Network and Application Performance Measurement Challenges on Android Devices

Mohammad A. Hoque, Ashwin Rao, and Sasu Tarkoma
University of Helsinki, Finland

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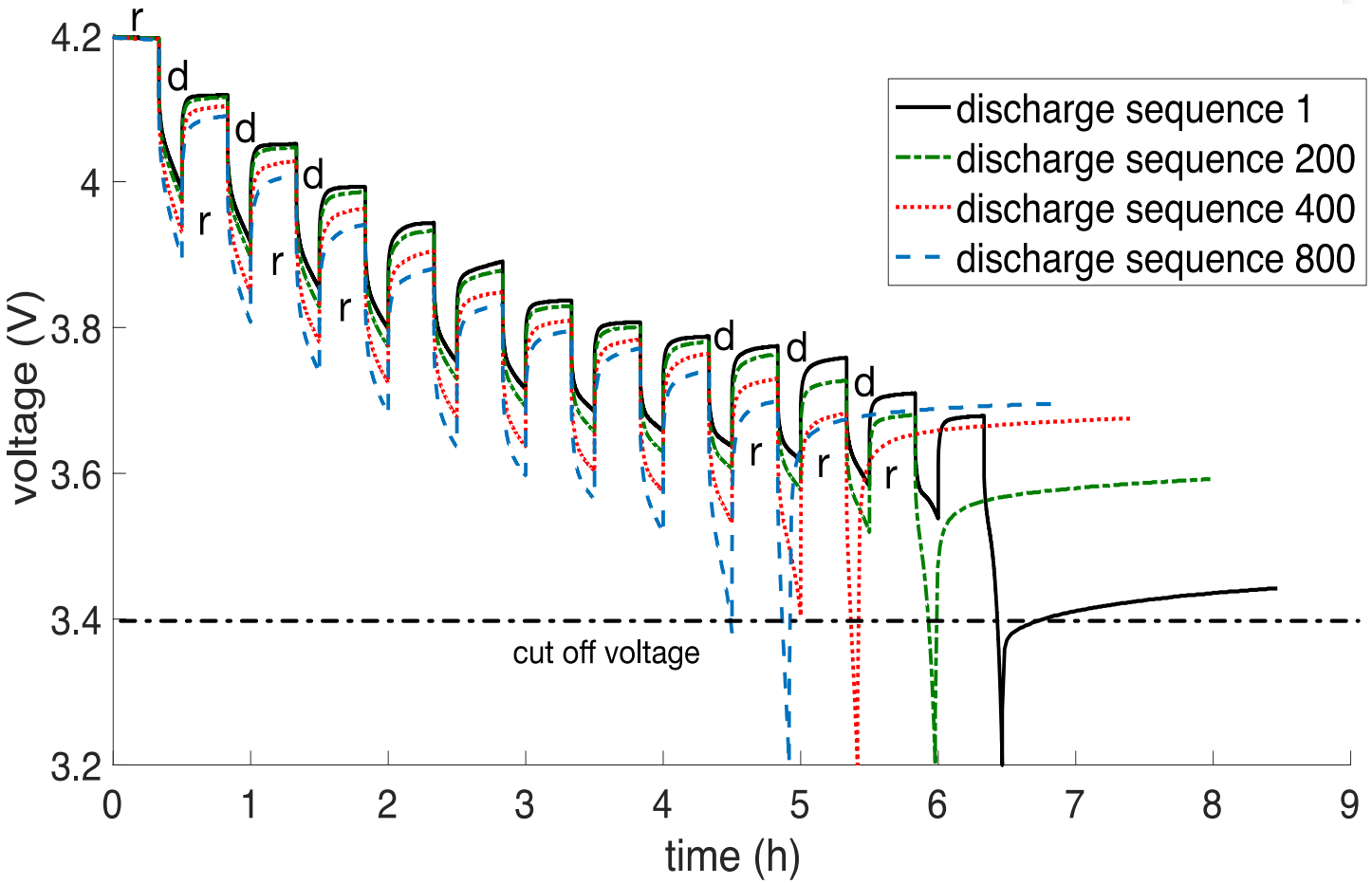
Background-System Optimization

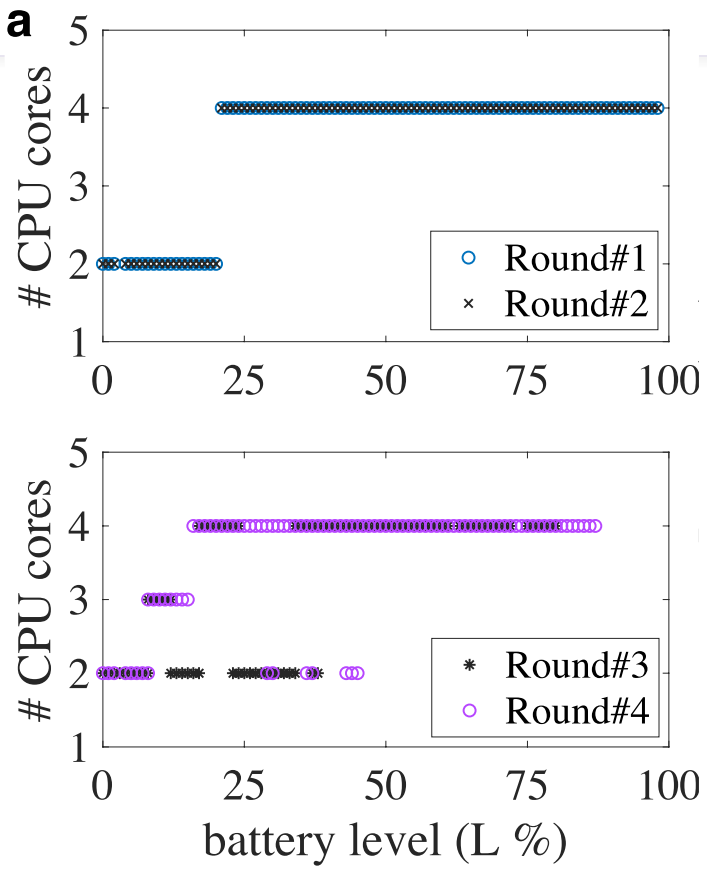
- Nexus 6 was always connected to the same AP.
- SpeedCheck and SpeedPro are the latency and throughput measurement tools.
- We had the values with very high variance and we were unable to explain the reason.
- When the battery level was low, the scrolling of webpages was not smooth with lower battery levels.
- These two observations convinced us that some battery – aware optimizations are happening.



As the battery ages, the voltage drop due to discharge load would cross the limit of the cut-off voltage threshold when there is a small amount of charge is available. This would shut down the device.

Background- System Optimization

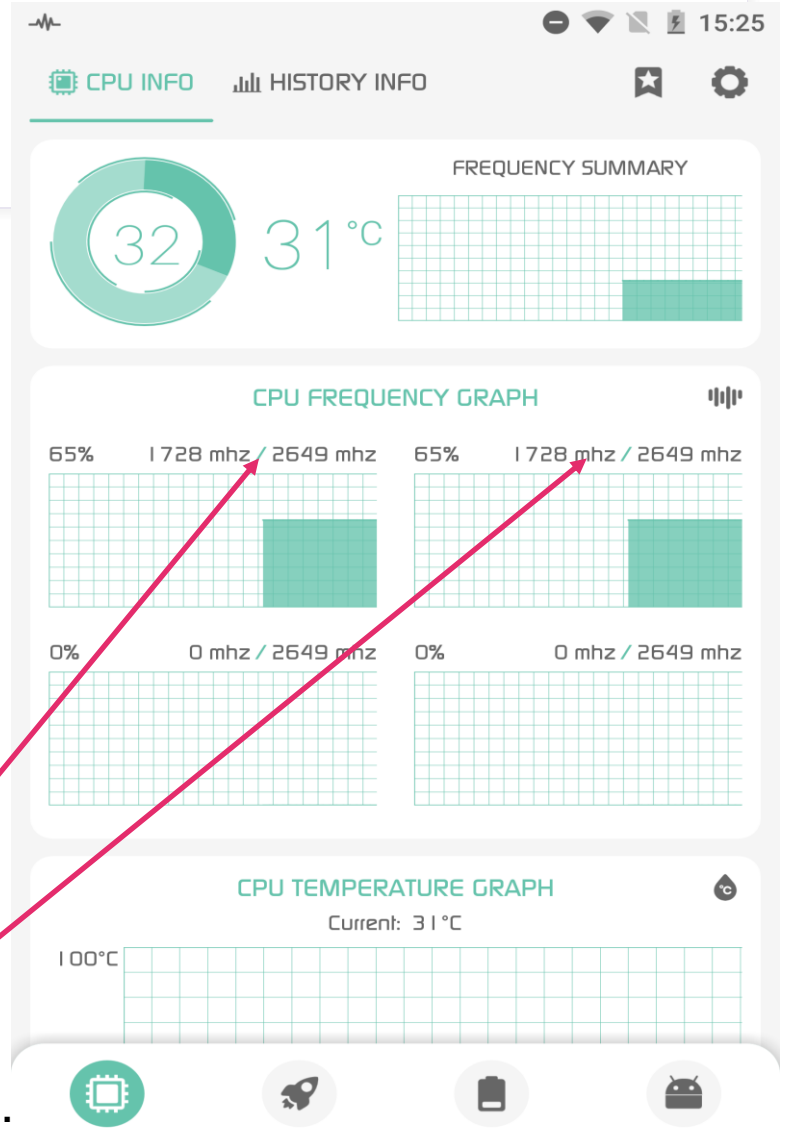
Nexus 6 has four homogeneous cores. We logged the available cores in the Background.



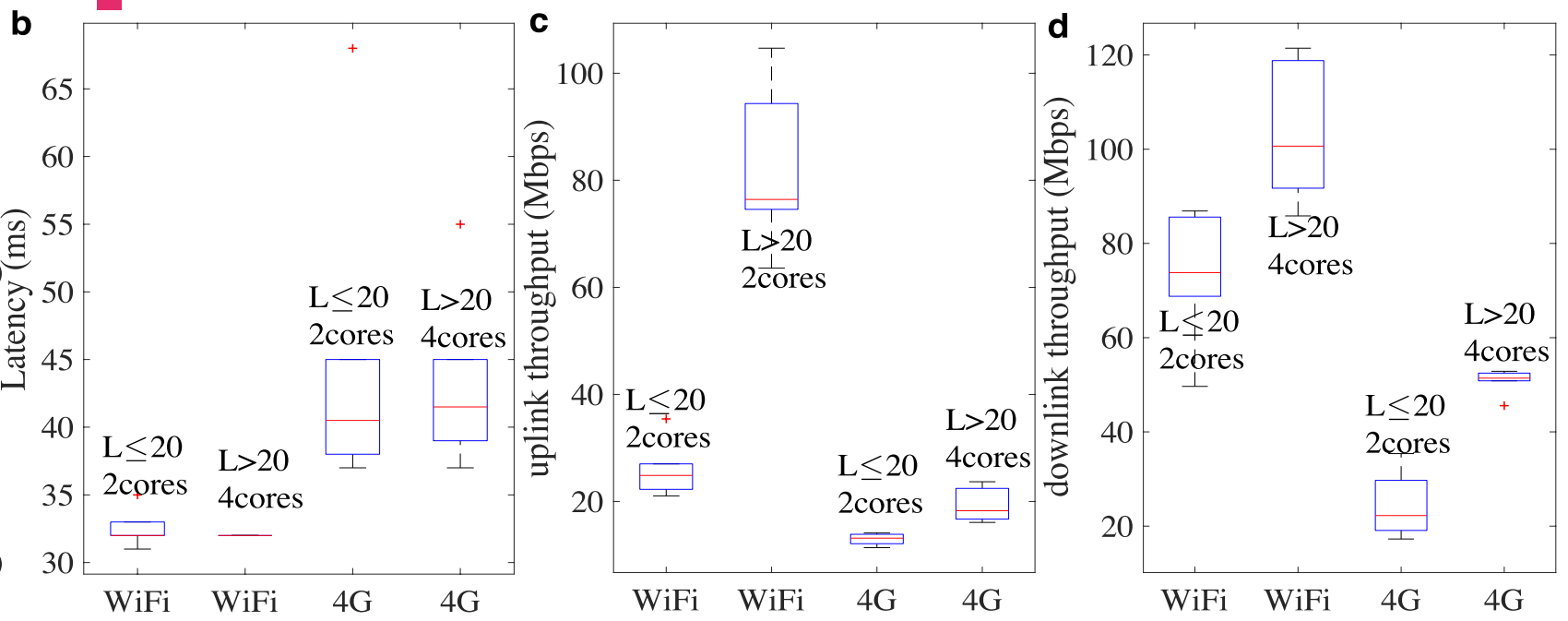
Round #1, 2 (early 2019)
(2 cores unplugged)

Round #3, 4 (early 2020)
(1-2 cores unplugged)

Nexus 6 also applies frequency scaling.



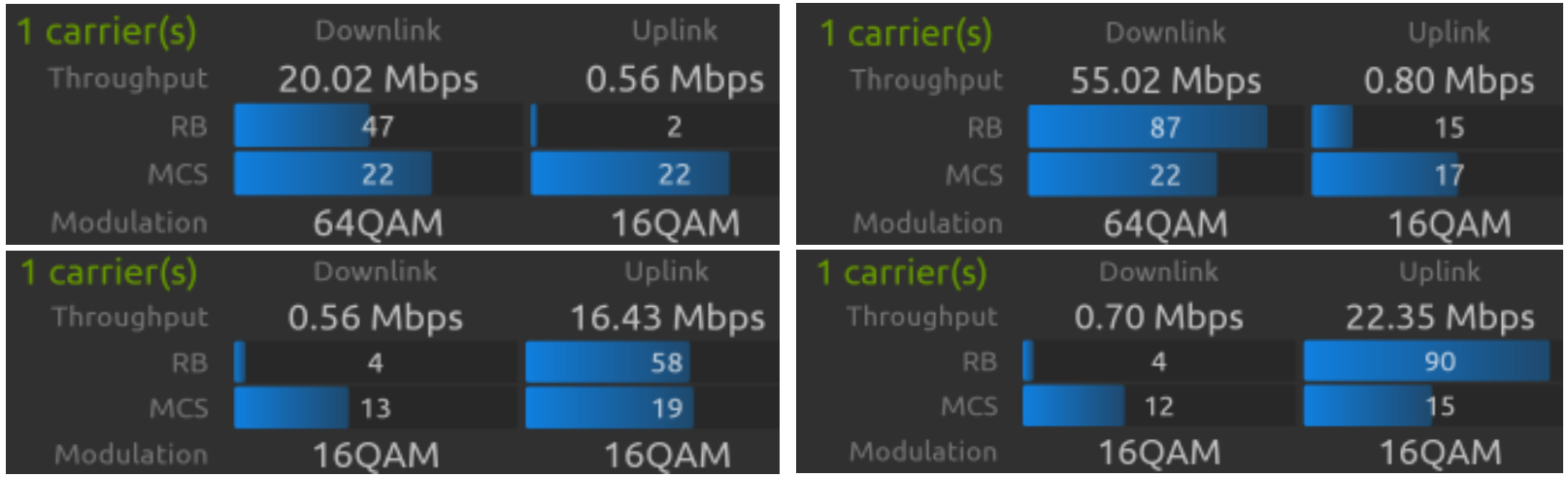
Impact of System Optimization



CPU core and frequency scaling do not impact the latency.

There is dynamic modulation scaling to limit the WiFi transmit power and this the WiFi uplink throughput.

CPU core and frequency scaling Impacts WiFi downlink throughput.



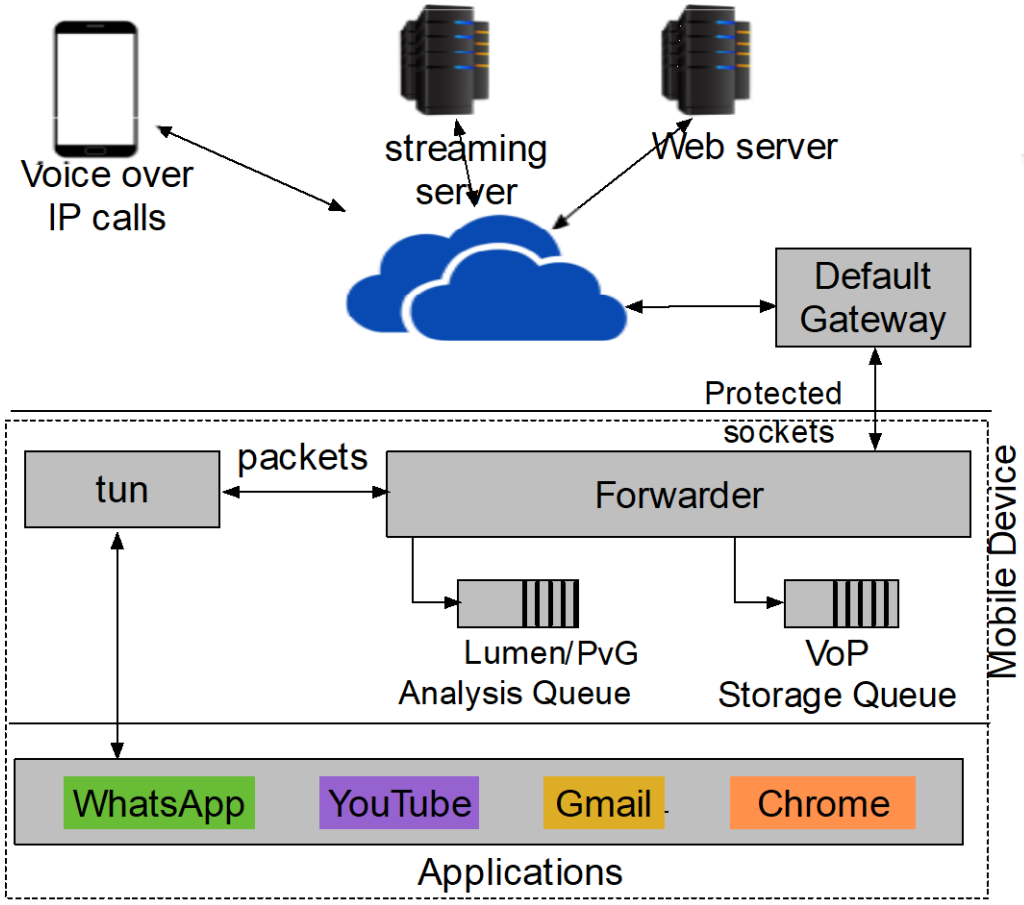
CPU core and frequency scaling impacts LTE uplink/downlink throughput.

Adaptive career aggregation could be applied for LTE-A.

Battery Level <= 20

Battery Level > 20

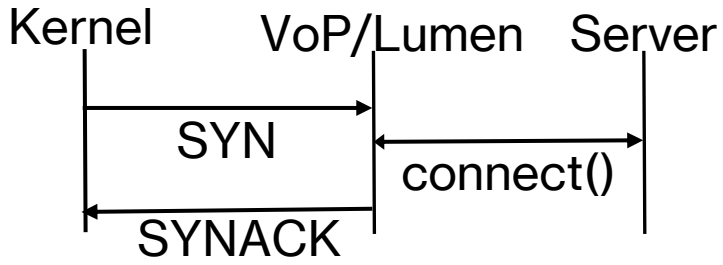
VPN-based Traffic Measurement and Analysis Tools



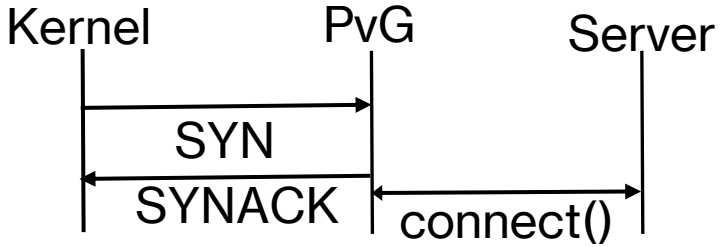
Video Optimizer / ARO: Traffic capture and offline analysis.

VoP/ARO/Lumen/PvG implements Android VPN service and transport protocols.

TCP Handshake Implementation (VoP/Lumen)



TCP Handshake Implementation (PvG)



Lumen/PvG: on-device packet analysis, whether any application is stealing personal or privacy sensitive information online.

Impactc on TCP Traffic

SpeedCheck uses TCP connect () API, (SYN-SYNACK pair) to measure the latency.

SpeedCheck implements a single TCP connection and uses large socket buffer to measure throughput.

SpeedTest uses multiple request/response pairs over TCP to measure the latency.

SpeedTest uses multiple parallel TCP flows to measure throughput.

PvG estimates very low **latency** using **SpeedCheck**, due to the TCP Handshake Implementation.

Lumen/PvG estimates lower **uplink throughput**: the underlying reason is the smaller buffer for the newly created TCP flows.

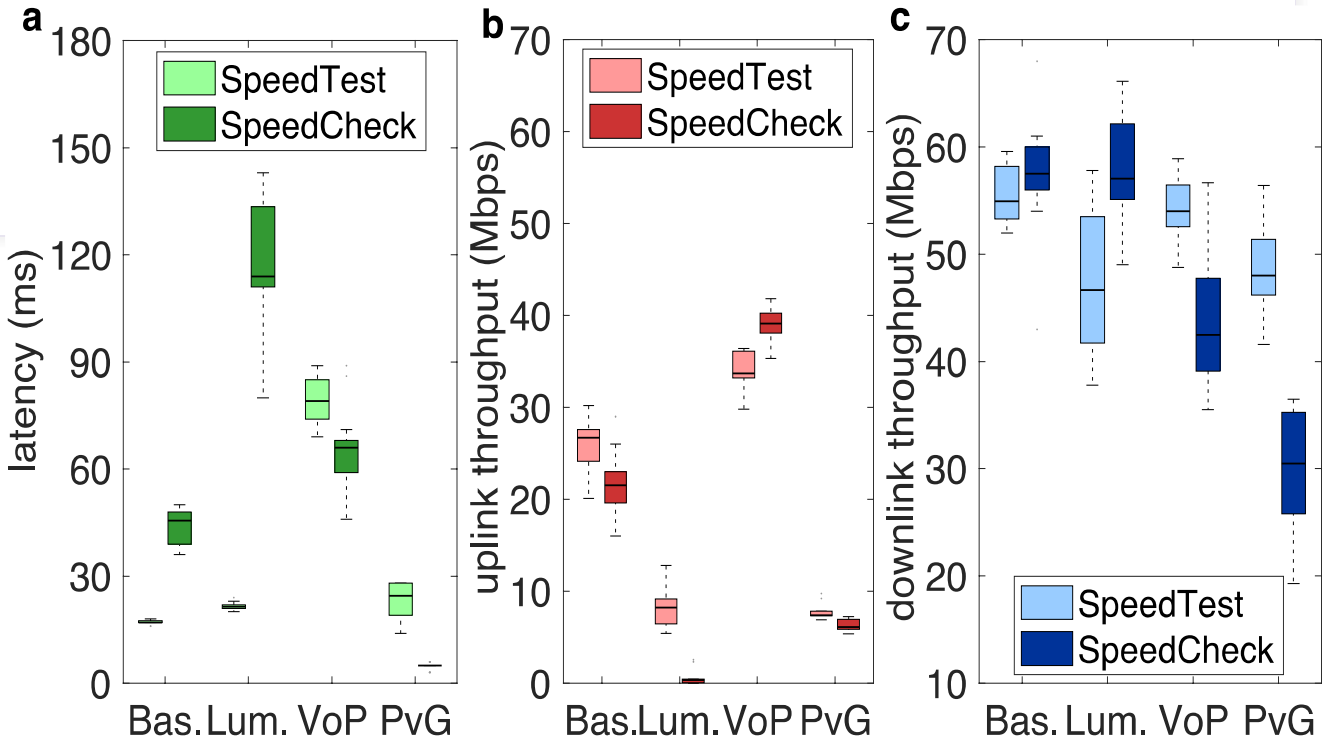


Figure 8: Impact on LTE network latency and throughput. *We used SpeedCheck and SpeedTest on Nexus 6 in the presence of Lumen (Lum.), VoP, PvG, and Baseline (Bas.).*

VoP estimates higher **uplink throughput**: the underlying reason is the large TCP buffer and artificial delay.

Impacts on TCP Traffic : socket options

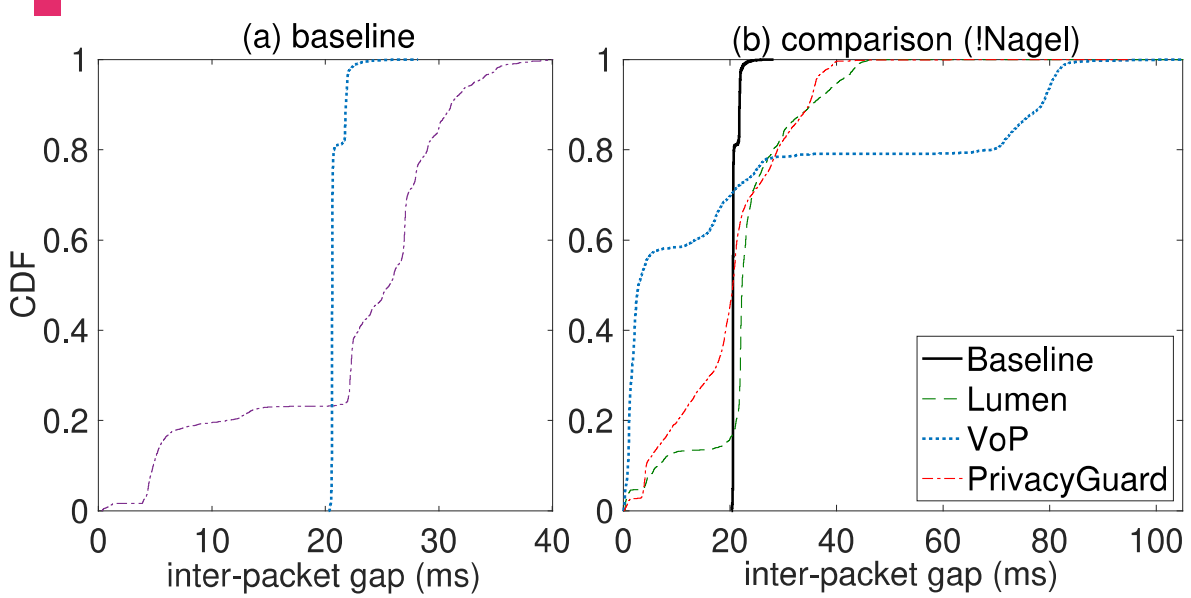


Figure 6: Distributions of the outgoing packet gaps observed at the network interface.

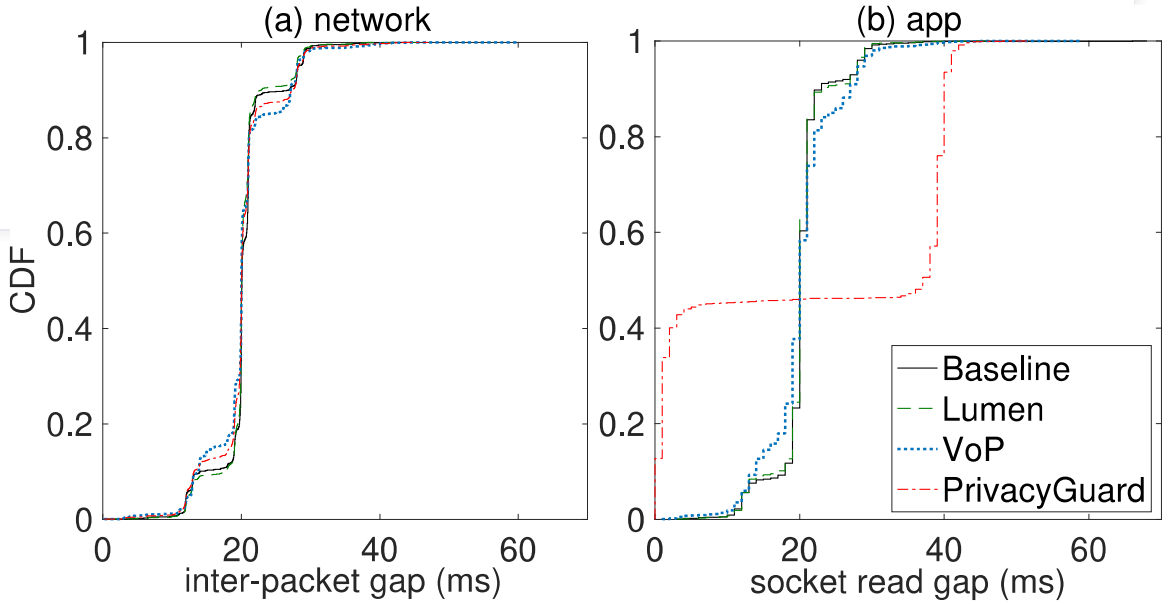
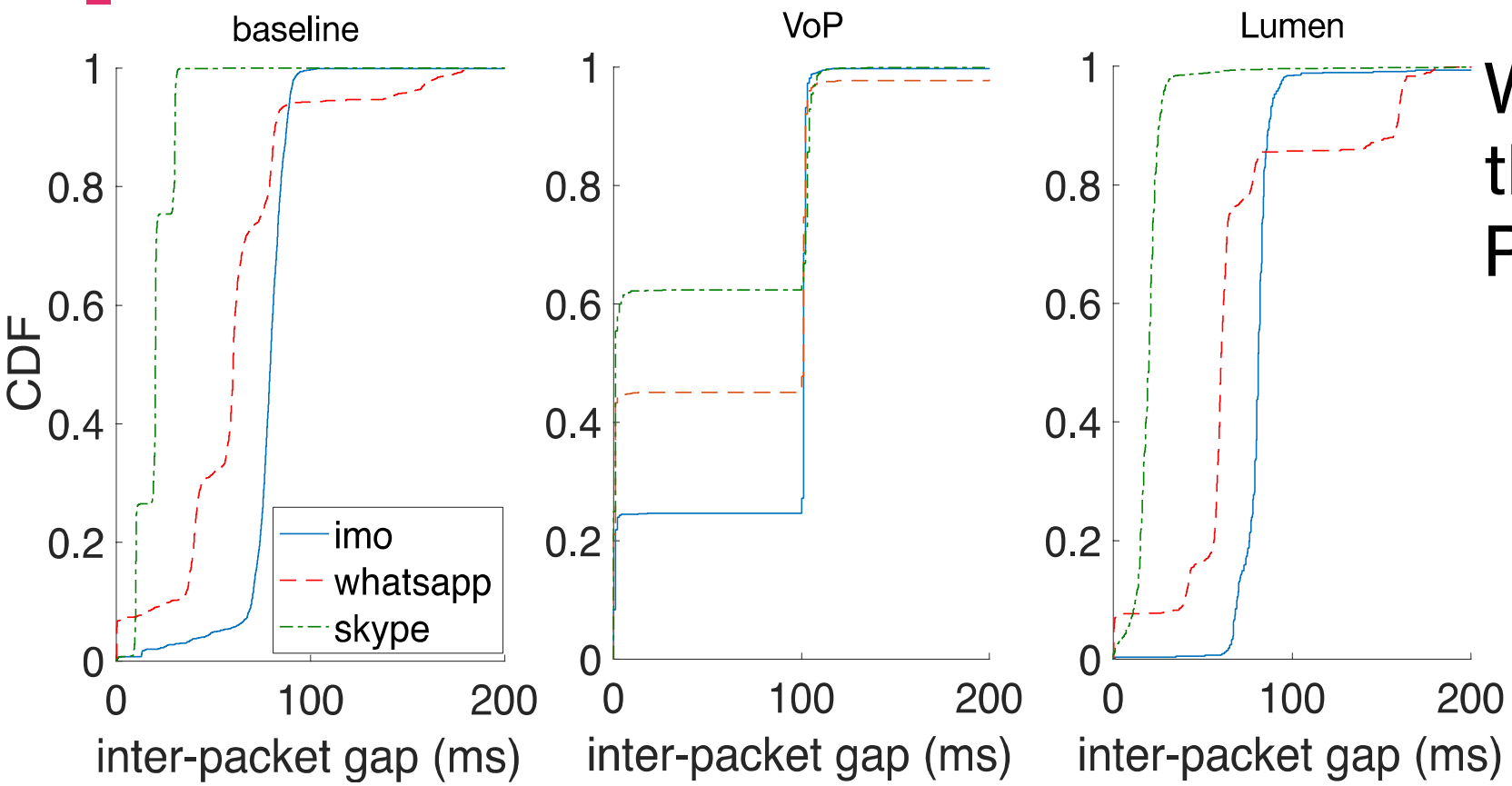


Figure 7: Distributions of incoming packet gaps observed at the network interface and application.

We logged the socket data read/write events and captured traffic using tcpdump

Impacts on UDP Traffic



We were unable to use these applications with PvG.

With VoP, the VoIP applications suffered from QoE issues as the outgoing packets were delayed.

Figure 5: Inter-packets gaps of the VoIP applications. *Baseline refers to the measurements without any localhost VPN.*

Conclusions and Future Work

- All these measurement tools modify the protocol headers. Video optimizer and privacy guard introduce fixed outgoing and incoming packet delays, respectively. The delay reduces the energy consumption of device.
- Lumen applies adaptive sleeping algorithm and avoids such delay. Therefore, Lumen can be extended for traffic capturing as well.
- We believe Snapdragon chipset models 8xx comes with such optimization. However, measurements on Mobile devices should be conducted when the device is fully charged (80-100%) and mentioning such contexts are essential.

- Crowdsourced investigation of system optimization with hundred of device models.
- Impact of fake battery (PowerMonitor) on the measurements.

Thank you