18)
- 8 websites
- 128 MONROE probes with 4G connectivity
- 6 operators in NO and SE
- 9 probes with roaming SIM card
- ~ 18K data points in total

IP path lengths towards the websites in fixed-line and LTE networks



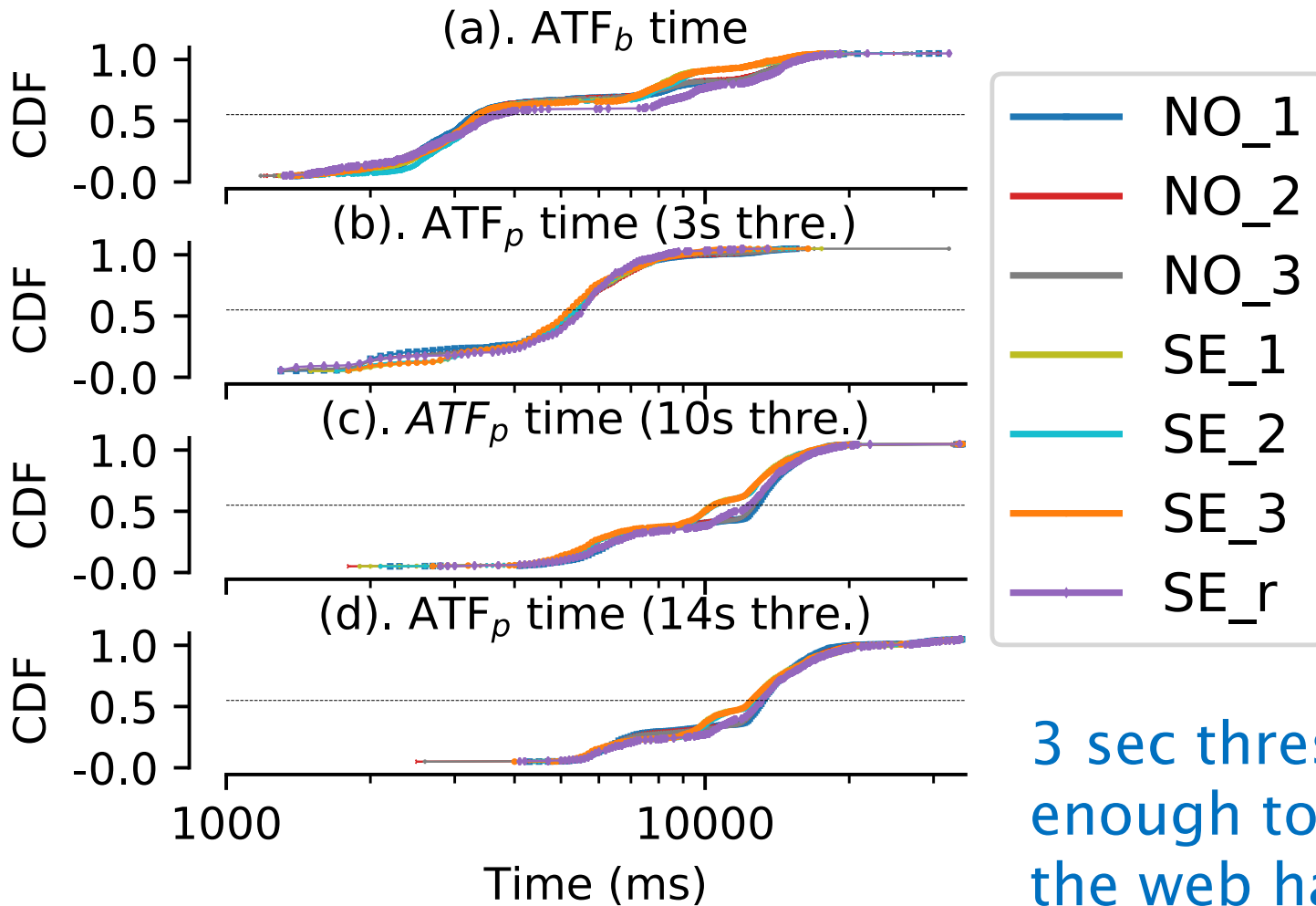
In the median case the IP path length is similar

Web Latency across operators



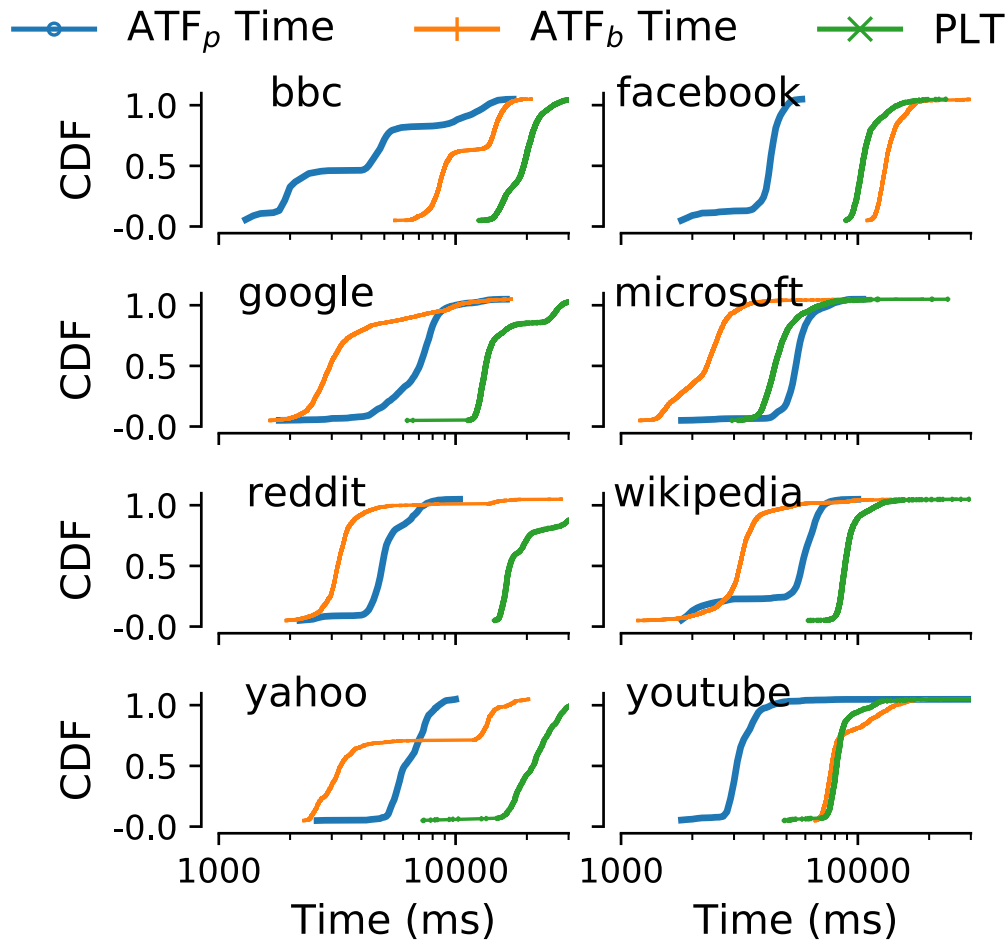
DNS lookup time & TCP connect time varies across different MNOs

The difference in QoE across operators in small.



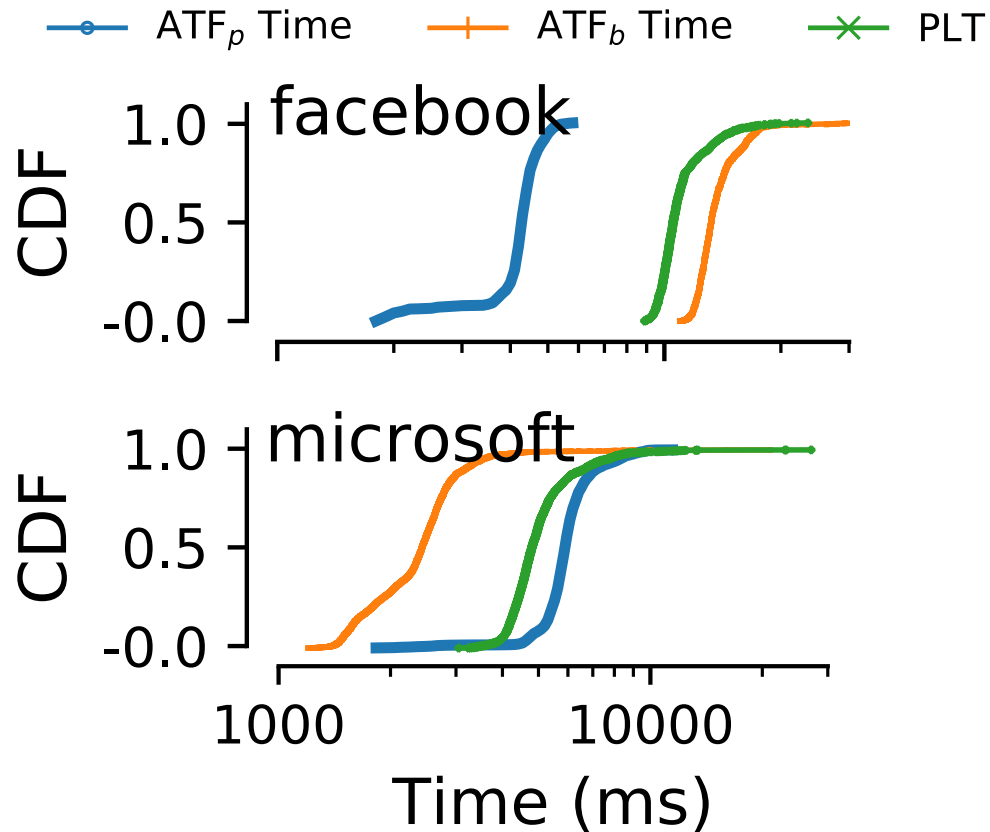
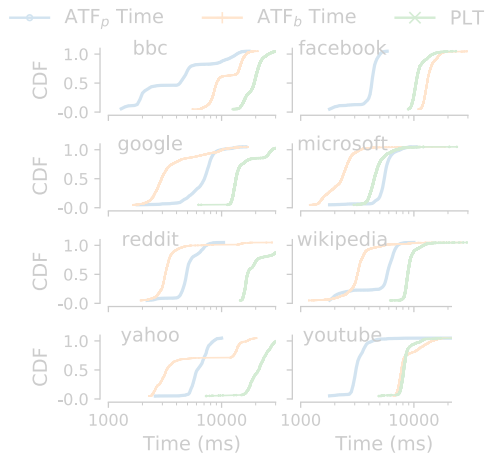
3 sec threshold is enough to declare the web has stabilized.

Website design and type need to be taken into consideration when applying the approaches to approximate ATF time.

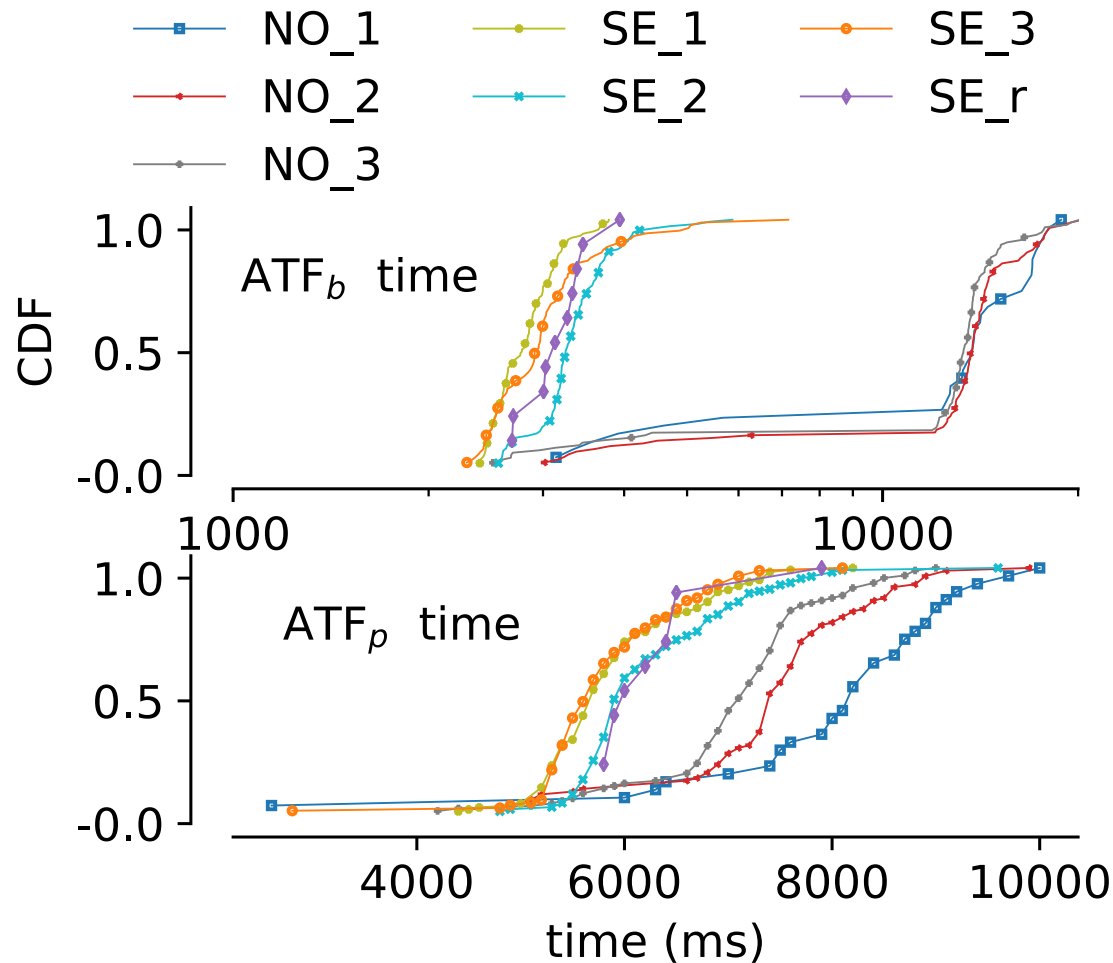


E.g., Facebook
vs
microsoft

Website design and type need to be taken into consideration when applying the approaches to approximate ATF time.



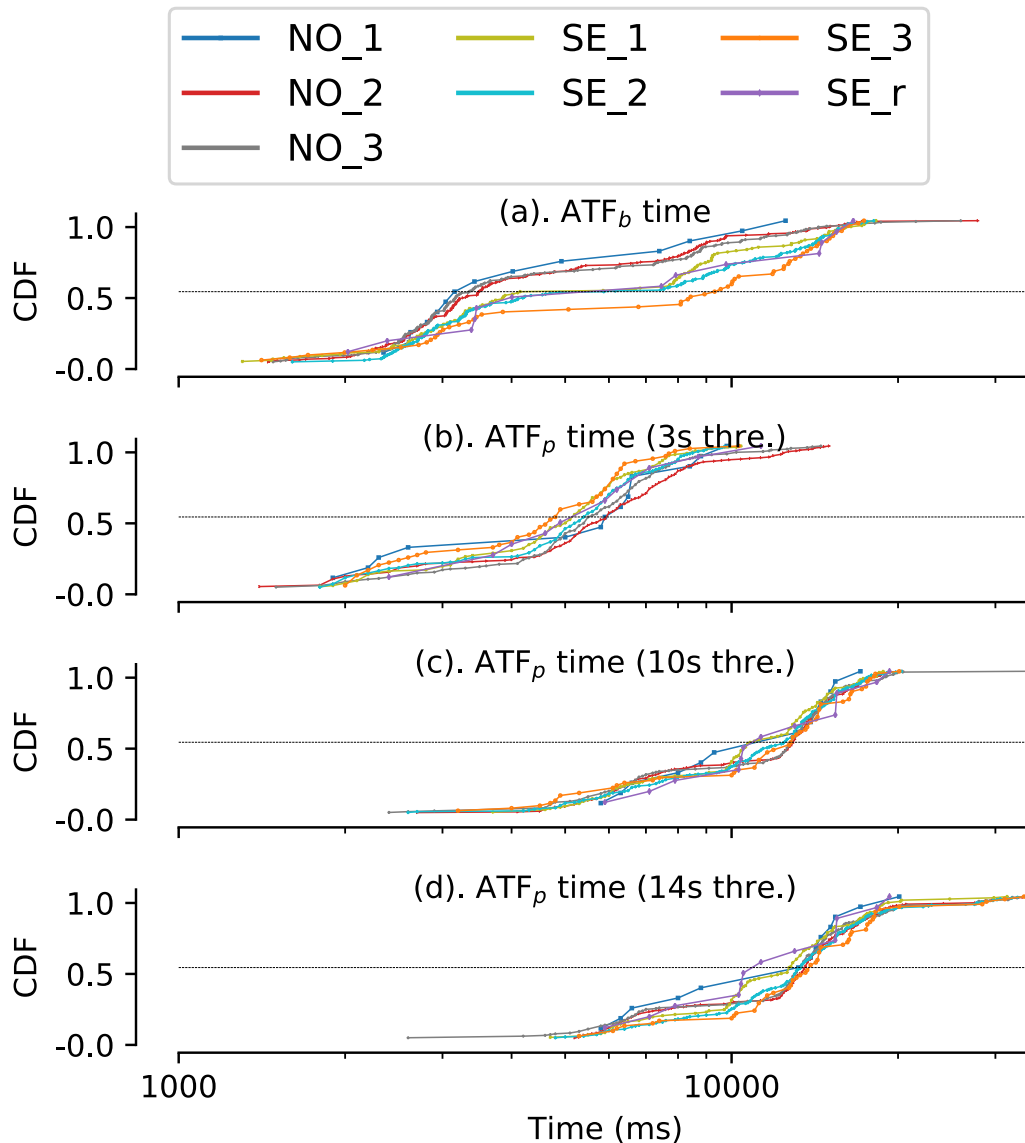
A Website may have different QoE on MNOs in a different country.



Yahoo has worst performance on Norwegian operators.

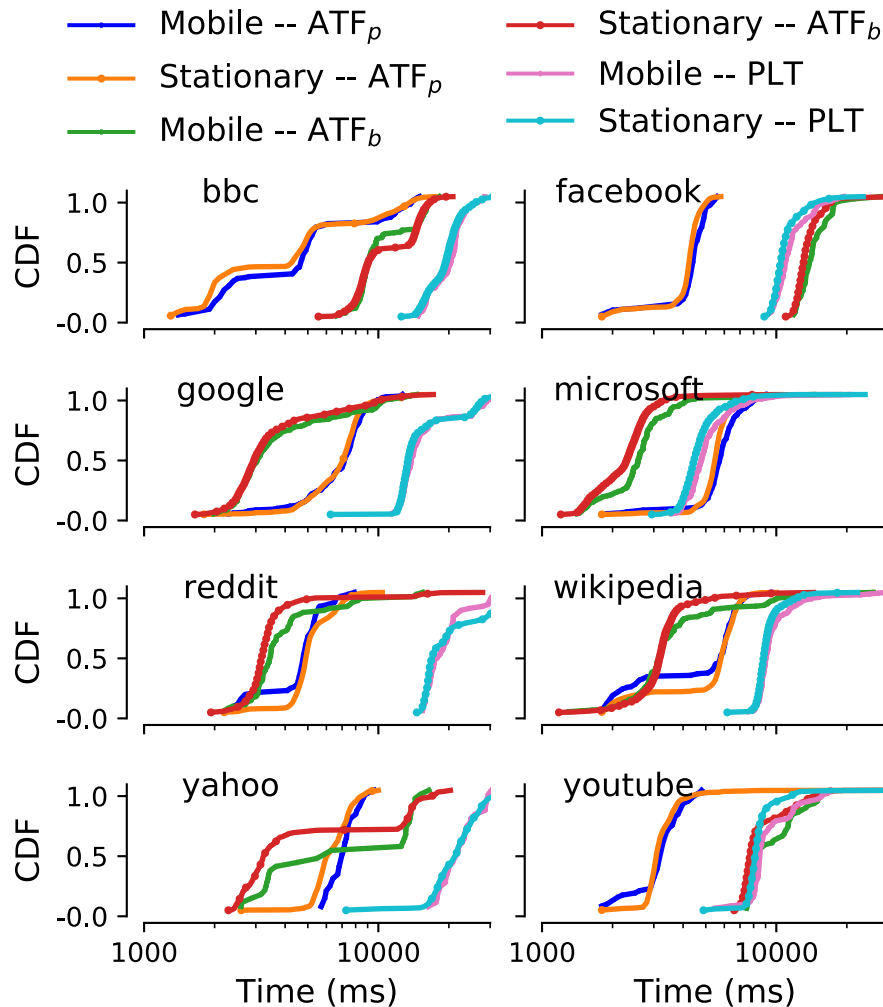
Home-routed roaming does not have effect on the browsing QoE, when the user travels small distance.

Under mobility scenario, the web QoE differs across MNOs.



The variation of ATF time between MNOs is higher than stationary situations.

Web QoE under stationary & mobility* condition



Mobility have higher impact on ATF time that the PLT

* Measured from trains and buses

Takeaways

- We designed and implemented WebLAR (<https://goo.gl/tUQB8T>)
- DNS lookup time is similar in fixed-line and LTE networks.
- TCP connect time and TTFB is longer in LTE networks
- PLT and ATF time do not have significant difference across MNOs
- Mobility has an impact on web QoE especially on the ATF time.
- Website design should be considered in approximating the ATF time
- **Reproducibility considerations:**
<https://goo.gl/Px6TQ2>

WebLAR: Measuring Web QoE in Cellular Networks

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