PART 04 Adaptive Battery Management on Smartphones

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Overview
Modern mobile phones are not single-purpose devices anymore. But rather, they are multi-functional programmable computers. Users run a plethora of applications in addition to voice calling on their smartphones. Significant diversity in usage habits combined with the diversity in hardware platforms makes battery life of smartphones unpredictable. If batteries lasted long enough, unpredictability would not have been a serious concern. However, the linear battery improvements are no match for the rate of new features and applications on smartphones. As a result, the average battery lifetime of smartphones gets shorter on each new generation of smartphones in the market.

In addition, many pervasive computing applications, such as those developed at CENS, have components that continuously run in the background. Such applications are particularly power consuming. Unlike traditional fully interactive applications, users do not have direct control over the resource consumption of background tasks. Therefore, many users are usually startled by their smartphone’s short battery life when running CENS applications.

In this work we introduce a new system to give users control over their phone’s battery life. We do so by CENS applications, which run in the background and consume significant power, adaptive to usage and context.

Approach
Four approaches to managing power consumption to minimize user surprises can be considered:

• Most systems leave battery management entirely to applications. Most commercial mobile platforms such as Android and Symbian follow this approach.

• The opposite of the previous approach is managing energy as a primary system resource. Applications can consume only what is allocated to them by the OS. ECOSystem and Cinder are research operating systems that follow this approach.

• A third approach to guaranteeing a reasonable battery life is limiting the amount of work that applications can do without the user's direct control. For example, the iPhone OS does not allow arbitrary background jobs by limiting multitasking.

• Our approach that we propose in this work combines the best of the first and second approaches.

Managing energy consumption at the highest layer, i.e., applications, is more effective. The application can make better choices to trade off accuracy and performance with energy. On the other hand, applications lack a global view of the system. Specially, effective battery management requires knowledge of other applications workload, something that applications do not expose to others for a good reason.

System(s) Description and/or Experiments

SystemSens (Power Monitor Service)
We continued improving and extending SystemSens, the logging software tool that was developed at CENS to log detailed system related information on Android smartphones. SystemSens can now run on any Android phone and report on a wider range of operating system events. We also implemented a web interface to visualize SystemSens traces. Each user can login to this service and monitor resource consumption on her phone through a number of time graphs. The SystemSens service builds models that related consumption of different resources to battery level changes on the phone of each individual. The model building process is repeated every night for each user and the resulting model is sent back to the SystemSens Client on the smartphone. The client then uses this model to regulate resource consumption of background services to meet user specified battery deadlines.
**WiFiGPSLocation Service**

WiFiGPSLocation is an Android service to simplify duty-cycling of the GPS receiver when a user is not mobile. It runs as an Android Service on the phone and defines a simple interface that all other CENS applications can use to get the updated location of the user. To duty-cycle the power consuming GPS receiver uses the WiFi RF fingerprint to detect when a user is not moving to turn off GPS, and when the user starts moving to turn it back on.

We implemented this service to be adaptive based on the signals from SystemSens. Therefore, any other location-based CENS application, such as Andwellness mobility, that uses this service will be adaptive as well.

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**Example of a SystemSens network traffic graph during two days of the smartphone of an example user**

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**Accelerometer Service**

As another example of an adaptive service that reports its resource consumption to SystemSens and complies with the energy consumption signals that SystemSens sends, we implemented a service to manage the Android accelerometer. Several other CENS applications such as Andwellness Mobility and SleepSens use this service.

**Future Directions**

The next step of our research is evaluating the performance of this system. Our efforts to this point have been focused on the implementation of this system. We will evaluate our system using real users and improve its performance if needed. We also plan to release our system to other researchers who face similar problems with managing smartphone battery life.