PhoneLab: a Participatory Smartphone Cloud Testbed

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Investigators: We highlight each author's previous work most relevant to the topic of this white paper, i.e., small devices, cloud computing, and testbed design. *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.

Vision: 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 1,000 reprogrammable Android devices used by SUNY at Buffalo students, staff, and faculty, supported by a back-end data center. 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. PhoneLab will provide *scale*, allowing researchers access to an order of magnitude more participants than typically used by smartphone studies. By minimizing experimental disturbance, PhoneLab will provide *realism*, ensuring that participants use their smartphones as they would normally. We believe that PhoneLab will accelerate research on phone cloud applications, networking, infrastructure, and system software, providing a standardized environment where experiments can be validated and competing approaches compared.

Evidence for Advances: There are four research areas PhoneLab will help advance. For each, we both list some of the pressing research issues in that area and describe an example experiment that PhoneLab will enable.

Applications: PhoneLab will enable emerging research issues in the application domain such as crowd-sourcing, social networking, user interaction, environmental sensing, and epidemiology studies. One of the authors, Murat Demirbas, is currently doing a project in this category, that uses smartphones to collect time-activity data for pollutant exposure estimation. PhoneLab would provide a realistic experimentation platform for this research.

Infrastructure: PhoneLab will also enable research into infrastructural issues such as environmental interaction, task distribution, and new wireless technologies. For example, Byung-Gon Chun at Intel Labs Berkeley expressed his interest in using PhoneLab for his CloudClone project

that "uses nearby computers or data centers to speed up your smart phone applications". PhoneLab would provide an ideal environment for testing his approach.

Networking: PhoneLab will provide a great platform for networking research such as multi-radio issues, delay-tolerance, and peer-to-peer. Many research project investigate ways to utilize multiple communication technologies — voice, SMS, WiMax, WiFi, Bluetooth — each with its own capabilities and limitations. PhoneLab is the perfect testbed to experiment with an integrated networking layer that attempts to divide traffic between multiple radios to improve performance.

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. One of the authors, Geoffrey Challen, is investigating more efficient energy management schemes, and PhoneLab would allow this work to instrument devices and study energy consumption patterns over a wide user base.

Extended Vision: 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. At each critical juncture, a group of scientists built shared infrastructure that helped carry the field forward.

Smartphone research has reached this critical moment. Smartphones are one of the most rapidly-adopted technologies in human history, and conference proceedings are bulging with papers attempting to harness the power of this emerging technology. As the smartphones change the way that we communicate and interact, scientists from a broad range of disciplines are anxious to study its effects and unlock its potential. But all of these efforts are stalled by the lack of a testbed remotely approximating the reality we are witnessing.

We believe that our vision for PhoneLab can meet this need by providing the power, scale, and realism required to enable the next-generation of mobile cloud computing research. Considering the research impact of other similar testbeds — EmuLab and PlanetLab on networking and distributed systems as well as MoteLab on sensor networking — we anticipate that PhoneLab can accelerate mobile cloud computing research.

PhoneLab will consist of three layers — phone, infrastructure, and interface — and we briefly describe how they work together to provide its core functionality.

Phone: We will distribute 1,000 next-generation Android phones to PhoneLab participants. We have chosen the Android platform because it is the only open-source mobile device operating system currently available. Access to the operating system layer allows PhoneLab experimenters to perform studies that cannot be performed via the Apple Store or Android Market.

Infrastructure: The infrastructure component of PhoneLab will consist of 4G base stations and server infrastructure installed on campus. 4G access points allow us to provide data access to our participants for free — a significant participation incentive — while producing a next-generation smartphone environment for experimentation. A back-end data center will collect and store experimental data for further analysis, while also allowing users to run code interacting with software deployed on the phones.

Interface: The access layer will consist of interfaces used by both users and participants. Users will use their interface to design, schedule, and monitor their PhoneLab experiments. Participants will use their interface to track the experiments they are part of and monitor the information being collected about them.