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].

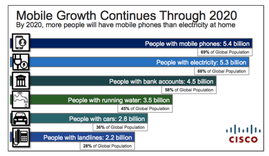


Figure 2: More People with Mobile than Running Water, Source[1].

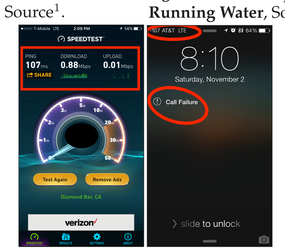
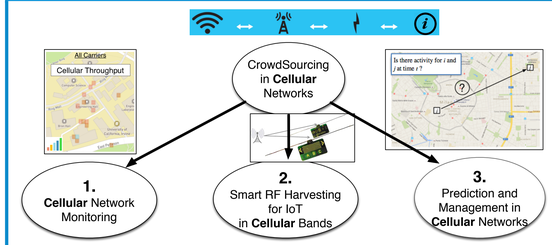


Figure 3: However, all of us have experienced: **Poor Performance** and **Failed Calls**.

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

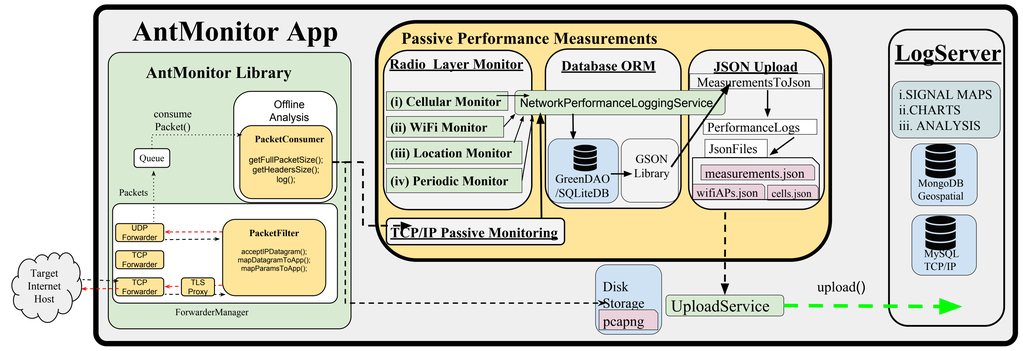


Figure 4: Network Performance Monitoring is built as part of AntMonitor [5], [6] and it can be a powerful tool for crowdsourcing rich, fine-grained, large-scale, network performance measurements.

AntMonitor PASSIVE NETWORKING MONITORING GUI

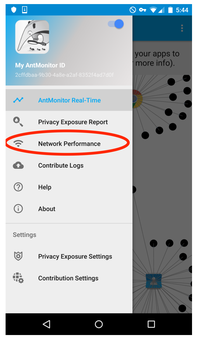


Figure 5: AntMonitor Main Screen.

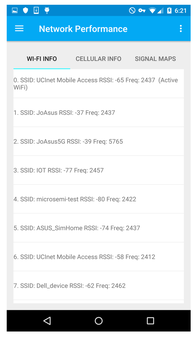


Figure 6: Surrounding WiFi Info.

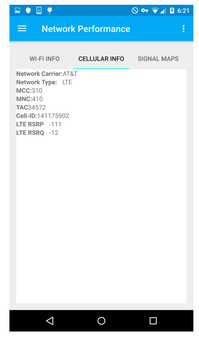


Figure 7: Cellular Connection Info.

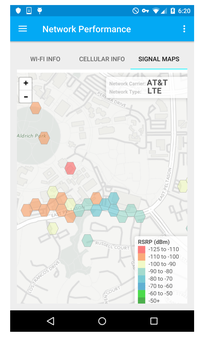


Figure 8: User's LTE RSRP Map.

APPLICATION-1: NETWORK PASSIVE PERFORMANCE MEASUREMENTS & MAPS

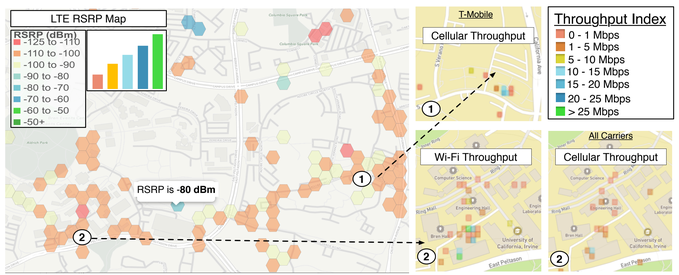


Figure 9: Compare LTE RSRP (Reference Signal Received Power) with Throughput: Interestingly, we observe that low RSRP does not necessarily result in low throughput.

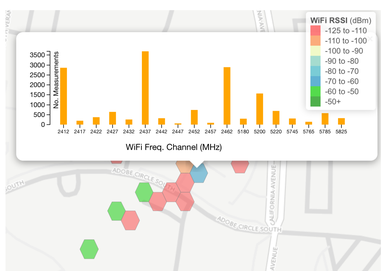


Figure 10: WiFi Frequency Stats per Location.

Passive vs. Active Measurements of Throughput:

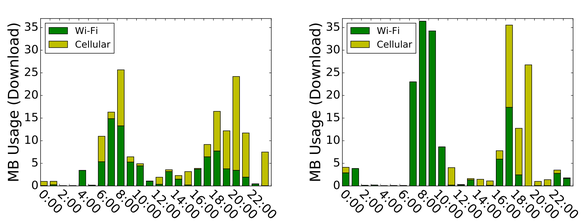
Exp #	1	2	3	4	5	6	7
AM: W=1	30.00	32.79	24.49	31.95	34.78	32.31	31.02
AM: W=5	21.24	29.26	22.83	27.01	30.75	26.84	26.14
Speedtest	19.96	28.42	22.39	28.74	31.66	26.98	27.22

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	134MB	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 ?**

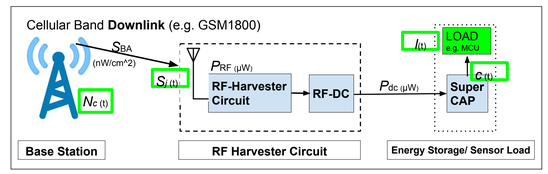


Figure 11: RF Harvesting Overview & System Model.

- **Efficiency:** $\eta_{e-e} = \frac{P_{dc}}{P_{RF}(S_{BA})}$.
- **Example:** [8] $\mathbb{E}[S_{BA}] = 84\text{nW}/cm^2 \Rightarrow P_{RF} = 50\mu\text{W} \Rightarrow P_{dc} \approx 3-8\mu\text{W}$ 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 : $\mathbf{x}_j^{(t)}$, 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: $c(t) = \eta_{e-e} P_{RF}^{(t_\kappa)} T + c(t-1) - l(t) - P_{leakage}$.

$\boldsymbol{\theta}^{(t)} \triangleq \left[l(t) \;\; S_j^{(t)} \;\; c(t) \;\; N_c(t) \right]^T$, **Transitions[2] Matrix**: $\mathrm{P}_{\theta_i \theta_j}$: Calculated Empirically.

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

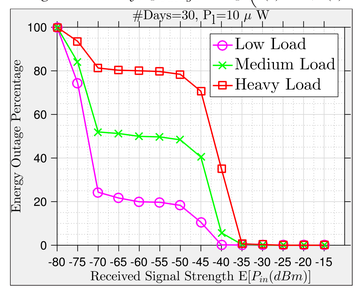


Figure 12: Energy Outage (p_{outage} Probability.)

RF Harvesting in Downlink can work only near Base Stations.

REFERENCES

[1] C. Cranor et. al. Gigascope: A Stream Database for Network Applications. In *Proc. of the ACM SIGMOD*, pages 647–651, June 2003.

[2] E. Alimpertis, N. Fasarakis-Hilliard, and A. Bletsas. Community RF Sensing for Source Localization. *IEEE Wireless Commun. Lett.*, 3(4):393–396, Aug 2014.

[3] E. Alimpertis. Community RF Sensing. Diploma thesis, School of Electronic and Comp. Engineering, Tech. Univ. of Crete, Greece, 2012.

[4] A. Nikravesh, H. Yao, S. Xu, D. Choffnes, and Z. M. Mao. Mobilyzer: An Open Platform for Controllable Mobile Network Measurements. In *Proc. of the 13th ACM MobiSys*, pages 389–404. May 2015.

[5] A. Shuba, A. Le, E. Alimpertis, M. Gjoka, A. Markopoulou. AntMonitor: System and Applications. *arXiv:1611.04268*.

[6] A. Le *et al.* Antmonitor: A System for Monitoring from Mobile Devices. In *SIGCOMM Workshop on Crowdsourcing and Crowdsharing of Big Internet Data (C2BID)*, London, UK, Aug. 2015.

[7] Vincent Liu, Aaron Parks, Vamsi Talla, Shyamnath Gollakota, David Wetherall, and Joshua R Smith. Ambient backscatter: Wireless communication out of thin air. *Proc. of ACM SIGCOMM*, 43(4):39–50, 2013.

[8] M. Piñuela et al. Ambient RF Energy Harvesting in Urban and Semi-Uban Environments. *IEEE Trans. on Microwave Theory and Techniques.*, 61(7):2715–2726, 2013.

[9] E. Alimpertis. Assessing the Potential of RF Harvesting for the Devices in the IoT Era, May 2015. Awarded with the UCI Electrical Engineering Fellowship by the Broadcom Foundation for 2015-2016.

[10] E. Alimpertis and M. Levorato. Assessing the Potential of RF Harvesting . Technical report, February 2016. Project Report, UCI Wireless Networking Class.

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