PHONELAB: A LARGE-SCALE PARTICIPATORY SMARTPHONE TESTBED

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Throughout the history of computing, testbeds have played major roles in advancing research. Multiple areas have reached a point at which small, limited, single-experiment instrumentation failed to provide the power, scale and realism needed to make progress. **We believe smartphone research has reached this critical juncture.** Large-scale shared infrastructure is now needed.

VISION

Smartphones are one of the most rapidly-adopted technologies in history. Conference proceedings are bulging with papers attempting to harness their power, and as smartphones change the way that we communicate and interact, scientists from a broad range of disciplines are anxious to study their effects. But these efforts are stalled by the lack of a testbed remotely approximating the reality we are witnessing.

We envision a publicly-available smartphone testbed called PHONELAB that enables smartphone operating system and mobile application research in a realistic environment at a scale not previously possible. PHONELAB will consist of a large number —1,000 or more — of reprogrammable Android devices used by students and staff at a university campus. PHONELAB will provide:

- **Power:** allowing the modification of smartphone software above and below the OS-application interface, while simplifying instrumentation and data collection to facilitate efficient experimentation.

- **Scale:** providing access to an order of magnitude more participants than typically used by smartphone studies.

- **Realism:** by minimizing experimental disturbance and allowing participants to use their smartphones naturally.

Compared to the Apple AppStore or Android Market, PHONELAB provides a controlled, yet realistic environment with a large number of participants in one location. We anticipate PHONELAB supporting experiments on emerging topics such as social networking, cyber-physical systems, smart environments, smartphone sensing, and crowd-sourcing. In addition, access to the operating system allows PhoneLab experimenters to perform studies that cannot be performed by installing applications. We believe that PHONELAB will accelerate research on smartphone-related areas by providing a standardized environment where experiments can be validated and competing approaches compared.

Considering the research impact of other similar testbeds — EmuLab and PlanetLab on networking and distributed systems, MoteLab on sensor networking — we expect PHONELAB to accelerate mobile cloud computing research. To bring this vision to fruition, we are designing an initial PHONELAB prototype.

POTENTIAL ADVANCES

To demonstrate the kinds of research that PHONELAB will enable, we identify four main research areas the testbed will advance.

- **Applications:** PHONELAB will enable the community to tackle emerging research issues in a wide array of application domains such as crowd-sourcing, social networking, user interaction, environmental sensing, and epidemiology studies. For example, PHONELAB would provide an experimentation platform for collecting sensor data such as time-activity traces for pollutant exposure estimation. PHONELAB could also assist the development of more realistic human mobility or social network models.

- **Infrastructure:** PHONELAB will support research into infrastructure aspects such as environmental interaction, task distribution, and new wireless technologies. For example, we believe that PHONELAB can be instrumental in designing and developing a cloud-backed smartphone infrastructure using nearby computers or data centers. There are many research questions in this area concerning off-loading computation, hierarchical storage designs that extend the limited smartphone storage to data centers, and privacy and security issues arising from interaction with data centers.

- **Networking:** PHONELAB will provide an environment for networking research such as multi-radio fusion, delay-tolerant protocols, and peer-to-peer interaction. Many research projects investigate ways to utilize multiple communication technologies — voice, SMS, WiMax, WiFi, Bluetooth — each with its own capabilities and limitations. PHONELAB would allow the deployment of an integrated networking layer that attempts to divide traffic between multiple radios to improve performance. Moreover, while 4G is slowly being adopted nationwide, there are few studies reporting 4G behavior in the wild.

- **Operating Systems:** PHONELAB will allow researchers to modify OS components, and help investigate issues such as mobile operating system design, distributed systems, energy management, and fault-tolerance. Operating systems modifications can be tested and compared on PHONELAB as experimenters will have access to the same group of participants with the same usage patterns over time. For example, experimenters can run a number of different energy management approaches over the span of a few weeks and compare the results.

INVESTIGATORS

We briefly highlight each author's previous work most relevant to the topic of this white paper:

Geoffrey Challen developed and maintained MoteLab, the first wireless sensor network testbed consisting of 200 sensor nodes and supporting over 700 users. **Murat Demirbas** helped develop and deploy the "Line In The Sand" 100-node wireless sensor network for detection, classification, and tracking, which led to the 1,000-node "ExScal" network. **Steven Ko** helped design the HP/Intel/Yahoo! OpenCirrus[TM] Cloud Computing Testbed, a federated multi-datacenter testbed spanning over 14 institutions in US, Europe, and Asia and including more than one thousand servers. **Tevfik Kosar** designed and developed both the Stork distributed data scheduling system currently used by institutions worldwide and the PetaShare distributed storage network that manages more than 700 Terabytes of storage located across nine university campuses in Louisiana.