# Participant Behavior in PHONELAB

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## 1 Introduction

This abstract examines the behavior of the participants in PHONELAB, a public smartphone testbed being developed at SUNY Buffalo. Currently consisting of 191 participants using Nexus S 4G smartphones, PHONELAB aims to provide a combination of unique features desirable for smartphone experimentation. This abstract briefly introduces PHONELAB and presents some of the early results of a usage measurement study conducted with 115 participants.

### 1.1 PHONELAB Overview

PHONELAB is designed to provide the following features necessary for smartphone research—open access, scale, power, realism, locality, and relevance:

- **Open Access:** After the initial approval process, PHONELAB allows any researcher to deploy their research prototype on the participants' smartphones.
- **Scale:** By 2014, PHONELAB will grow to 700 participants already incentivized and recruited to participate in experiments; participants of PHONELAB receive discounted voice, data, and messaging.
- **Power:** By utilizing the Android open-source smartphone platform, PHONELAB allows application-level experiments as well as platform-level, i.e., the OS kernel, middleware, and libraries.
- **Realism:** Participants use the phones as their primary device.
- **Locality:** Most participants live in Buffalo near SUNY campuses, enabling research requiring device-to-device interaction.
- **Relevance:** PHONELAB allows researchers to stop relying on out-of-date datasets. Instead, new data can be collected in the most appropriate way for the experiment.

PHONELAB application-level experiments are distributed through the Play Store; participants are notified of new experiments and install the experimental applications directly from the Play Store. On the other hand, PHONELAB platform-level experiments are distributed through the PHONELAB control software that runs on each participant's phone; this control software is capable of updating platform components, e.g., libraries and kernel modules. To the best of our knowledge, PHONELAB is the only testbed that provides all the above features together.

| **Affiliation** | | | |
|---|---|---|---|
| Freshman | 64 | Masters | 5 |
| Sophomore | 33 | PhD | 53 |
| Junior | 1 | Faculty/Staff | 29 |
| Senior | 1 | None | 5 |
| **Gender** | | | |
| Female | 51 | Male | 140 |
| **Age** | | | |
| Under 18 | 12 | 30–34 | 15 |
| 18–19 | 74 | 35–39 | 6 |
| 20–21 | 12 | 40–49 | 13 |
| 22–24 | 22 | 50–59 | 7 |
| 25–29 | 29 | 60+ | 1 |

**Table 1:** Demographic breakdown of 191 PHONELAB participants. Date ranges are inclusive.

### 1.2 PHONELAB Demographics

Currently, PHONELAB consists of 191 participants. Roughly half of our participants are first- and second-year undergraduates, a quarter PhD students, and a fifth faculty, staff and other professionals. However, males greatly outnumber females, and the young outnumber the middle-aged and older, both unrepresentative features we will try and rectify in the future years. For management reasons we limited participation to people with a SUNY Buffalo affiliation except for several exceptions: a local reporter, a technology writer, and an international rock star. Table 1 summarizes our demographics.

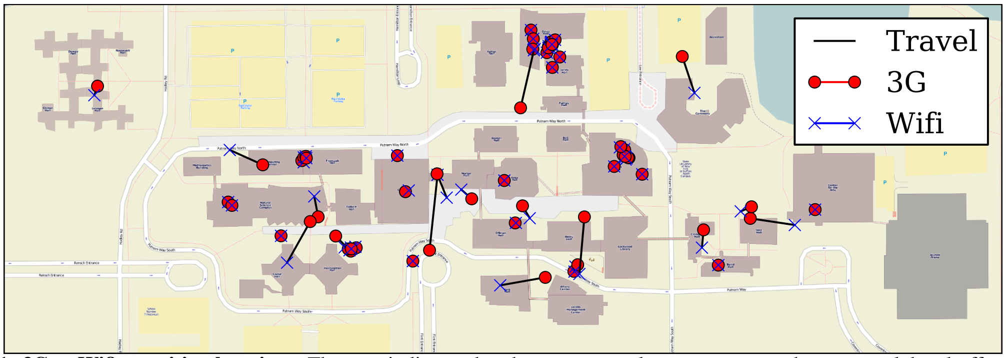


**Fig. 1: 3G to Wifi transition locations.** The map indicates that there are several common areas where network hand-offs occur.

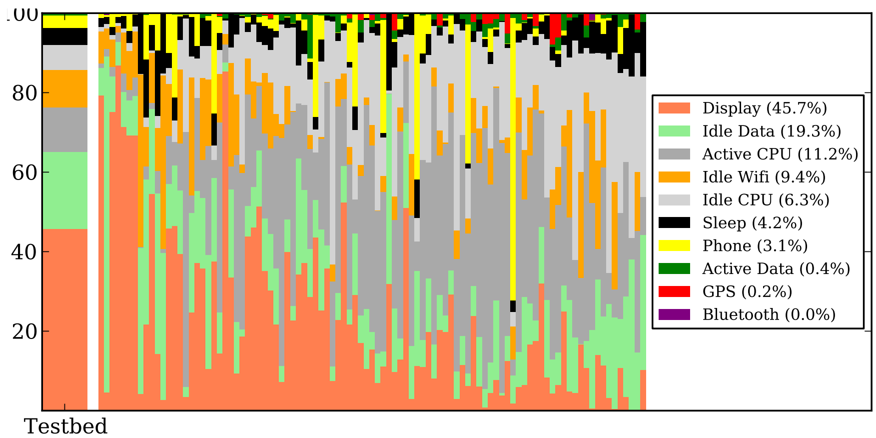


**Fig. 2: Power usage by component.** The large bar at left shows an aggregated breakdown for all participants. The participant bars are scaled against the participant with the most energy usage.

## 2 Participant Behavior

We have conducted a usage measurement study with 115 participants over 21 days. For this purpose, we have developed a measurement application that collects all salient features of smartphone usage: networking, mobility, power consumption, and application usage.

This section presents some of the early results of this study. We show the network transition behavior between 3G and WiFi first and the battery and charging behavior next.

### 2.1 Mobile Network Transitions

Mobile devices like smartphones move through a complex network environment. Providing the illusion of seamless connectivity requires negotiating hand-offs both between Wifi access points and between Wifi and 3G radios. We were interested in observing hand-offs between 3G (provided by Sprint, PHONELAB's operational partner) and Wifi and found many in the dataset collected by our usage experiment. Since the Android `ConnectivityService` frequently switches network interfaces for exploration purposes, we have defined a transition as two one-minute or longer sessions on different interfaces separated by less than one minute. We further limit ourselves to cases where we received a location update during the transition.

Figure 1 plots the location of transitions that occurred on or near SUNY North Campus. We notice that many cluster in expected locations: near the entrance and exits of buildings where participants are likely to be moving from campus Wifi to 3G.

### 2.2 Energy Breakdown

A single-day component-by-component breakdown is shown in Figure 2. Our results are similar to those reported by a previous smaller-scale study [4], and indicate that mobile data (labeled as "Idle data" and "Active data" depending on the state), the screen, and CPU usage are the main sources of smartphone power consumption. The per-participant bars also show a great deal of variation, with differences in both the amount and the breakdown of energy consumed by each participant.

One supposedly power-hungry component that has less of an impact than we had expected is the GPS. This is particularly surprising given the large amount of location-monitoring work motivated by GPS power consumption. One of several factors may be at work. First, the Android platform estimates the GPS chipset current consumption at 50 mA. This number is used by the standard "Fuel Gauge" battery monitor and by our calculations. However, it is lower than the data sheet for the Broadcom 4751 GPS receiver [1] and may represent a best-case average. Still, even if the GPS current consumption is off by as much as a factor of five, it does not represent a significant contribution. Other hypotheses are that Android network location is providing location with sufficient accuracy for many applications, eliminating the need for GPS, or participants and applications may simply be conscious of GPS power consumption and taking steps to control it.

### 2.3 Opportunistic Charging

One way that users work around the battery limitations of their smartphone devices is by finding new times and places to charge their phones: plugging in at their desk at work, in the car during their commute, or at home before a long night out. We refer to these charging sessions as *opportunistic* to distinguish them from *habitual* nightly charging. Assuming that many smartphone users encounter plug points throughout the day, engaging in opportunistic charging becomes an additional sign of energy awareness, and understanding opportunistic charging becomes necessary to improving energy management on mobile devices. Others have analyzed this behavior before [2, 3] and our goal is to examine the battery charging behavior of PhoneLab partipants.

Figure 3 shows that many users engage in opportunistic charging. We define a charging session as opportunistic if is long enough to not be spurious (over 10 minutes) but does not bring the battery to a fully-charged state, indicating that the user disconnected the device before charging could finish. For a representative day during our experiment, of the 245 charging sessions we observed that day, 96 (39%) were opportunistic by this definition. 50 of 95 active participants engaged in opportunistic charging at some point during our experiment an average of once per day.

Opportunistic charging may be a response to an anticipated need for more smartphone battery power: the student who plugs her smartphone in for a brief charge before a night out. Our data also allowed us to examine how many of these opportunistic charging sessions were necessary to bridge the gap to the next full charge. We found that 24 of the 96 (25%) of the opportunistic charges we observed were necessary. We believe that this indicates that participants have responded to their smartphones' battery limitations by engaging in conservative charging behavior, grabbing power whenever possible even if they do not anticipate needing it later.

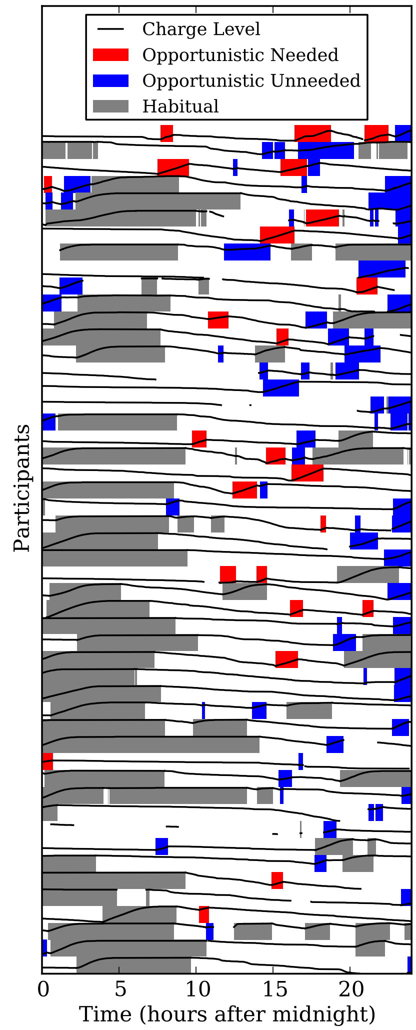


**Fig. 3: Patterns of opportunistic charging.** Many users perform opportunistic charging multiple times during the day.

## 3 Conclusions

This abstract introduced PhoneLab, a new large-scale programmable smartphone testbed operated by SUNY Buffalo and presented the participant behavior in terms of network transitions, energy, and charging.

## References

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