Using AntMonitor for Crowdsourcing Passive Mobile Network Measurements

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Mobile is King

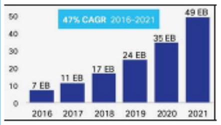


Figure 1: Exponential Global Mobile Data Traffic Growth, Source[1].

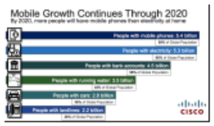


Figure 2: More People with Mobile than Running Water, Source[1].

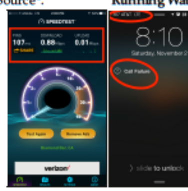
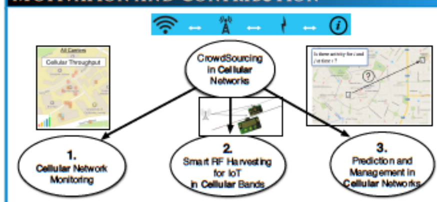


Figure 3: However, all of us have experienced: Poor Performance and Failed Calls.

1. Cisco Visual Networking Index: Global Mobile Data Traffic Forecast Update, 2016-2021, http://www.cisco.com/c/en/us/solutions/collateral/service-provider/visual-networking-index-vni/mobile-white-paper-c11-520862.html

Motivation and Contribution



0. Mobile Coverage Maps by users themselves?
1. Granular Network Performance Monitoring (per user, per app, per location)?
2. Is Cellular Signal Strong Enough for 24/7 Batteryless Devices?
3. Prediction and Provisioning in SDN with Crowdsourced data?

A. Where can I find "5 by 5" signal? B. How? ✓ Users' Mobiles as Sensors!

1. Users: find Best Network.
2. Carriers: monitor their network.

Network Performance Monitoring Approaches

	Network Infrastructure	MySignals [3]	Speedtest.net, Mobilyzer [4]	Our Work AntMonitor
Granular Large-Scale	✓	✓	✓	✓
Infrastructure Access Free	✗	✓	✓	✓
Precise Location	✗	✓	✓	✓
Network Edge	✗	✓	✓	✓
Cellular Info	✓	✓	✓	✓
WiFi Info	✗	✗	✗	✓
Active Throughput	✗	✗	✓	✗
Passive Throughput per TCP/IP flow	✓	✗	✗	✓
NO Data Overhead	✓	✓	✗	✓
NO User Action	✓	✓	✗	✓

Table 1: Network Performance Monitoring Approaches Compared with Our Work.

Network Performance Module in AntMonitor

⇒AntMonitor [5], [6] monitors all packets in/out of a mobile device:

1. Data Collection:
   (a) Passively Monitor.
   (b) Packets/Headers + Semantics/Context.
   (c) Granularity: Per Flow, Per App.
   (d) User Preferences.
2. Deployment:
   (a) User-Space Mobile App.
   (b) Runs in the Background.
   (c) Incentives for the users.

System Overview

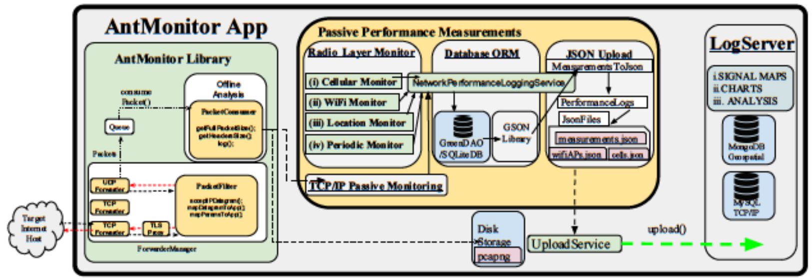


Figure 4: Network Performance Monitoring is built as part of AntMonitor [5], [6] and it can be a powerful tool for crowdsourcing rich, fine-grained, large-scale, network performance measurements.

AntMonitor Passive Networking Monitoring GUI

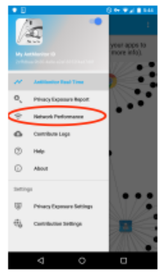


Figure 5: AntMonitor Main Screen.

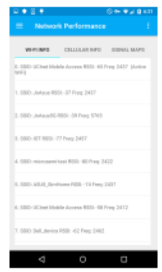


Figure 6: Surrounding WiFi Info.

Figure 7: Cellular Connection Info.

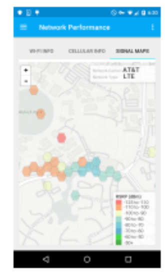


Figure 8: User's LTE RSRP Map.

Application-1: Network Passive Performance Measurements & Maps

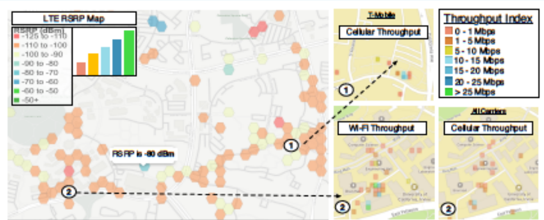


Figure 9: Compare LTE RSRP (Reference Signal Received Power) with Throughput. Interestingly, we observe that low RSRP does not necessarily result in low throughput.

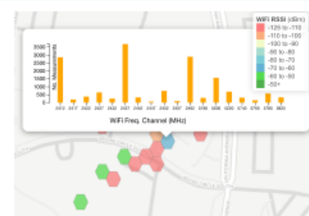


Figure 10: WiFi Frequency Stats per Location.

Passive vs. Active Measurements of Throughput:

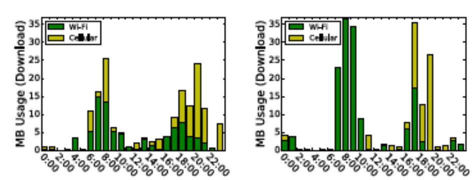
Exp #	1	2	3	4	5	6	7
AM: W=1	30.00	32.79	24.49	31.95	34.78	32.31	31.02
AM: W=5	21.24	29.26	22.83	27.01	30.75	26.84	26.14
Speedtest	19.96	28.42	22.39	28.74	31.66	26.98	27.22

Table 2: **Throughput (Download Mbps): Active (using Speedtest) vs Passive (using AntMonitor: AM) measurements.** Our Approach is close to Speedtest but does not incur any measurement overhead.

Metric	Data Overhead	Memory	CPU	Battery
Speedtest	50 MB	116 MB	14.7%	−0.5%
AntMonitor	0 MB	134 MB	43.4%	−0.7%

Table 3: **Resources Utilization** for AntMonitor and Speedtest per Exp.

User's Data Patterns: (Left) Week Day, (Right) Weekend Day



AntMonitor Webpage

The AntMonitor Project: `http://antmonitor.calit2.uci.edu`

Application 2: RF Harvesting Potential

Motivation: Internet of Things (IoT) Era: Batteryless Sensors via RF Harvesting [7].

- **Question:** What is the *energy outage probability, i.e.* **is 24/7 possible ?**

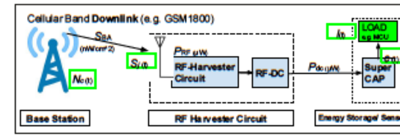


Figure 11: RF Harvesting Overview & System Model.

- **Efficiency:** $\eta_{e-e} = \frac{P_{dc}}{P_{RF}(S_{BA})}$.
- **Example:** [8] $\mathbb{E}[S_{BA}] = 84nW/cm^2 \Rightarrow P_{RF} = 50\mu W \Rightarrow P_{dc} \approx 3-8\mu W$ with $\eta_{e-e} = 7-18\%$. MCU, LED or low power sensor can work!

Our RF Harvesting Assessment Approach: [9], [10]

Input: User's Location: $x_j^{(t)}$, RSS $\mathbb{E}[P_j^{(t)}]$ (*i.e.* **measurements given by** AntMonitor)

1. Sensor's Power Load Markov Process: $l(t) = \{e, 0\}$.
2. Shadowing Markov Process: $S_j^{(t)}$ = {Low, Medium, High}.
3. Cellular Load Random Process: $N_c(t)$.
4. Super Cap Energy: $c(t) = \eta_{e-e} P_{RF}^{(t_n)} T + c(t-1) - l(t) - P_{leakage}$.

$\theta^{(t)} \triangleq \left[l(t) \;\; S_j^{(t)} \;\; c(t) \;\; N_c(t) \right]^T$, **Transitions Matrix:** $P_{\theta_i \theta_j}$: Calculated Empirically.

Output: *Energy Outage Probability*, $p_{outage} = p\left(l(t) = e, c(t) < e | P_{RF}^{(t)}, x_j^{(t)} \right) = ?$

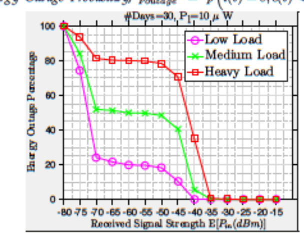


Figure 12: Energy Outage (p_{outage} Probability.)

RF Harvesting in Downlink can work only near Base Stations.

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Acknowledgments

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