Quality Measurement over Quality Data Reuse in Cellular Networks

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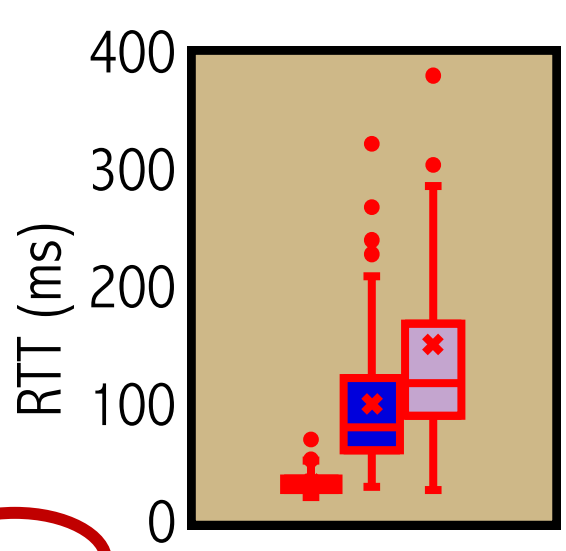
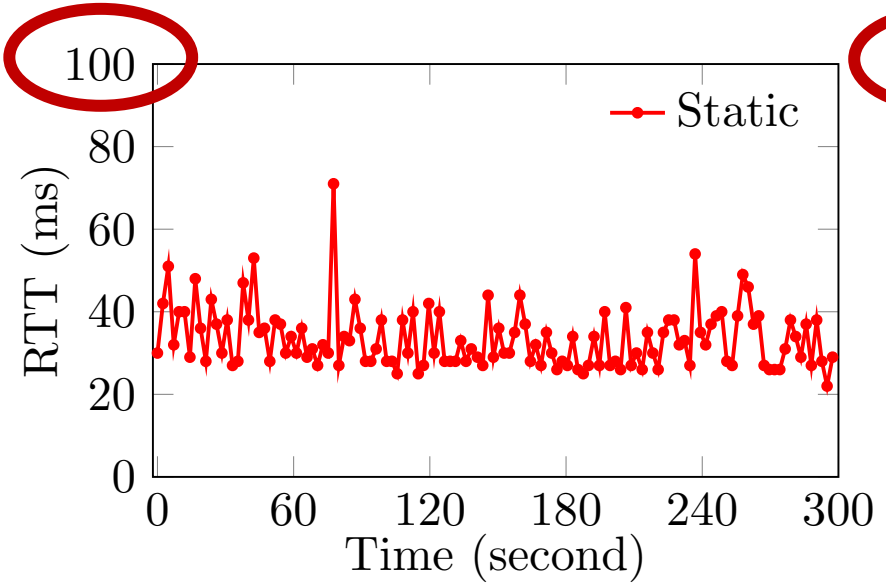
Example on latency measurement

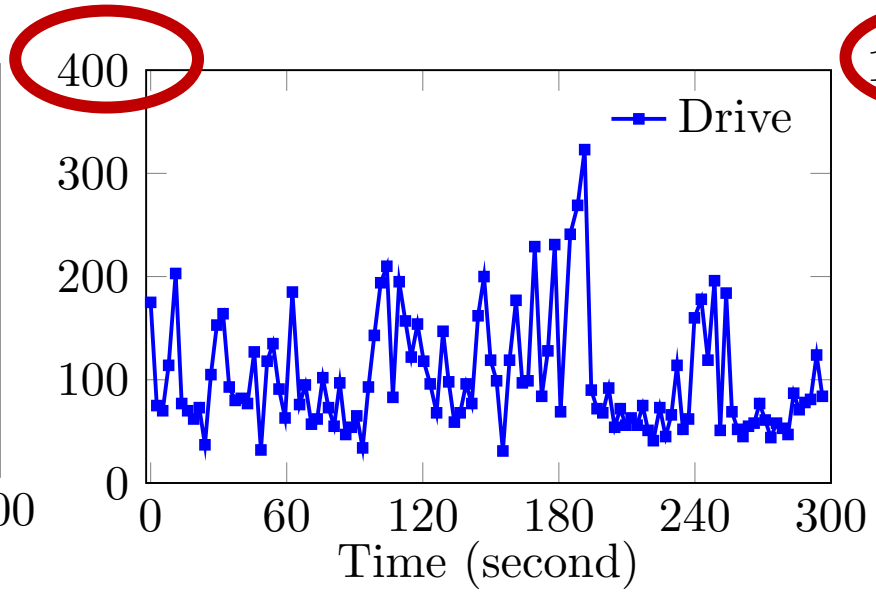
AT&T (4.5G), April 2, 2021 @ West Lafayette, IN

Latency = RTT of ping google.com

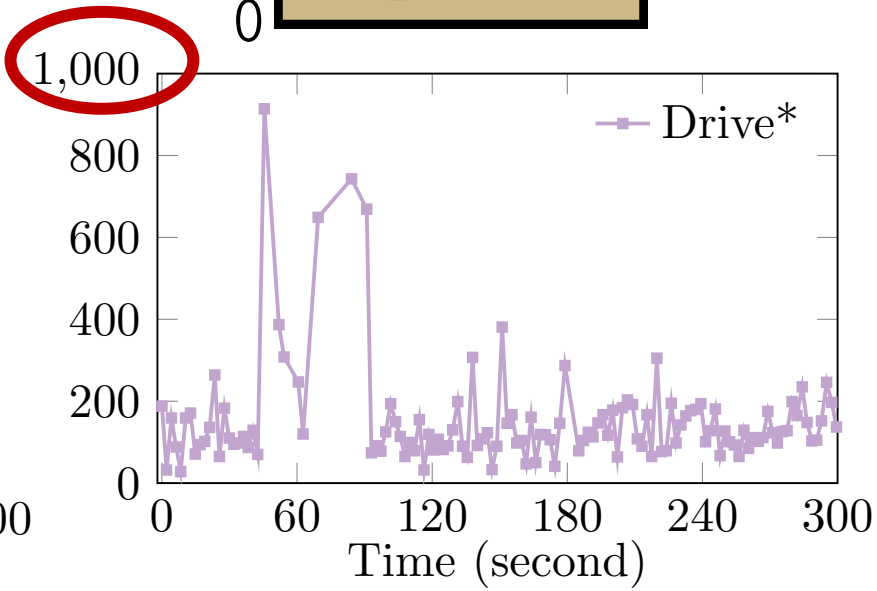




(a) Static (at home)



(b) Drive (~20mph)



(c) Drive* with heavy traffic

What have we learned regarding 4.5G latency in the wild?

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Measurements are biased

- Affected by a number of explicit and implicit experiment settings
  - Controlled (explicit)
    - Automated exp programs, e.g., test traffic, network settings and operations at test equipment, …
    - Manual operations, e.g., test locations/routes, driving speed, hours of a day, …
  - Uncontrolled (implicit)
    - Network elements beyond our test equipment, e.g., dynamic traffic loads at base stations
    - Uncontrolled factors at test equipment, e.g., accompanying foreground and background traffic in user study
- Particularly in cellular networks: wireless and mobility
- Scale (big data) needed to combat the bias
  - Choice of network operators and measurement companies

What we can do? (What we are good at?)

What we have

What we want

Small

Medium

Large

Super-Large

Scale

High

Medium

Low

Quality

+ Controlled
+ Fully open
+ Well-documented
+ Versatile (rich research types)

+ Papers at IMC, SIGCOMM, NSDI, MobiCom, Mobisys, SIGMETRICS, PAM, ...

PAWR

PhantomNet

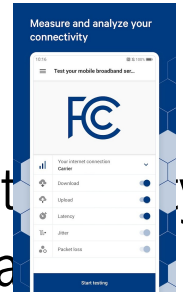
MobiLab

Infrastructure for Studying and Improving the Design of Mobile Computing Systems

PhoneLab

MI LAB

MI-LAB



AT&T

verizon

OpenSignal

...

T-Mobile

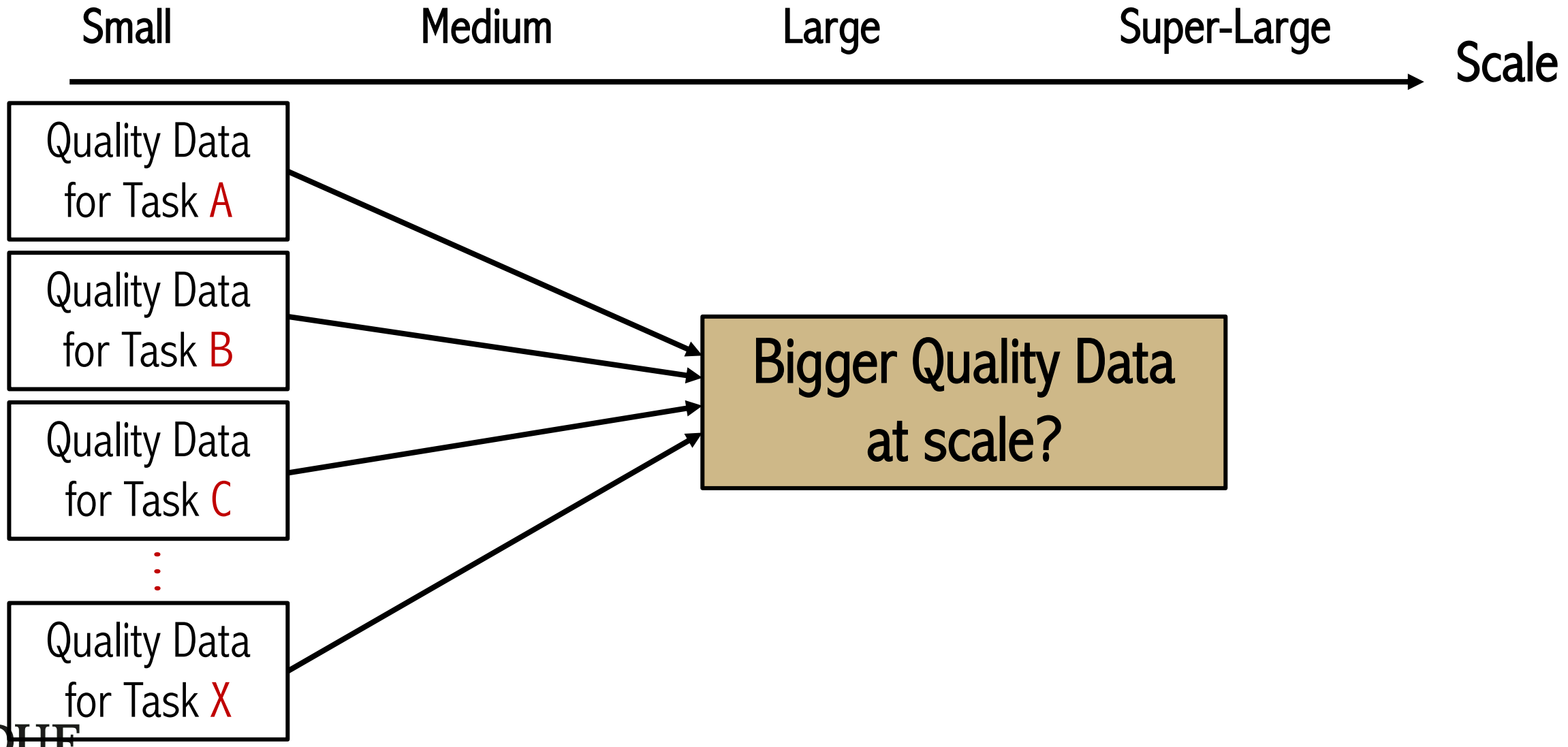
OOKLA

SPEEDTEST

Google

- Uncontrolled
- Largely closed
- Poorly-documented
- Limited types (e.g., speedtest)

Quality data reuse?



Case study: Five-year latency measurement [MobiCom'21]

No dedicated, exactly same measurements throughout five years

A: Web-latency analysis [ICCCN'18]	**Web browsing (bing.com)** Data collected: - E2E latency from web SDK - Pcap files Dataset: - Mainly in 2017 - 2018 - Globally
B: Handover config [IMC'18]	**Ping Google.com** Data collected: - Mobileinsight logs - Phone info Dataset: - Mobileinsight logs - Phone info - Primarily in LA - Five US carriers
C: Across-the-US drive tests(2019)	**E2E latency** **Ping Google.com** **Pcap files**
D: Low-latency VR [SIGMETRICS'18]	**MobileVR**
D: Missed speed [MobiCom'20]	**File downloading**
E: signaling latency [MobiCom'17]	**Any traffic (radio link establishment and handover)**

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[MobiCom'21] Li et. al, Experience: A Five-Year Retrospective of MobileInsight, 2021

Not fully reusable, but partially

A: Web-latency analysis [ICCCN'18]	Web browsing (bing.com) E2E latency: ~ 473 ms
B: Handover config [IMC'18]	Ping Google.com No E2E latency
C: Across-the-US drive tests(2019)	Ping Google.com E2E latency: ~ 50-70ms with good coverage
D: Low-latency VR [SIGMETRICS'18]	Mobile VR E2E latency: ~ 83 ms (DL: < 15ms, UL: < 1ms)
D: Missed speed [MobiCom'20]	File downloading No E2E latency
E: signaling latency [MobiCom'17]	Any traffic No E2E latency Radio link establishment: ~ 170ms

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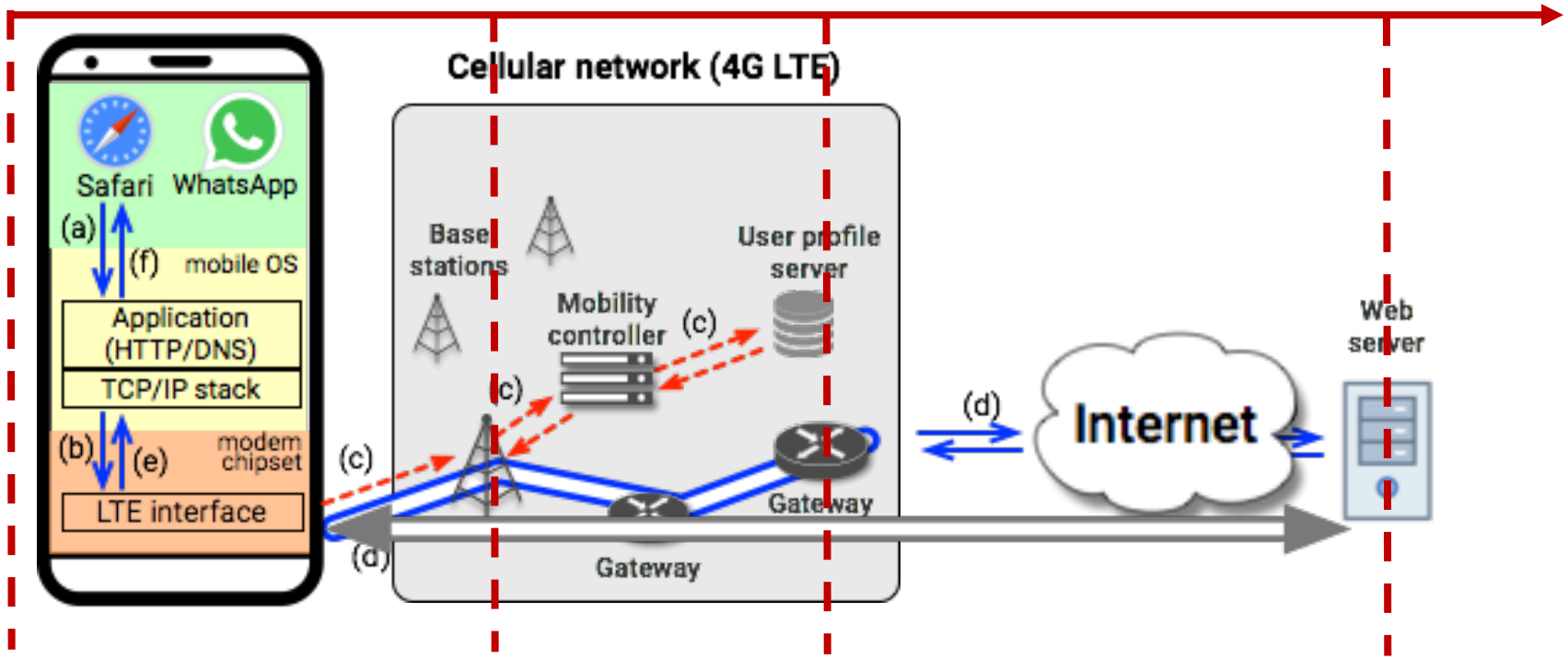
E2E latency breakdown

Use web-latency as an example

Horizontal Breakdown



E2E latency breakdown

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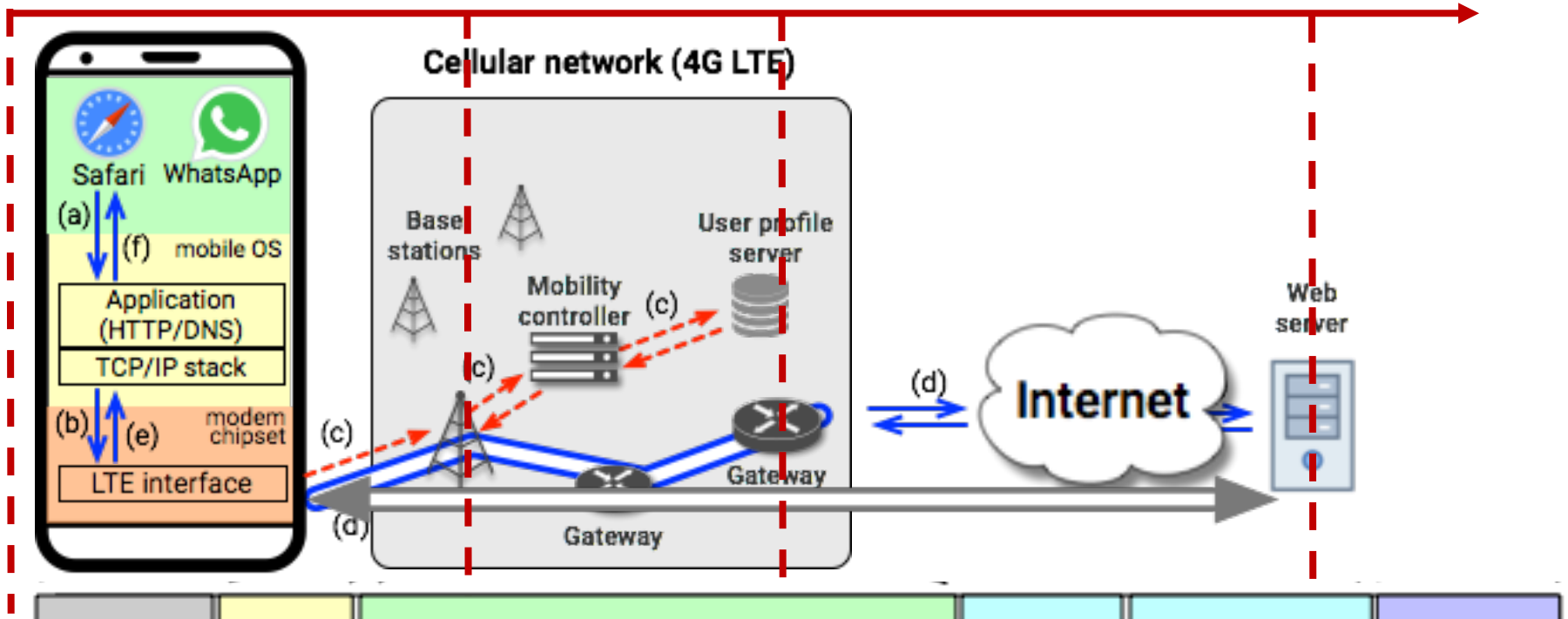
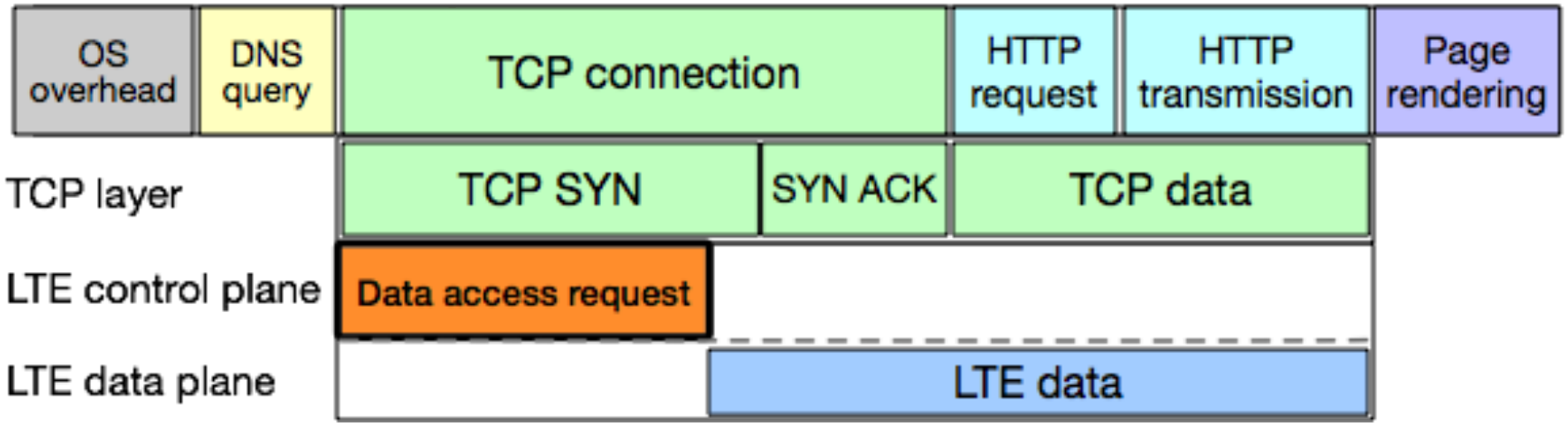
Horizontal Breakdown



Vertical Breakdown



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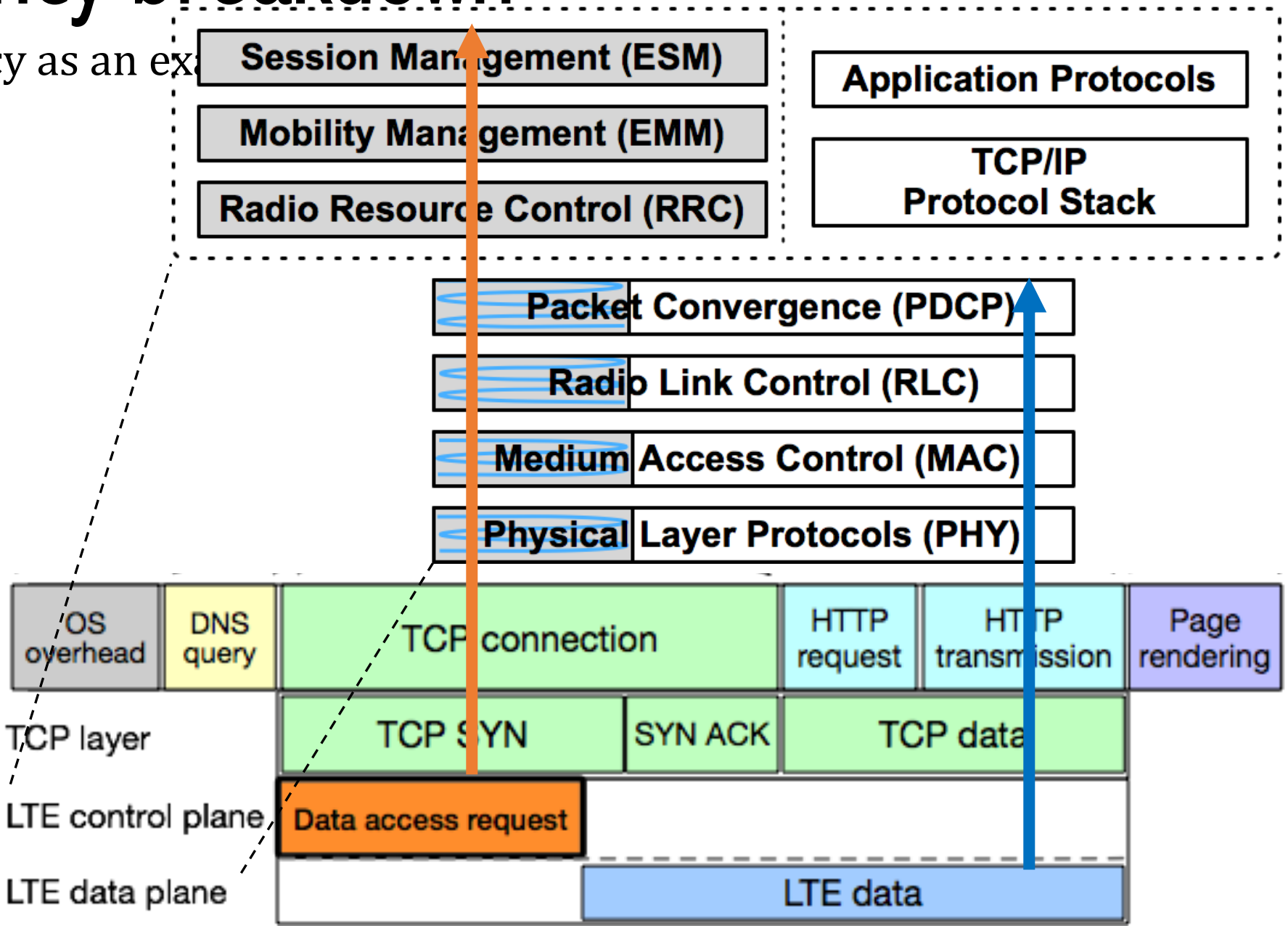
E2E latency breakdown

Use web-latency as an ex



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Data reuse for five-year latency measurement

$$\tau_{e2e} = \sum \tau_i$$

No data reuse for τ_{e2e}, but for τ_i (of research interests)

$$= \tau_{ctrl} + \tau_{data}$$

$$= \tau_{ctrl} + \tau_{radio} + \tau_{higher}$$

- 0ms, if no control-plane signaling in RRC and NAS is needed
- Radio link establishment, if there is no active radio connectivity (RRC state = idle)
- Handover, if there is active radio connectivity but handover is needed (RRC state = active)
- Failure recovering, if failures

Extracted from MobileInsight logs even without no latency measurement records

(control messages exchanged between phones and base stations)

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[MobiCom'21] Li et. al, Experience: A Five-Year Retrospective of MobileInsight, 2021

What we need: Enable & facilitate quality data reuse

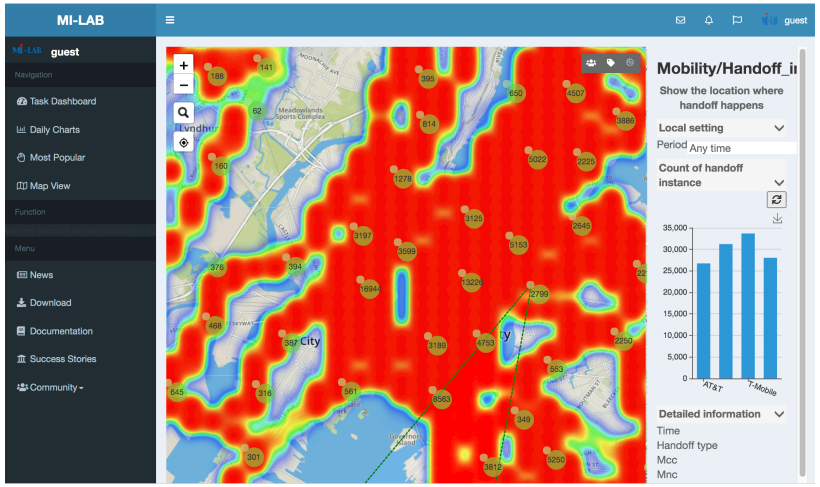
Technically,

- **Breakdown/cause** analysis (decouple reusable components, primary data of measurement and additional data to understand why)
- Design **modular** experiments (with common/standard components)
- Recommend **baseline** experiments
  - Bottlenecks or common interests (e.g., Speedtest, radio link measurement)
  - Recommended exp settings (say, cost-effective, more controlled, extensible)
- Develop **advanced ML** algorithms for domain-specific data reuse (exploiting network models/protocols/functions)
- Share **everything** (primary data, additional data, metadata/exp settings, source codes for data collection and analysis, readme for manual operations, …)
  - Follow community convention/standard

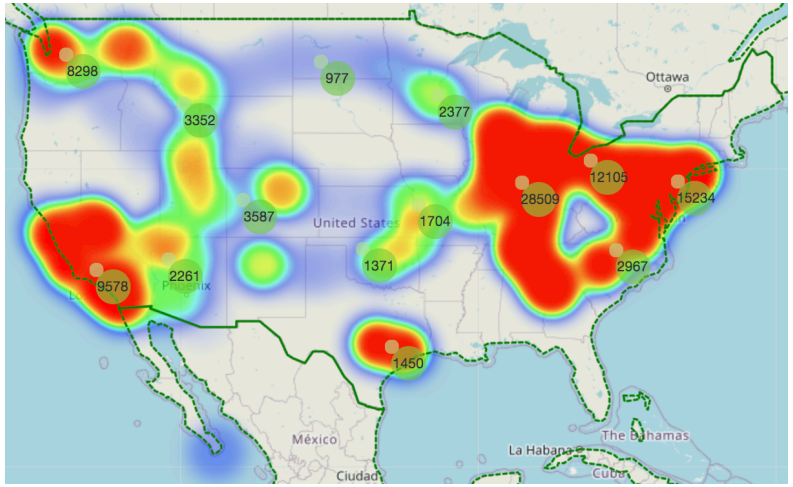
Our attempts towards quality data reuse

http://milab.cs.purdue.edu/

- Open data (>6.5TB mobileinsight logs, > 3.2TB pcap as 04/02/2021)
- Managed per task (linked with its exp codes, data configuration)
- Simple data reuse showcase enabled (task-dependent)
- Generic data reuse ongoing



Mapview (as Guest)



Datasets in the US
(as of 04/15/2021)

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What we need (more)

Immediate actions by the community, e.g.,

- Define standards and recommendations on how to design experiments, annotate data, share artifacts, build benchmarks and streamline common data processing,
- Support and reward such efforts
  - Artifacts Evaluated – Highly Reusable (compliant with recommendation 15.1.0)

Many more in non-technical aspects, e.g., fund, measurement testbeds, industry-academia collaboration, …

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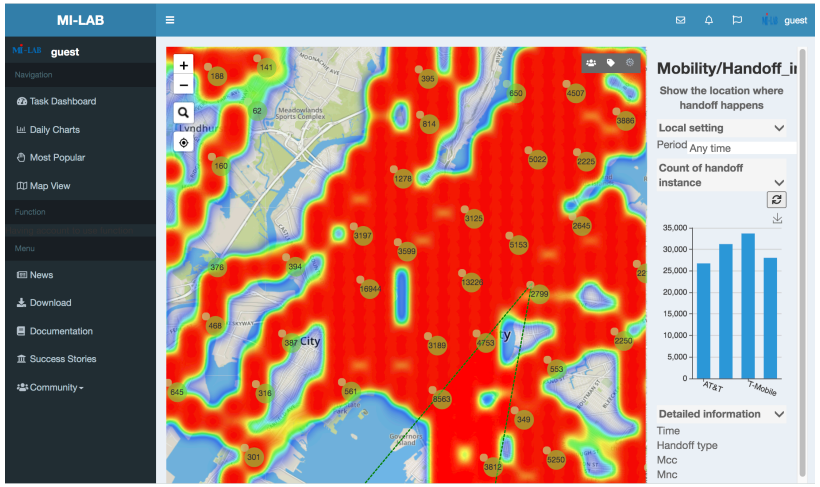

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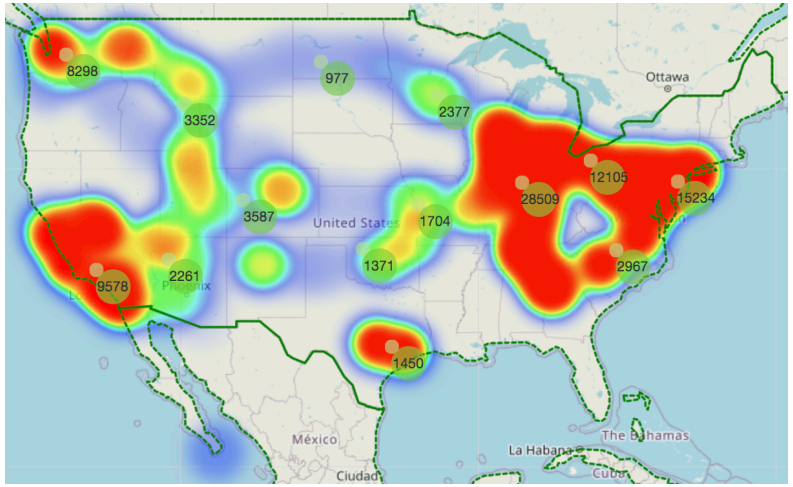

US-datasets (as of 04/15/2021)

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