6-5-2014

Low Energy Smart Phone for the Homeless

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Date: June 5, 2014

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Low Energy Smart Phone for the Homeless

BE ACCEPTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF

BACHELOR OF SCIENCE IN COMPUTER SCIENCE AND ENGINEERING

Thesis Advisor

Department Chair

Low Energy Smart Phone for the Homeless

by

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Submitted in partial fulfillment of the requirements
for the degree of
Bachelor of Science in Computer Science and Engineering
School of Engineering
Santa Clara University

Santa Clara, California
June 5, 2014

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ABSTRACT

For our senior design project, we conducted research on the Android mobile operating system, looking for ways to improve it for the homeless. The problem with the current system is that it is designed for wealthier consumers, while less fortunate consumers such as the homeless have different requirements for them. In our researched, we attemepted to reconfigure the android operating system so that it would be more tailored to the homeless.

We first researched what features the homeless value in a mobile device. We then determined how we could improve the battery life at a user configuration level based on the requirements of the homeless. Following these initial improvements , we determined how we could improve the battery life of the android system by modifying the source code. We found that more conservative use of the processor has a noticable affect on the system's battery life. We recommend developing a version of Android that uses the processor more conservatively by default to save battery life.

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Chapter 1

Introduction

1.1 Problem Statement

For this project we wanted to perform research on how to best configure mobile smart phones to be better suited for homeless individuals. Currently, a problem arises because mobile phones are created for a wealthier consumer, with little concern for mobile phone use by lower income people. Our team proposes a low-cost and low-power phone for individuals who cannot access power sources and do not have the means to purchase such a phone. We worked with Qualcomms SnapDragon board as well as a Nexus 7 tablet to evaluate the current state of phones' power usage and hardware. Through our research, we discovered how to create a low-cost, efficient mobile operating system that meets the needs of the homeless community. This system is easy to use, and implements the power saving techniques we found in our research. Our solution can aid homeless people in their struggles with communication and access to power sources.

1.2 Background

The past few decades have seen a great increase in technological growth, leading to cheaper devices. Unfortunately, there remains a need for inexpensive sources of communication for the homeless community. It is important for the homeless to stay connected to society so that they can find services such as soup kitchens, mobile medical facilities, shelter, and career fairs. Mobile phones are required for people of all socio-economic standings.

Currently, mobile devices are quite expensive and require the owner to agree to a two-year service contract to bring the cost down. Phones that are currently available include unnecessary features that are often not applicable to someone living on the street. These devices are designed for people of higher economic standing. There is no phone that is tailored to the needs of the homeless, primarily that it is as power efficient as possible. Though there are lower-cost phones, they tend to lack some

of the features that the homeless do need, such as the ability to get on the internet and long battery life.

Various attempts have been made to create a more efficient phone in terms of energy efficiency, but such attempts are intended for expert phone users. Android is the primary operating system which has made changes to its kernel that aim to save energy. Even the kernels that show power saving potential do not maximize this potential, and because speed is the priority when improving the phone, there is still room for improvement with battery efficiency. These kernels and many others are usually side projects for the people who create them and tend to have little research attached to them. For this reason, our work provides great value to those interested in how to maximize power efficiency.

In the existing Android kernel, there are ways to change the CPU frequency, from the alteration of the CPU governor, to the powersave governor which minimize CPU frequency in order to save power. Though this is the case, the governor is not the default which comes with the phone, and changing to this governor requires a great deal of technical expertise.

Another alteration to the actual Android OS in an effort to save battery life was made by an individual named Jeff Sharkey[9]. He altered the screen color scheme to be displayed with varying types of filters, and discovered that with a display that only uses red pixels, the amps used were 42% of the overall Default color scheme. Unfortunately his results were found for an older version of Android and similar system changes have not been attempted for the current Android version.

1.3 Objectives

In order to carry out our research successfully we had to find the areas of the phone which show the most room for improvement. Our selected method of testing each attribute was through the use of the Trepn profiler application, which measures the amount of Watts used over time by the whole phone. We used these values later in order to compare each statistic that we find. Our research followed these steps:

1. Our initial objective was to find out how much battery life is improved when configuration settings are changed. Thus, we planned to run tests for battery efficiency while altering the Bluetooh, WiFi, and brightness settings.

2. After completing these initial tests, we planned to alter settings that are internal system settings. We did this by making changes to the CPU frequency minimum and maximum, the CPU governor, and applying a screen filter which will alter the color scheme.

3. Once we completed these tests we attempted to create a system profile which is significantly more battery efficient than the default system.

Chapter 2

Requirements

By communicating with the Community Technology Alliance (CTA)[1], we discovered the various needs of homeless individuals for their mobile phone. Their needs differ a great deal from ours in terms of priority. Wealthier consumers require ease of use with texting, the ability to check and write e-mail on the go, fancy picture taking abilities, and an aesthetically pleasing layout. We discovered that the homeless had much different requirements. We separated the requirements into functional and non-functional categories. Functional requirements define what the phone must do, and non-functional requirements define the manner in which the functional requirements are met.

Functional	**Non-Functional**
Efficient Battery Life	Affordable
WiFi Connectivity	Usable
Cellular Connectivity	Stable

Figure 2.1: Requirements Table

The most important requirements for the homeless are efficient battery life, Wifi connectivity, and Cellular connectivity. The homeless need WiFi and Cellular connectivity to stay connected to society. Hopefully these tools can aid them in getting jobs so that they can work their way out of homelessness. While conducting our research, we kept this in mind, and made sure that whatever we did to a device, it could still connect.

Battery life is arguably important to all users, but most only need their phones to make it through one day so that they can plug it in again before they go to sleep. The homeless need efficient battery life because they do not have the same access to power outlets to charge their phones. Unlike the welthier consumers, they do not necessarily have somewhere to plug their phones in every night

before they go to sleep. When they do charge their phones, they do not always have time to charge it completely. To stay connected and safe, they need their phones to last as long as possible, sometimes several days. For this reason, our research was directed at improving the battery life of mobile devices running the Android operating system.

Chapter 3

Technologies Used

3.1 List of Technologies

- Trepn Profiler[7]
- Dragonboard 8060a[6]
- Nexus 7 Tablet[4]
- Arch Linux[12]
- Oracle VM VirtualBox[5]
- Ubuntu 12.04 LTS[2]
- Android Debug Bridge (adb) and Fastboot[3]
- Android Open Source Project (AOSP)[3]

3.2 Trepn Profiler

Trepn Profiler is a diagnostic tool made by Qualcomm for profiling performance and power consumption of Android applications as well as the system as a whole on devices that use Qualcom Snapdragon processors. Trepn data can be saved as a comma separated value (.csv) file and transfered to a computer for analysis. We used the Trepn Profiler to collect data on power consumption on both the Dragonboard 8060a as well as the Nexus 7 tablet.

3.3 Dragonboard 8060a

The Dragonboard 8060a is a mobile development board made by Qualcomm, based on the Snapdragon processor. Qualcomm boasts that the Dragonboard is ideal for conducting research on mobile platforms and for teaching and learning electronic engineering.

We used the Dragonboard as our initial development device but began experience problems when we tried to make system changes. Since the Dragonboard is made by Qualcomm, it runs its own specific version of Android that no commercial devices use. Once we did find the source code for this specific version of Android, we ran into many issues compiling and running it. Due to these aspects, we eventually changed development devices to a Nexus 7 tablet. Figure 3.1 shows a photograph of the Dragonboard 8060a.

Figure 3.1: Dragonboard 8060a[6]

3.4 Nexus 7 Tablet

Google's Nexus 7 tablet, manufactured by Asus, is a simple, affordable tablet that uses Qualcomm's Snapdragon processor.

When we decided to continue our research on a new devices, we decided to use the Nexus 7 because like the Dragonboard, it has a Snapdragon processor[4], meaning that we could continue to run the Trepn Profiler. The Nexus 7 is affordable, which was not only convenient for us, but also reflected the demographic that we conducted our research for. We also chose it because it can run many different versions of Android, all of which can be found on on the Android open source project.

3.5 Arch Linux

The Android source must be compiled on a Max OSX system running a specific version of OSX and a specific version of XCode, depending on which version of Android you want to build, or on a Linux system that has been configured properly. Arch Linux is a popular Linux distribution among Linux users. It is lightweight, fast, and highly customizable. Arch Linux has a very active community, and a great wiki. Since we already had access to a machine with Arch Linux installed on it, and we knew that we could get support from the community, we initially used it as our development platform for the Android Open Source Project, however, after some running into platfrom issues, we switched to Ubuntu 12.04 LTS as our development platform.

3.6 Oracle VM VirtualBox

Oracle VM VirtualBox is a powerful, free, opensource virtual machine application that we used to create an Ubunu 12.04 LTS virtual machine within our Arch Linux machine. This configuration obviously created a lot of overhead and slowed our already long builds, so we eventually moved to a machine that ran Ubuntu 12.04 natively.

3.7 Ubuntu 12.04 LTS

Ubuntu 12.04 LTS is the Linux distribution that Google uses as their development platfrom for the Android Open Source Project. As mentioned, we started using this distribution as our development platfrom when Arch proved too dificult to configure properly for buildling Android.

3.8 Android Debug Bridge (ADB) and Fastboot

The Android Debug Bridge (ADB) is an Android SDK tool for interacting with Android devices form a Linux terminal. It can be used to install apps, login to the device's shell, issue shell commands to the device, and boot the device in bootloader mode. Once a device is booted into its bootloader,

Fastboot is used to communicate with it. From Fastboot, new system images can be flashed to the device.

We used these tools to modify the kernel governor, and flash new systems onto the device. When we have created our own boot image with our own kernel, we will use ADB and Fastboot to flash this new boot image onto the device.

3.9 Android Open Source Project (AOSP)

The Android Open Source Project contains the source code for Android and the tools needed to build and implemet the code. AOSP can be found and downloaded at source.android.com. On their site, there are instructions on how to download the Android Open Source Project, as well as instructions on how to download and build a kernel.

Figure 3.2 shows the layered structure of the Android operating system. The top layer, the Application Layer, is where all applications run. We knew that there was not much we could do to affect the system's power consumption at this layer, so we moved down to the next layer, Application Framework. This layer is responsible for managing the applications that are running on the system and the Java classes which run them. For example the Resource Manager allocates resources, such as memory, to the applications that are running. We decided that there was not much we could do at this level to have a significant effect on the system's power consumption. At the Android Runtime layer there is the Dalvik Virtual machine which is useful for emulating whatever changes are made to the system. Since we were attempting to test the power consumption of the device, we were not able to utilize this layer too much because it did not accurately emulate the power being consumed. In the Libraries layer, there are various packages which are utilized by the system in order to operate. Various attempts were made here to alter the scheme and find possibilities of altering power consumption, but for the most part it was not used.

The kernel is where there is the most opportunity for improvements in power efficiency. The Android operating system uses the Linux kernel in order to maintain basic system functionality. During our project, we were primarily concerned with the kernel's control of the CPU. Within the kernel there are various settings which control both the minimum and maximum CPU frequency, or rate at which the CPU operates, as well as when it increases the CPU frequency. The governor is the unit which controls the increasing or decreasing of CPU frequency. This is primarily where we were able to make changes, and used the powersave governor which maintained a low CPU frequency at all times. The default governor was the ondemand governor, which sets the frequency depending on

how much of the CPU is being used.

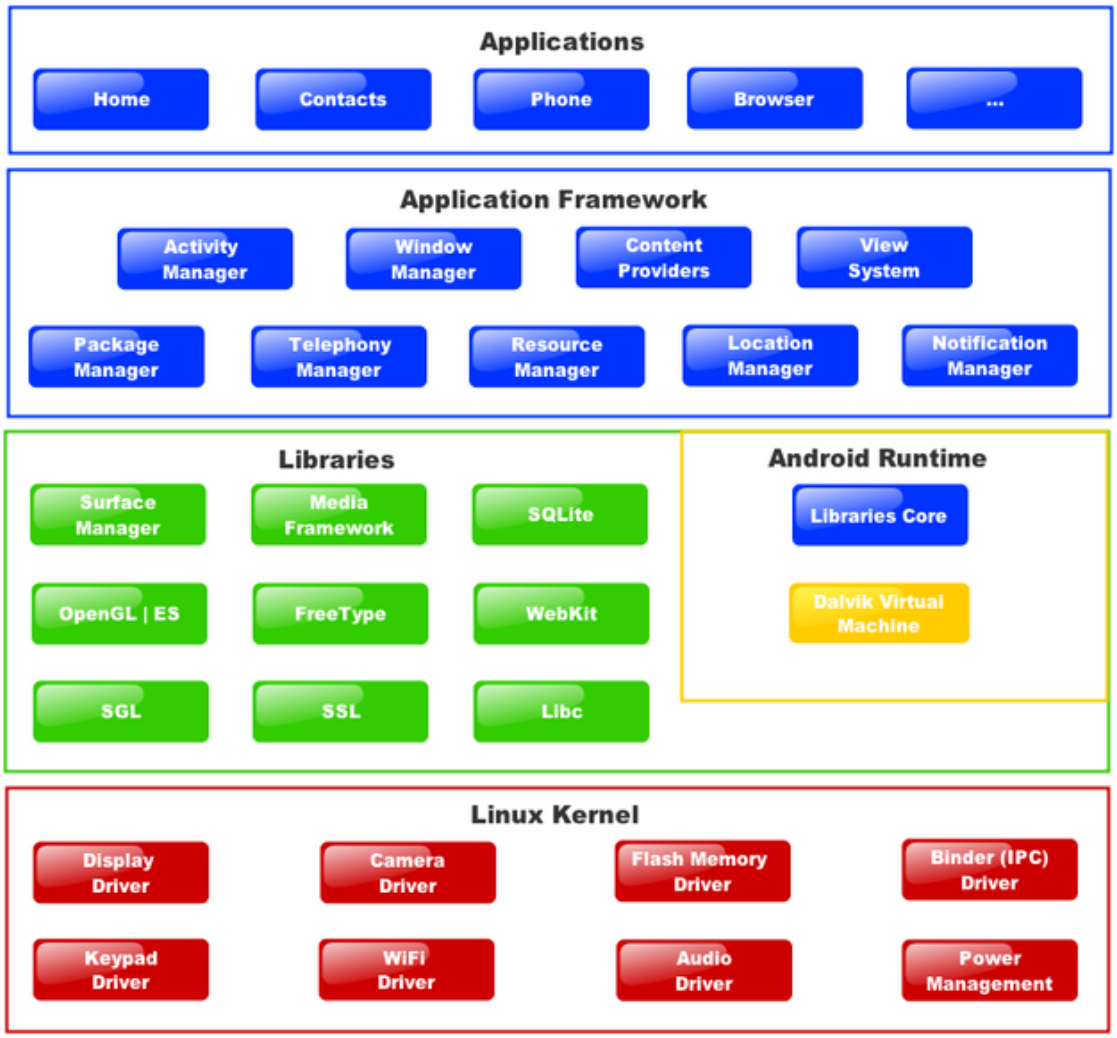

Figure 3.2: The structure of the android operating system[8]

Chapter 4

Research Plan

Before beginning our research, we carefully designed a plan for how to go about finding accurate and desirable results. We did this by breaking our overall research into two parts: system and device settings. Within each change, we made baseline tests, isolated change tests, and then made comparisons based on the results.

4.1 Testing

In order to find results which would accurately translate to an estimation of power use, and eventually the number of hours the device could be used, we needed tests that would provide such information. In addition, in order to create results which were comparable, we needed to set up as constant an environment as possible. Without a consistant test, our results would show inaccurate statistics which would skew our data and make it nearly useless in terms of comparing with other tests.

4.1.1 Measurements

Our Trepn profiler provided many different types of statistics which were measured over time. We were primarily concerned with power usage, which was measured by the Trepn profiler in the form of battery power. The units for this measurement was in micro watts (μW). The measurements for the time was in milliseconds (ms). Based on these values, we were able to see how much power was consumed over a period of time. After completing all of our tests with the Trepn profiler and recieving wattage, we also sought to translate these values to a rough estimate of how long the device would last in terms of hours. We accomplished this using the following equation:

$$Hours of Activity = (Ah \times V) \div W$$

Where Ah stands for Ampere-hours, V for Voltage, W for Watts used. We found the Ampere-

hours and voltage of the Nexus 7 hardware to be: 3.7 V and 3950 mAh[4]. The Snapdragon S4 APQ8060A Ampere-hours and Voltage were: 2200 mAh and 3.7 V[6]. In order to apply a wattage to this equation, we calculated the average of our Trepn profiler results over the amount of time.

4.1.2 Consistant Testing

We needed to not only test an environment with as little differentiation between tests as possible, but also an environment which was a somewhat accurate simulation of how homeless individuals would be using a mobile device. We accomplished this by first and foremost eliminating all applications running in the background except the Trepn profiler. Any other applications running in the background could increase battery usage and thereby ruin our results. We made sure to turn off the device's sleep mode in order to ensure that the device's screen light would stay on as if it were in use. We would also require a set amount of time that the profiler would run in case allowing the device to run longer affected the amount of Watts used. We ran each test for 2 minutes and used those results.

For the first set of tests where we only manipulated the configuration settings on the device, we chose to simply allow the device to stay on with whatever configurations we chose to set, and then retrieve the results. For the second set of tests, we found that using the Nexus 7 was superior because it allowed us to more easily alter the system settings and it had a newer version of Android with more resources available. For this second set of tests, we provided a consistant environment by keeping all applications except the Trepn profiler as well as Google Chrome running. In this test we utilized a browser because we felt that it would be a better indication of how long the Nexus 7 would last if a homeless individual were using it. Again, we tested for 2 minutes and stopped after these results were found.

4.2 Configuration Tests

Before making any system changes, we wanted to see where in the configuration settings the largest opportunity for battery life improvement might be. This being the case, we tested the configuration settings of the SnapDragon in order to see how Bluetooth, WiFi, and screen brightness would effect power consumption of the device. In order to do so, we needed to isolate each test as well as have a baseline test to compare with. We accomplished this by first creating a test with Bluetooth, and WiFi off and screen brightness on its lowest setting. In addition, we decided to create a test with all settings on and the brightness at its highest setting. After we established baseline tests which we could compare our results to, we individually turned a configuration setting on with the rest off (or

in the case of brightness, turned down to its lowest level) . This allowed us to accurately compare graphs from the Trepn profiler. Below is a table indicating each test and their corresponding value. For Bluetooth, a value of 2 indicated on, and 0 indicated off. For WiFi, a value of 3 indicated on, and 1 indicated off. Screen brightness has a minimum setting value of 30 and a maximum of 255[7].

Test	**Bluetooth Only**	**WiFi Only**	**Brightness Only**	**All On**	**All Off**
Brightness Setting Value	30	30	255	255	30
Bluetooth Setting Value	2	0	0	2	0
WiFi Setting Value	1	3	1	3	1

Figure 4.1: Configuration Test Settings

4.3 System Tests

After performing configuration tests, we needed to make changes at the system level somehow. We needed to do this because the internal system of operating systems tends to be directed at a wealthier consumer who wants a fast device with a highly aesthetic appeal. Both of these attributes come with a sacrifice in battery life, which is our primary concern in development for homeless individuals. We decided to concentrate on the CPU frequency maximum and minimum levels, the CPU governor, and screen filters as variables for these tests. For these second tests, we used the Nexus 7 while still using the Trepn profiler.

In order to change the minimum and maximum frequency of the CPU frequency as well as the CPU governor, we used an application called *No-Frills CPU Control*[10]. In this application, we were able to select the desired minimum and maximum CPU frequency, as well as the CPU governor, with the push of a button. For the screen filter, we selected an app called *Twilight*[11]. This app placed a red screen filter which made the user interface of the device seemingly red. In order to magnify these effects, we turned the screen brightness to full when the filter was both on and off.

Once we had all of the applications we needed, we tested the baseline settings just as we had

with the configuration tests. This was accomplished by making an initial test using all of the default settings for the Nexus 7. After doing so, we isolated each of the variables we had by changing them to particular values and tested their performance individually. We also chose to perform a test with the brightness at full in order to compare with the screen filter test, during which we also had the brightness at full, thereby magnifying the filter's effects on battery life. Below is a table of each test and their corresponding settings. For each individual test, as mentioned before, we left the WiFi on and used Google Chrome.

Test	**Default Settings**	**Governor Change**	**CPU Frequency Min/Max Change**	**Full Brightness**	**Screen Filter**
Brightness	30	30	30	255	255
Minimum CPU Frequency	1.026 GHz	1.026 GHz	384 MHz	1.026 GHz	1.026 GHz
Maximum CPU Frequency	1.512 GHz	1.512 GHz	594 MHz	1.512 GHz	1.512 GHz
CPU Governor	ondemand	powersave	ondemand	ondemand	ondemand
WiFi	3	3	3	3	3
Bluetooth	0	0	0	0	0

Figure 4.2: System Test Settings

4.4 Homeless Configuration

After performing our research, we intended to use our results to create an Android configuration for the purpose of being used by those who desire a power efficient device rather than one that is optimized for performance. We did this by analyzing our research results in order to find out where the most power consumption of the device is. After we discovered attributes of the device where we thought we could make the greatest changes, we customized the Android operating system to default to the changes we made. By doing this, we had a flashable operating system that did not require technical expertise in order to use. This means that potentially homeless individuals will have the opportuniy to purchase a mobile device with the homeless configuration of the Android operating system and use it. We ended up finding that lowering the maximum and minimum CPU frequency had a significant effect on battery life, as did the use of the powersave governor. We decided to combine these two battery efficient alterations into one kernel and create a loadable boot image for the Nexus 7. We used the powersave governor, set the minimum CPU frequency to 384 MHz and the maximum to 594 MHz in our new "homeless" kernel.

After we had a fully functioning configuration which required little to no technical expertise, we performed tests on the device and compared our results with previous test results. We accomplished this by following a similar process as the one used in previous tests on the Nexus 7. This consisted of us browsing the web on Google Chrome while using the Trepn profiler over a 2 minute time span to calculate power consumption.

In addition to calculating power consumption, we also ran a timer from a shell for Google Chrome, which connected with the Nexus 7 and calculated the length of time a web page took to load. Because accessing the internet is such an important aspect of homeless life, we needed to make sure that our alterations to the kernel did not have a devastating effect on the length of time it took to access webpages. We measured this in milliseconds and accessed Google, Yelp, Craigslist, and LinkedIn websites.

Chapter 5

Research Results and Analysis

Through our tests on both the configuration and system settings, we found out a great deal of information about the Android operating system and where battery efficiency improvements can be made. We went into each test with an open mind, but expected certain changes to result in improvements in battery efficiency. We did not know exactly how much of an effect each individual change would make to the battery life, and this was our primary concern.

5.1 Configuration Test Results and Analysis

The configuration tests resulted in varying power at certain elapsed times. In order to analyze these results, we created scatter plots for each test (see Figures 5.1- 5.5. Because each graph had fairly sporadic power levels, we used the trend line feature of excel to provide a better display of how much power was used during the trepn profile. After we performed each test, we recorded the average amount of power used. Upon finishing all of the tests, we created a cumulative graph with each trendline in order to easily compare each test's effects (see Figure 5.6).

5.1.1 Results

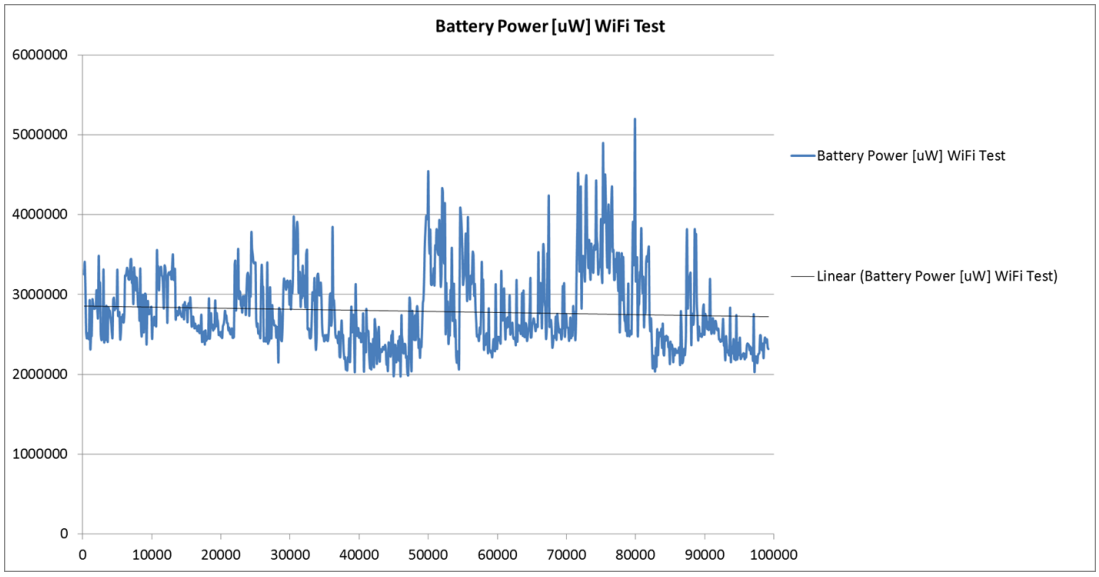

Figure 5.1: WiFi Power Usage Results

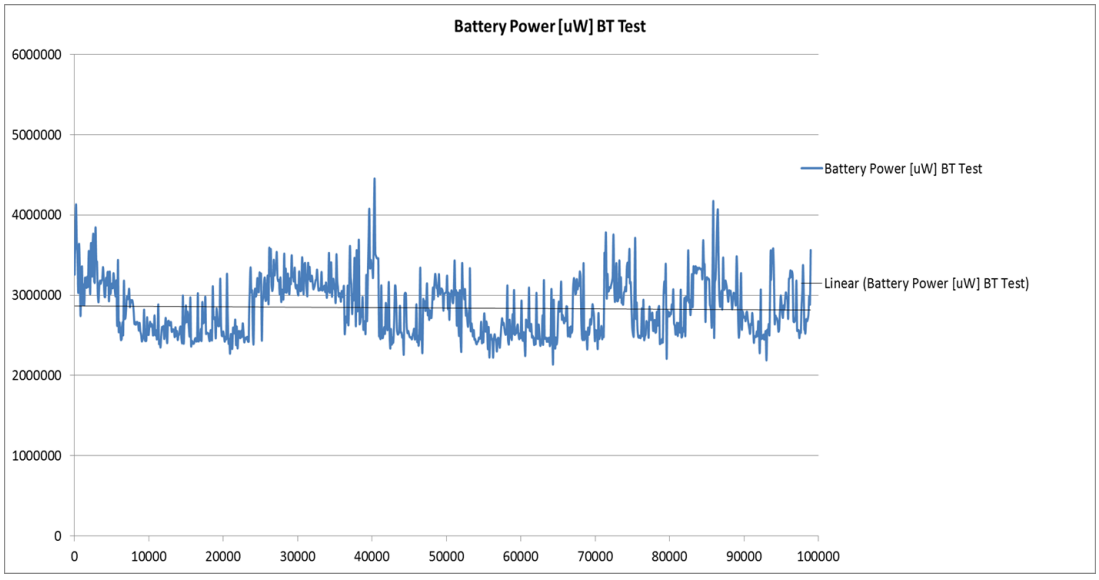

Figure 5.2: Bluetooth Power Usage Results

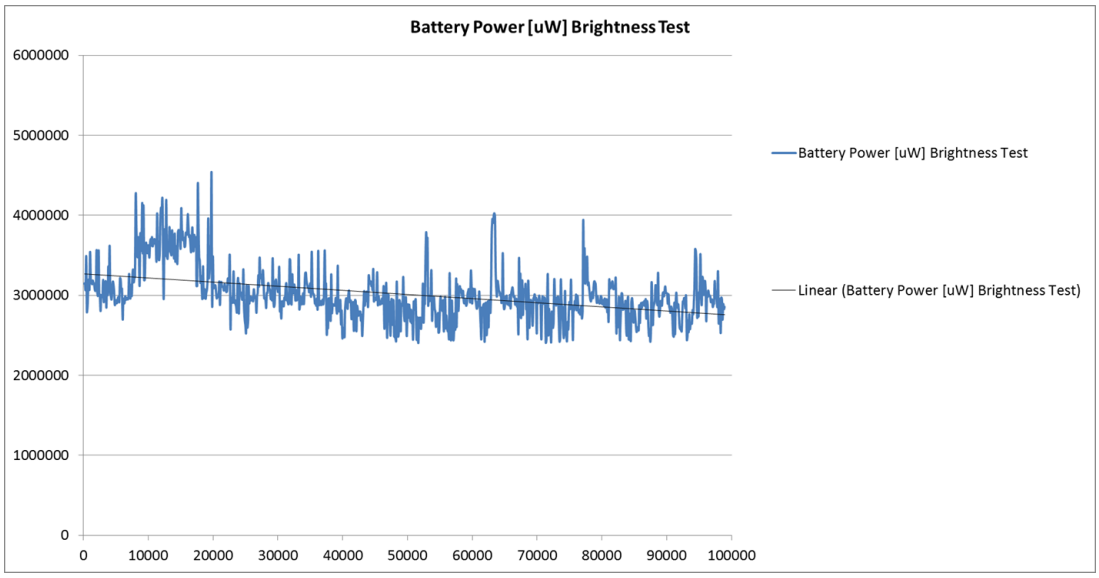

Figure 5.3: Brightness Power Usage Results

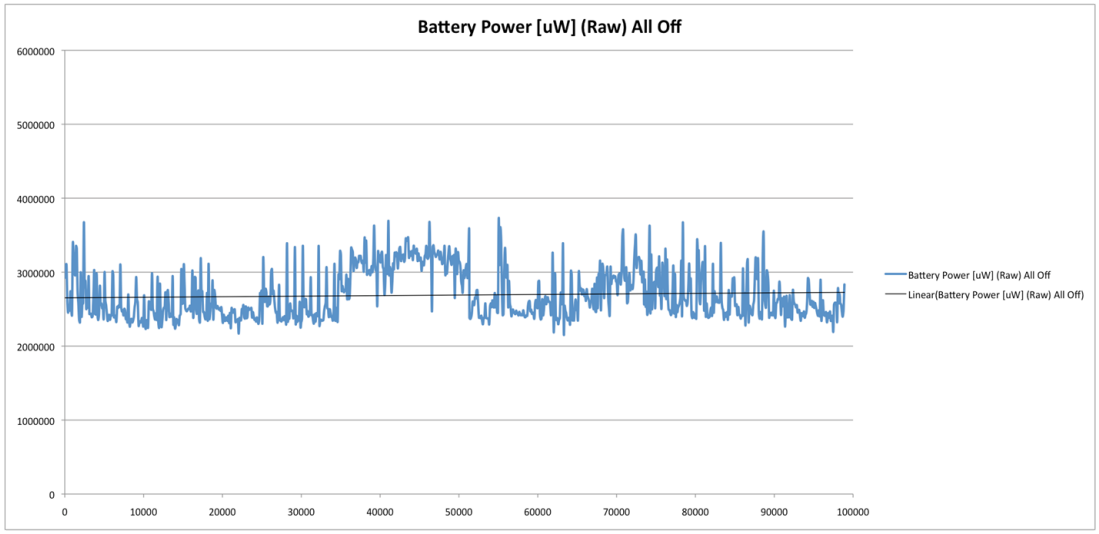

Figure 5.4: All Configuration Settings off Power Usage Results

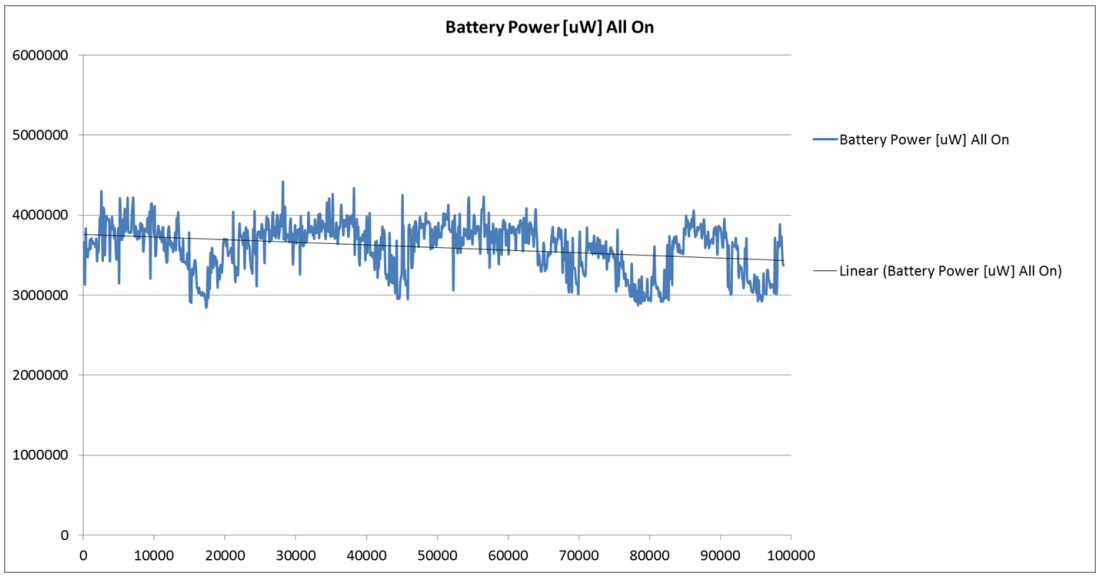

Figure 5.5: All Configuration Settings on Power Usage Results

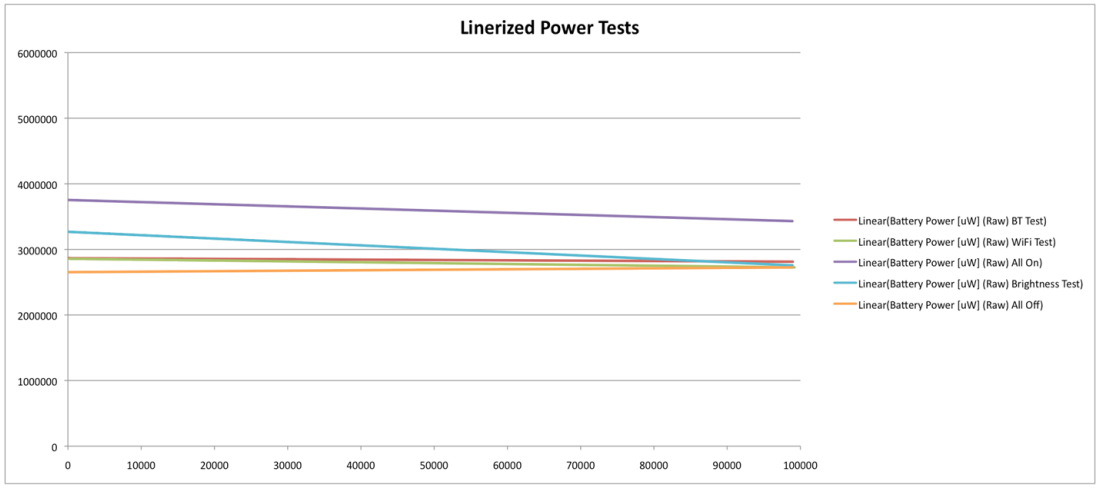

Figure 5.6: Cumulative Linearized Configuration Settings

Test	**Bluetooth Only**	**WiFi Only**	**Brightness Only**	**All On**	**All Off**
Power Used (μW)	2839738.77	2793961.89	3013765.67	3592854.19	2689959.27
Estimated Usage Time (hours)	2.87	2.91	2.70	2.27	3.02

Figure 5.7: Configuration Test Average Power Used and Estimated device Life

5.1.2 Analysis

After recieving our results, we were not entirely surprised by what we found. It can be seen that turning each individual setting on or to its highest setting has a negative effective on battery life. With all of our settings off and turned down, we found an estimate of 3.02 hours of battery life, and with all settings on we found an estimate of 2.27 hours of battery life. Though seemingly insignificant, we were constrained both by the battery and the outdated operating system. When observed in terms of the ratio of battery life, turning all of these settings off from the on state results in 1.33 times more battery life, which is quite significant.

We found that individually the Bluetooth and WiFi had little effect on the battery life with estimated hours of 2.87 for Bluetooth and 2.91 hours for WiFi compared to the 3.02 hours with all of these settings off. Having the WiFi on only takes the battery life to 96.3% of the battery life of the device with all settings off. This is actually a good sign however, because it means that homeless individuals need not worry as much about having their WiFi on due to its battery consumption. We did not find any evidence of homeless people having a high desire for Bluetooth, but in the case that they do need it, it only takes the battery life to 95% of what it is when this setting is off.

The most signficant effect on battery life was the screen brightness. We found that turning the screen brightness all the way up has a devastating effect on battery life, given an estimated usage time of 2.27 hours. This is 75% of the battery life when the brightness is all the way down. This shows ample room for improvement, and neccessarily so. When using a device outside on a sunny day, it is quite difficult to see the screen on one's device due to glare. This is especially problematic for people who live a nomadic lifestyle and tend to be out in the sun for long periods of time. This essentially implies that homeless individuals only recieve 75% of their device's battery life while using their mobile device during the day.

We found through our tests that brightness has the largest effect on the battery efficiency, with WiFi and Bluetooth have little effect. One aspect that might skew our results is that the WiFi and Bluetooth being on have an effect even while the device is in sleep mode. The brightness of the device only has an effect on the device when the user is interacting with the device. Ultimately, these configuration test results are quite valuable because they are built in settings that can be quickly changed without technical knowledge in order to conserve battery life.

5.2 System Test Results and Analysis

We performed quite similar tests for the system as we did in our configuration tests. We still used a linearized trendline for each graph in order to give a better indication of the power usage. Instead of having one baseline test for each varied system test, we had a default test graph with the brightness low to compare with the CPU frequency and CPU governor alteration graphs. For the screen filter, we chose to increase the brightness in hopes that we might magnify the effect of the red screen filter.

5.2.1 Results

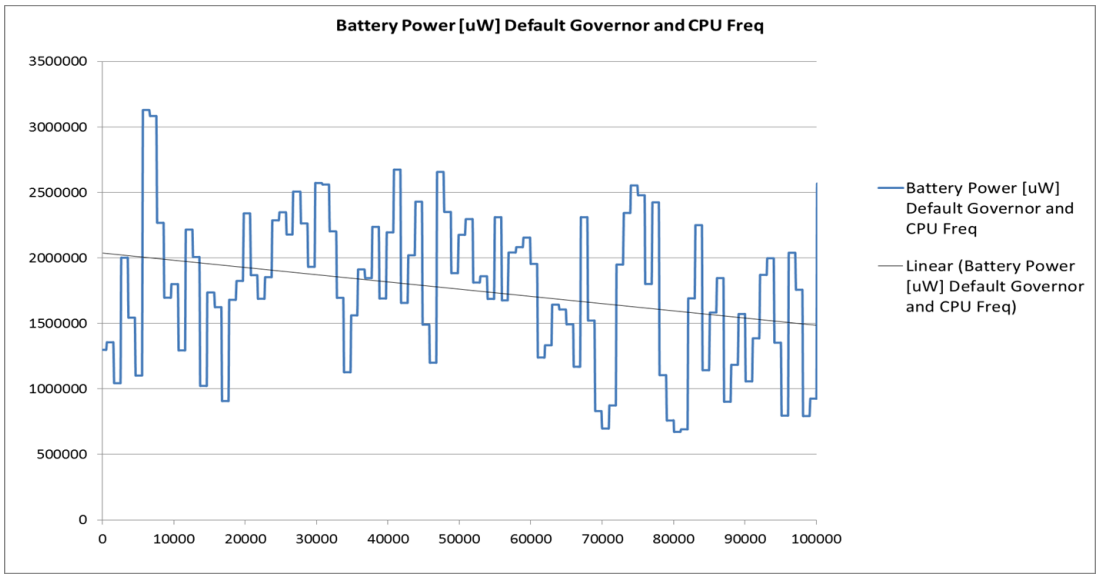

Figure 5.8: Default Settings Power Usage Results

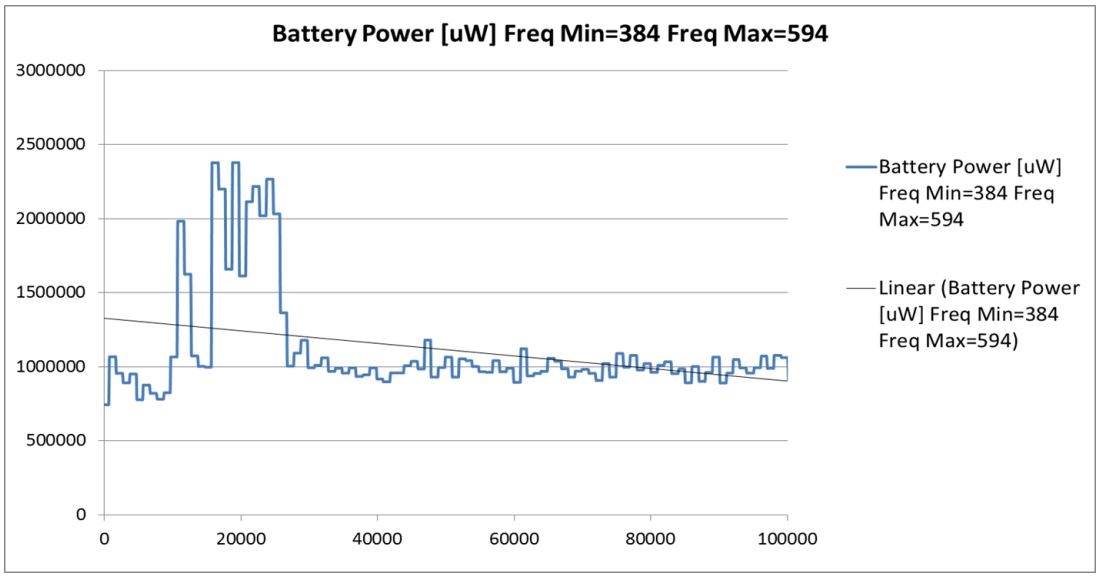

Figure 5.9: CPU Frequency Change Power Usage Results

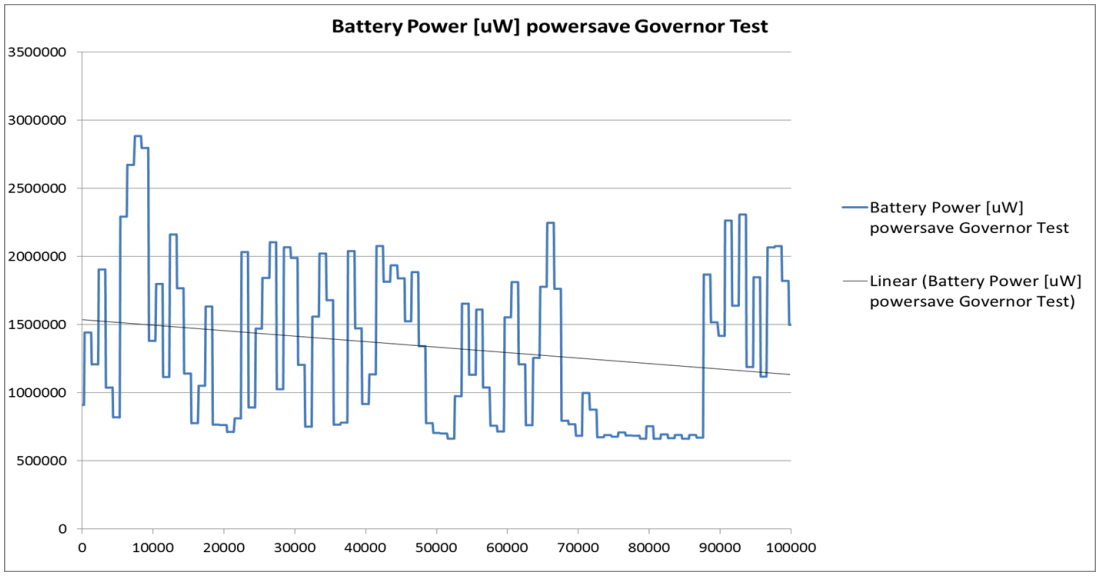

Figure 5.10: powersave Governor Power Usage Results

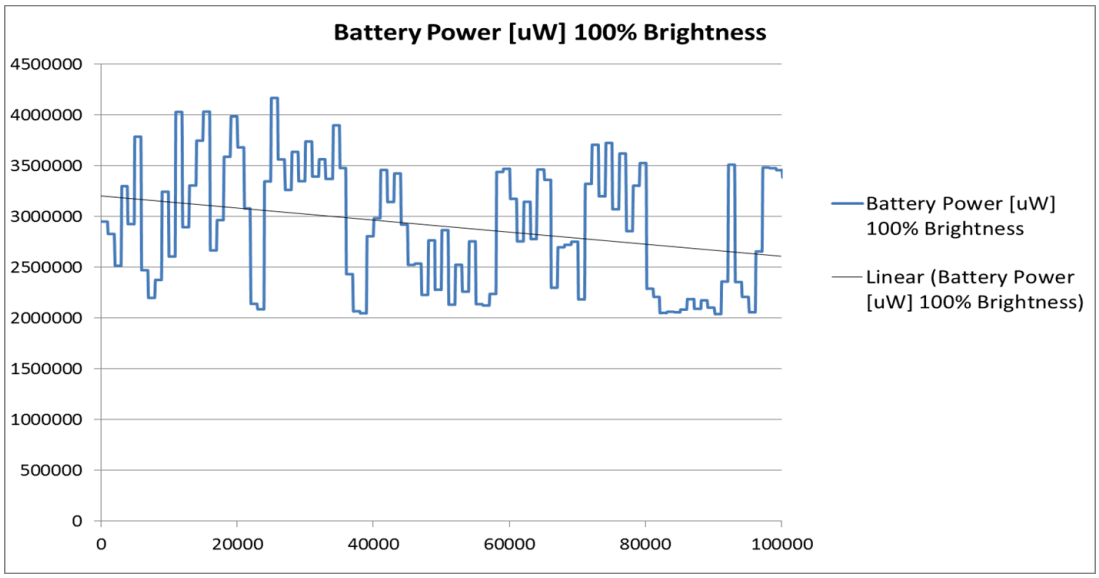

Figure 5.11: Full Brightness Power Usage Results

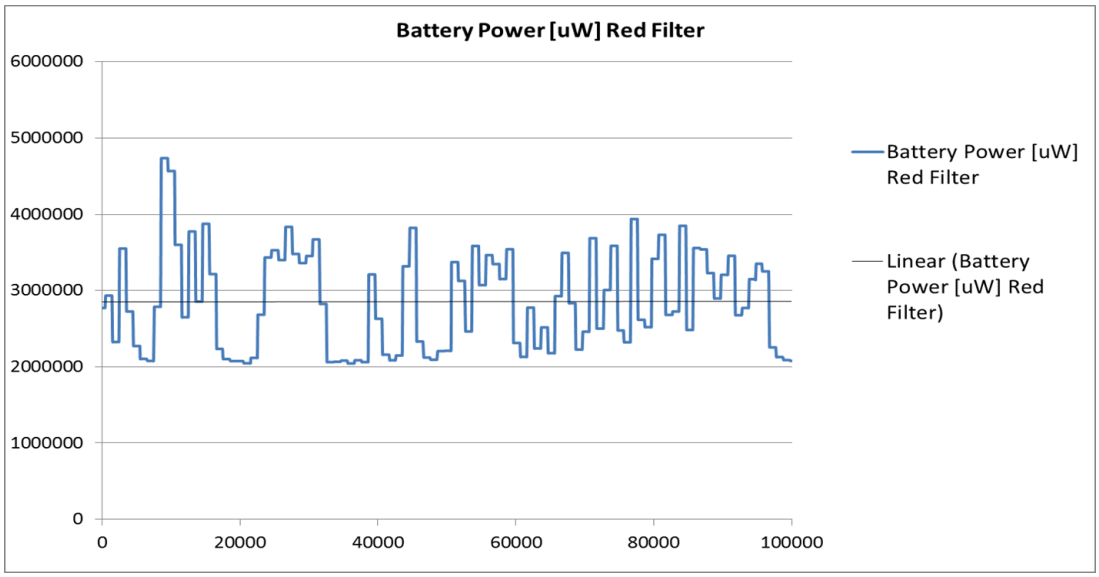

Figure 5.12: Red Filter Power Usage Results

Test	Default Settings	Governor Change	CPU Frequency Min/Max Change	Full Brightness	Screen Filter
Power Used (μW)	1697608.53	1443032.64	1373488.27	2710691.19	2761176.19
Estimated Usage Time (hours)	8.61	10.12	10.64	5.39	5.29

Figure 5.13: System Test Settings

5.2.2 Analysis

After changing the system settings that controlled the CPU frequency, we had a great deal of improvement in battery life. The default CPU settings showed an estimated usage time of 8.61 hours. Changing the CPU governor of the device to the powersave governor led to an estimated battery life of 10.12 hours which was 1.18 times the amount of battery life with the ondemand governor. Though this is not as large an effect as turning the brightness down, it is significant because the CPU governor is constantly being used and therefore it is always conserving the amount of powerused even when the device is on sleep mode. Even more impressive was the change to the maximum and minimum CPU frequencies. The battery life after lowering these frequencies was 10.61 hours, which was 1.23 times the amount of battery life of the default frequencies. Again, this is important because these are settings which persist even when the device is in sleep mode. In addition, these settings can be combined to create an even longer lasting device. Typically changing these settings has a drastic effect on the speed of the device, but this is a less crucial attribute for homeless individuals than the battery life. While using the web, we found very little noticeable effect from lowering both of these attributes, though we did not perform any actual tests to measure this. The extra 2 hours of device usage is a great deal, and provides crucial device usage for the homeless.

Changing to full brightness on the Nexus 7 had a much greater effect on battery life than when we changed this setting on the Snapdragon. We calculated an estimated battery life of 5.39 hours when the brightness was turned on full. This is 62% of the battery life when this setting is all the way down. Since we had already performed a test on the screen brightness, we were less concerned about the results of this test and more concerned about it as a comparison to our filter test. It is also important to note that this difference in effect on battery life is likely a product of the screen size of the Nexus 7 which has a screen specification of 7. The Snapdragon on the other hand has a screen specification of 4". This significant difference is a likely cause of the greater effect on battery

life.

When we changed the screen filter in hopes of reducing power consumption, we actually found the exact opposite. The battery life was estimated to last 5.29 hours with the red filter applied. We concluded that this is the case for a number of reasons. One of the main reasons is that the screen filter is not acting on the actual individual pixels of the display and is instead simply providing a red tint to the screen rather than a filter. In order to see an actual reduction in power consumption, one would need to alter the Android source code where each pixel is allocated. By doing so, one could remove the other colors that make up a single pixel which would lead to less power consumed by the user interface. In addition, when we ran the full brightness test we were not running any applications other than Google Chrome and the trepn profiler. When we applied the filter application, the applicatication was constantly running in the background in addition to the screen brightness. Because an additional application was running, it caused a greater power consumption than when only the brightness had been altered. Unfortunately this leaves us without a conclusion as to whether or not altering the pixel color effects the battery life of the device.

5.3 Homeless Configuration Results and Analysis

After we had found results from each of the configuration and system tests, we decide to make a boot image for the Android operating system and test how much our configuration would improve the battery efficiency.

5.3.1 Results

For our homeless kernel test, we chose to only perform one test which would compare to the rest of the tests we had performed with the Nexus 7. We still used a linearized trendline for our graph in order to give a better indication of the power usage. We used the lowered minimum CPU frequency of 384 MHz and maximum of 594 MHz for this test, as well as a powersave governor.

Not only did we test battery efficiency, but we also tested the amount of time to load Google, Yelp, Craigslist, and LinkedIn to make sure the changes did not have a drastic effect on such an important utility for the homeless. We found the results of this elapsed time in milliseconds.

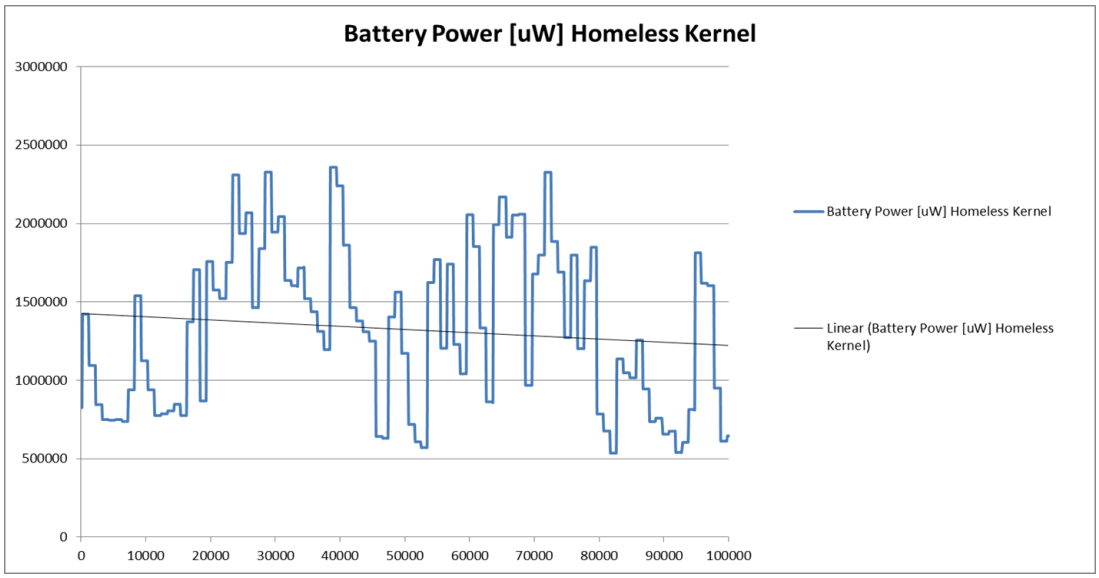

Figure 5.14: Homeless Kernel Power Results

Test	**Default Settings**	**Homeless Kernel**
Power Used (μW)	1697608.53	1307428.828
Estimated Usage Time (hours)	8.61	11.17

Figure 5.15: Homeless Kernel Results

Website Elapsed Time (ms)	**Default Settings**	**Homeless Kernel**
Google.com	1445	5398
Craigslist.com	1202	17050
Yelp.com	2733	7334
Linkedin.com	635	1364

Figure 5.16: Homeless Kernel Page Loading Time

5.3.2 Analysis

When we made our collective system changes and combined them into a single kernel, we saw quite a significant improvement in battery life. As we observed before, we found that with the default frequency and settings we estimated 8.61 hours of battery life. After changing the kernel to our customized homeless kernel, we found that there was an estimated battery life of 11.17 hours. This was a 29.7% increase in battery life. This is a potentially life saving statistic because that nearly

30% more battery life translates to almost two hours for the Nexus 7. Though it might be less of an increase in battery life for a homeless person's mobile device, it is still a significant time increase in useage which would potentially be lifesaving and a change which is absolutely free of cost or technical expertise, assuming they could purchase the phones with the boot image on the phone.

We found less than pleasing results when we attempted to navigate various webpages. When we tested the timing for the Google homepage, we found that for the default kernel it took 1.445 seconds and for the newly installed kernel it took 5.398 seconds. This was a signficant difference in time, and was much worse when we tried to visit Craigslist. Visiting Craigslist on the regular kernel took 1.202 seconds and using our homeless kernel the page took 17.050 seconds to load. We concluded that this is likely because this was the one webpage which did not have a mobile website, which caused it a much greater loading time. When we tested Yelp we had around a 5 second difference between our kernel and the default, which was significantly less than Craigslist but still greater than visiting Google. Finally, we found a much smaller difference when we visited LinkedIn, with a default kernel time of .635 seconds and homeless kernel time of 1.364 seconds. In terms of ratio, this is still double the time it took initially and is quite disappointing.

Despite the times being significantly greater, homeless individuals might be willing to make this sacrifice in order to have a longer lasting phone for phonecalls or other tasks which might not show as significant a difference in time. We were not able to test repeated lowered frequencies, but we felt that this was a large source of issue with regards to timing of webpage loading. Had we been able to perfect the frequency to the point where a signficant amount of battery life was improved while having a more manageable phone in terms of speed, we might have a device which could be better suited for the homeless community. Despite the slowness of the phone, it does indeed still work and in a more energy efficient manner, which was ultimately our goal. We were forced to take away the luxury of a rapidly reacting phone for much needed hours of battery life.

Chapter 6

Societal Issues

In accordance with the School of Engineering, we will address the societal issues that are relevant to our project.

6.1 Ethical

We believe it is of the upmost importance that we follow the Software Engineering code of ethics set forth by the Association for Computing Machinery (ACM) and International Electrical and Electronics Engineers (IEEE). After reviewing this code of Ethics, we found that our work on this project is indeed consistent with it.

After reviewing this code of ethics, we found that our work on this project did not raise any social ethical questions because it promotes social justice and equality for marginalized members of society. Our target users are ostracized because they do not have the means to communicate and network that we do. Many marginalized people go to great lengths so that they can have a phone so that they can stay connected with society, and hopefully work their way out of the margins. It is difficult for these people to to afford a cellur phone and plan, but they do it anyways because smartphones allow them to communicate in all of the ways that we do today. Since these phones are designed for wealthier consumers, and the homeless only make up a fraction of the customer base, their needs are often overlooked. Through our research we attempted to develop a better system, designed with the homeless in mind.

6.2 Social

If implemented, our project will not have any negative social impact in society, as it is designed to aid societal improvement by helping those in need. As members of Santa Clara University we are responsible for promoting social justice and equality. Today there is a large gap between the

wealthy and the poor, and as the poor are disconnected from society, they lose opportunities to get themselves out of poverty. This cycle increases the social stratification. With our project we hope to aid these people in staying connected, and hopefully working their way into a better financial situation and social standing.

6.3 Politcal

Political issues do not have any relation to our project.

6.4 Economic

Economically, there were many issues we ran into with our project. One particular issue was that we experimented with an operating system which is used on a variety of different types of mobile devices, but these devices are not always the most low cost devices available. This was an issue because we were attempting to distribute a power efficient phone to homeless individuals who might not be able to afford such a phone. Typically the homeless youth use a different type of phone, called a feature phone, which seems to be directed toward this population.

Since we were trying to cater a phone to the homeless population, economy was of great importance. Unfortunately we were unable to alter the hardware which is the primary place where costs can be reduced. Even if we were able to alter the hardware to make it a cheaper phone, a company would still be required to manufacture such phones and might still potentially not make money off the phone if homeless individuals did not find it useful.

6.5 Health and Safety

Our project could improve the health and safety of the homeless because they are safer when they have a functioning mobile device so that they can call 9-1-1 in an emergency. Our project will enable these devices to last longer so that the homeless are protected by them for a longer period of time. Not only this, but being able to access food shelters and meals in general partially depends on the mobile phone for homeless individuals and, if their phone dies they may go hungry.

6.6 Manufacturability

Our project will be easy to implement because mobile phone manufactureres can simply offer their devices with our system for those who need extra battery life and are not concerned with having a high perfromance device. This way when someone purchases a mobile phone, they could be offered

our alternative, power-efficient version of Android so they would not have to install a new system by themselves. Since most phones are directed toward a wealthier consumer, it may be difficult to find companies who want to deploy our version of Android on their phones. We aim to make a convincing argument in favor of providing an operating system option for their phone which would be free of extra costs because Android is open source and therefore free.

6.7 Sustainability

Our project will be sustainable in the sense that it will continue to be viable and useful for as long as the Android operating system is run on mobile devices. Since the main focus of our project became Android kernel governors, which are part of the Android system, adding our own governor to the system will mean that it can be maintained along with the Android system.

Our project will be sustainable in the sense that it will use resources effectively so that it can sustain its life for a long time because that is the intention of our project, is effect resource management in order to conserve energy and extend battery life.

6.8 Environmental Impact

Our project is related to the environmental issue of energy. Since our project is meant to conserve energy by lowering the power consumption of mobile devices, it will have a positive impact on the environment. Though the manufacturing of mobile devices is not environmentally friendly, our project aims to make the devices themselves more environmentally friendly. We will do this by using less power with a more battery efficient phone. In doing this, people will need to charge their phones less frequently and thereby aid in reducing power consumption. We will not be altering hardware, and thus will not have an effect on recycling or disposal of actual hardware parts which inevitably hurts the environment.

6.9 Usability

Our operating system is as simple to use as the regular Android operating system . From a user's standpoint, there is no difference in use of the system. The only difference is within the system, that a user will never see. Because the Android operating system is already quite user friendly, there is little problem being able to interact with one's mobile phone. We did end up slowing down the phone a great deal in order to improve battery consumption, which made is slightly more difficult to use the device. In addition, if we had chosen to implement a screen alteration in order to conserve

battery, it may be difficult for some to see the display, but thus far we have not seen this to be a problem. A final change we could make going forward is the implementation of a button which would turn the phone on a low battery mode to sustain battery life. If we did implement this feature, it would be quite easy to use and require little to no technical knowledge.

Chapter 7

Project Management

7.1 Project Timeline

Below is the timeline of our project in the form of a Gantt chart. Because our group consisted of two people, we chose to work on every task together. The different colors on this chart differentiate the different tasks being completed. It can be observed in our chart that we did most of our documentation in fall quarter, and the thesis was done in spring quarter. Our design conference documentation was done beginning in winter quarter and through spring quarter. Our actual research was conducted over a long period of time because we had a dynamic project scope that was constantly changing direction, and thus the direction of our research. Our measurements were taken partially during our research plan because we would create a test and then proceed to take measurements, and then come up with another test.

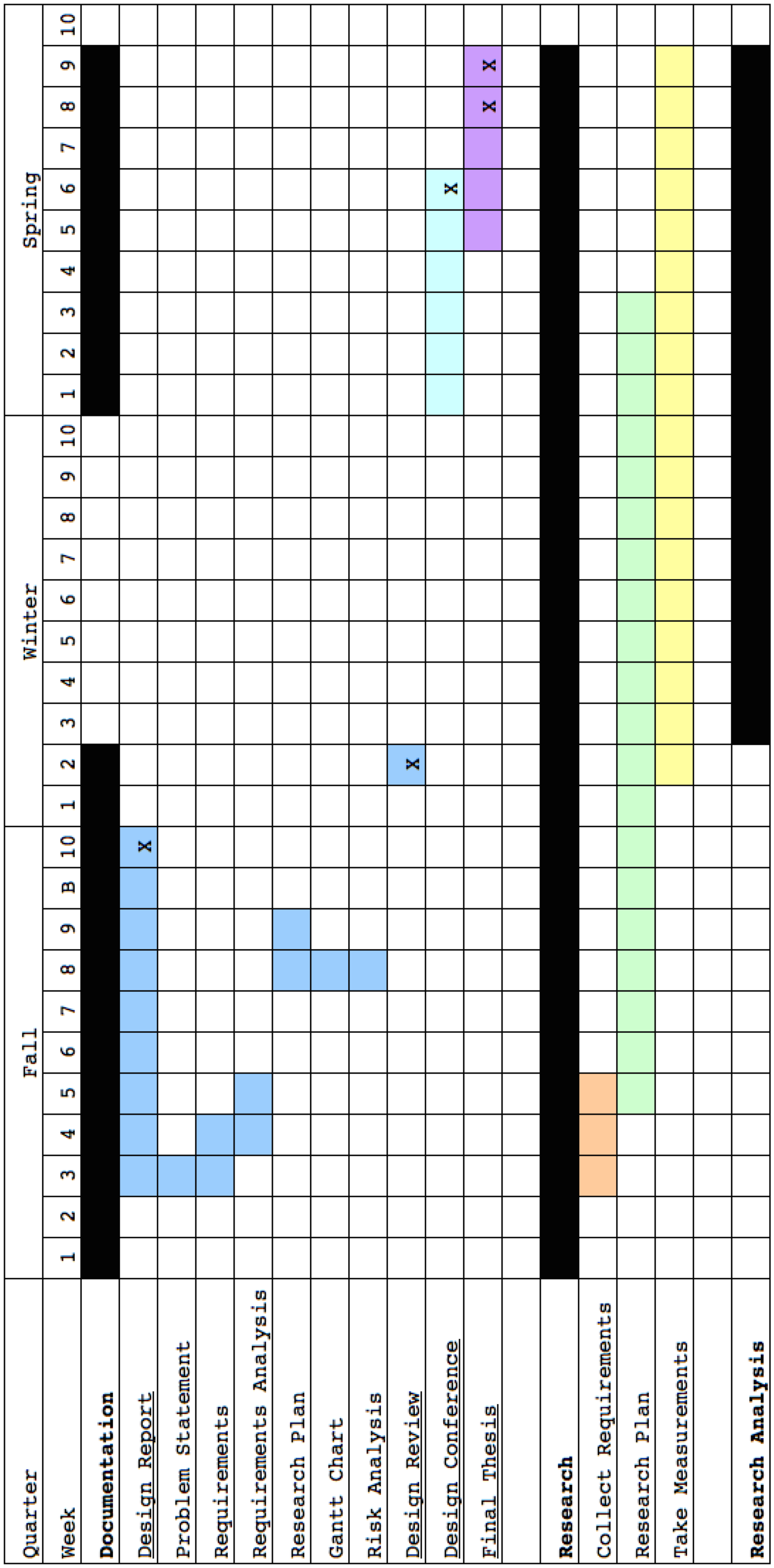

Figure 7.1: Project Timeline

7.2 Risk Analysis

Below is a table with our risk analysis for the project. In the first column we came up with risks for our project, and then in the second column we predicted their potential consequence. We then measured how important they were by multiplying their probability to occur (P) and severity if the event does occur (S) in the third and fourth columns, to provide an importance value (I) in the fifth column. Finally, we came up with ways around each of these issues, which is located in the column with the heading "Mitigation Strategy".

We ended up finding that time was indeed the most important, as it ended up having a huge effect on our project. Much of what we were trying to do was a difficult task in the amount of time we had. We had to do a great deal of learning about the Android operating system, which we did not expect, and it ended up being quite costly in terms of time. We could have avoided this issue by doing more research at the beginning of our project about the operating system, so we would know what we were going to be dealing with down the road.

Risk	Consequence	P.	S.	I.	Mitigation Strategy
Time	Inconclusive research	.50	8	4	Prioritize results and speak with customer to stay on track
Unable to find mobile phone improvements	Research does not provide use to mobile phone companies	.2	9	1.8	Change scope of project
Conclusions made are not valuable to mobile phone companies	Mobile phone for homeless is unable to be created	.2	8	1.6	Meet with customers regularly to discuss requirements
Loss of research results	Forced to restart research and obtain results	.1	9	.9	Back up research results

Chapter 8

Conclusion

8.1 Summary

Our goal for this project was to ultimately perform research which could help the homeless individuals of the world stay connected and improve their connectedness. The issues that wealthy phone consumers have with their phones are far different from marginalized people. We found that we could help these individuals through creating a phone configuration which was more suited toward their needs, primarily a longer lasting mobile device.

We initially tested various configuration settings and their battery efficiency, then we tested lower level system settings regarding CPU frequency and display drivers. Finally, we used our knowledge and analyses from these tests in order to create a more battery efficient operating system. Though we found that our system was slower than the original, it had a great increase in battery life, which was our initial goal.

8.2 Lifelong Learning

This project greatly prepared us for learning on our own and inspired us to study new material. Going into this project, we only had an elementary knowledge of operating systems, as well as what it is like to work on a large project. We did not know where we were going to start such a broad project. As we progressed in our project we learned more and more about the Android operating system, and the source code that it is composed of. We learned how to configure a development environment for a specific project on a Linux system. Even now, as we write this document, we are learning how to use LaTeXto formally document a project.

The most important thing we learned in this project is how much we still do not know. This realization inspired us to continue studying new material, and never be satisfied with how much we do know. Not only this, but going into the project we had no idea the condition of homeless individuals

with regards to trying to keep up with the rapid advances our society has had with technology. With great advances in technology, people are becoming more and more connected, which is causing an expectation of connectedness to the world. This expectation is difficult for the homeless to meet, and we found that phones are a primary reason for this difficulty. This new awareness to the plight of marginalized people was a lifelong lesson that will aid us in a more compassionate stance toward them.

8.3 Advantages and Disadvantages

8.3.1 Advantages

The main advantage of the changes that we were able to make to the Android operating system is decreased power consumption by the system. As mentioned in the body of this document, increasing the battery life of mobile devices was our primary goal. The advantage of increasing the battery life is that homeless individuals can use their devices for longer without needing to charge. This is a huge advantage to the homeless, as they do not always have somewhere to plug their mobile devices in to charge, and they rely on their mobile devices for food, shelter, medical attention, and job opportunities. Having a phone with an extended battery life will not single handedly help someone work his way out of homelessness, but we hope that it will help in the fight.

We found that there are a lot of forums in the Android community about making changes to the operating system to improve performance or battery life, but it was only speculation by users who felt that their devices were lasting longer without charging. We did not find any data to back up what people were saying. Through our research, we were able to collect data on how many microwatts our system was using. We then calculated how many hours of usage we could add to the device by making changes to the system.

Another advantage of our research is we were able to successfully build our own boot.img for the Nexus 7. This image can be flashed to any Nexus 7 running the same version of Android. By learning how to do this, we have laid the ground work for others to continue our research, and develop kernels of their own on different devices.

8.3.2 Disadvantages

The main disadvantage of our work is that it is currently only research, and it is not ready for implementation. It would be difficult to implement our changes because there are so many different versions of Android, and we only have our system working on one specific version, on one specific device, as more of a proof of concept.

Another disadvantage of our project is that we spent so much time learning how to successfully compile the Android Open Source Project that we did not have much time to actually make and test as many changes as we would have liked. If we do not continue our own research, we hope the others will, and they can use our information on how to begin developing for Android as a starting point.

8.4 Compassion

Compassion was a big part of the inspiration for this project. Our advisor, Dr. Figueira, is very dedicated to using technology to help those in need. She made us aware of the suffering of others all around us and how we can help them. Our project does not aim to relieve the suffering of the homeless, but to help end their suffering. Mobile devices are a great tool for the homeless to form connections in society, get jobs, and find other resources to help them out such as soup kitchens, shelters, and free medical attention. A major problem for the homeless is that they do not always have somewhere to charge their devices, so we are trying to help solve this problem so that they do not have to charge their devices as often, and can rely on their devices for a longer period of time.

8.5 Going Forward

Based on our results, we hope to find even further improvements in the Android operating system. Much of what we found to be improvements were already existing knowledge, but knowledge that went unused because of people's desire for an optimized phone in terms of performance. We seek to communicate with Community Technology Alliance in order to better accomodate the Android operating system to the needs of the homeless in hopes that it will keep them connected to the world in a better way. We were not able to fully implement our alterations to the screen in order to conserve battery life, and this is an important convservation technique that future groups who choose to take on this project could implement. We would also like to perfect our homeless kernel so that the CPU frequency does not have such a drastic effect on the ability to browse the internet.

We scratched the surface in terms of what can be done for battery efficiency when one is willing to strip away certain attributes in favor of a longer lasting phone. Going forward, groups who take on this project could also seek to improve different aspects of the kernel or other areas of the Android operating system. Not only this, but we did not even seek to improve the Android operating system for any purpose other than battery efficiency. Had we looked into ways to improve other areas such as improved WiFi usage or perhap an application directed at homeless mobile phone users, we might

be able to better marginalized people's situation even more.

Problems facing future groups are primarily focused on distributing such research and finding a way to make large companies interested in distributing phones with our configuration installed on the system. We were able to create a kernel which was low energy for the Nexus 7, but the mobile devices homeless people are buying would likely be different. This means that going forward, groups would have to either find a phone which a majority of the homeless use, or figure out a way of abstracting the homeless kernel to the point where it can be flashed on any sort of mobile device. These issues would be easily dealt with if a group decided to commit themselves to year long work on continuing our efforts to improve homeless connectivity.

Appendix A

Appendix A

A.1 Configuration Test Results

Time [ms]	Battery Power [uW] WiFi Test	Battery Power [uW] Brightness Test	Battery Power [uW] All On	Battery Power [uW] All Off	Battery Power [uW] BT Test
52	3511937	3590114	3662175	3105707	3257506
102	2944850	3145972	3409839	2925111	3719529
202	3253060	3149992	3139670	3101829	4132034
303	3406279	3071741	3821797	2631479	3682118
403	3057153	3488362	3564020	2454738	3483676
504	2534682	2793760	3521821	2531974	3029689
604	2450845	2853650	3473167	2484306	3635189
704	2515621	3069858	3577271	2740776	3283112
805	2513009	3199791	3562106	2500536	2741028
906	2447360	3077543	3691932	2421079	3284515
1015	2931734	3543176	3580030	3381743	3354864
1105	2327751	3190480	3708161	3126643	2884180
1205	2480281	3172376	3660148	2985029	3134283
1306	2479826	3139404	3674664	2958690	2875998
1406	2936892	3185297	3637096	3352991	3217844
1506	2885382	3151425	3647715	3320043	3212569
1606	2826465	3149474	3633941	2746332	3092620
1707	2820919	3085057	3601875	2584501	3231621
1807	2830582	3055346	3703283	2354595	3111283
1907	2856596	3099701	3422258	2322180	3543035
2009	3055528	3566627	3604660	2997917	3382982
2110	2826033	3033533	3540010	2410942	3017996
2214	2712570	2996184	3794020	2563091	3648539
2326	3483925	3563531	3972619	2585068	3232707
2417	2985924	3015359	3761431	3673414	3602411
2515	3139789	3011856	4299607	2802239	3751390
2616	2504594	2803703	3882317	2882932	3177633
2716	2429537	3001096	3428842	2505440	3156834
2812	2441880	2984857	4087066	2562890	3841309
2912	2541106	2977672	4055648	2523891	3427619
3015	3315401	3192827	3499461	2946248	3417702
3113	2403827	2920701	3830405	2434623	3015269

3213	2456424	2969632	3983259	2436063	2913673
3313	2432562	3035971	3971119	2434815	3112314
3414	2856100	3173946	3935330	2389884	3180426
3514	2815850	2845693	3945173	2405589	3143316
3618	2405725	3140626	3945984	2701386	3184902
3715	2837158	3007198	3418481	3023733	3196590
3815	2804688	3361950	3833165	2438831	3349093
3915	2799315	3101384	3812175	2429481	3198243
4019	2716583	3620350	3978534	2982495	2982865
4130	2636676	3032136	3852135	2434392	2979260
4216	2525392	2989078	3867504	2353336	3214025
4316	2459308	2950866	3707965	2425901	3122255
4417	2932687	3097536	3836958	2815043	3286742
4521	2960671	3173369	3658386	2560416	3288982
4618	2809245	3130567	3446353	2576833	2925027
4719	2845146	3033366	3547125	2510294	3294429
4819	2848732	2880057	3561524	2512756	3023766
4919	2830875	2933482	3824929	2375862	3108227
5018	3313306	2940590	3149954	2998321	3144807
5119	2732502	2900376	4198874	2620536	3090635
5219	2729669	2932109	4088818	2554079	3271333
5319	2777093	2971911	3697850	2439050	3187588
5422	2443537	2980320	3687747	2340162	3036780
5521	2517746	2918898	3942684	2410374	2989083
5621	2717296	3215439	3729777	2421332	3174659
5722	2698302	3193880	3885173	2356256	2619656
5822	2749685	3054631	4079209	2421079	3439632
5922	2648475	3082005	3793743	2412550	2550265
6027	2750766	2697113	4014067	3007617	2662898
6125	3238687	2953166	3832865	2964903	2575310
6225	3231128	2895987	4218177	2390066	2441831
6327	3275576	2909068	3789916	2414159	2458517
6426	3335247	2989646	3787609	2386705	2662109
6527	3294834	2944153	3776524	2329923	2513860
6627	3196456	2965140	3791933	2530981	3180307
6727	3185664	2966015	3780857	2514577	2704579
6827	3206013	2947740	4027393	2550501	2715441
6929	3437888	2979287	4120277	2530776	2830965
7027	3444481	3267829	4209497	3103588	2985890
7127	3148305	2968078	3824821	2542738	2950408
7231	3135920	2960659	3732427	2469027	2988197
7342	2883407	3132138	3858972	2483550	3077027
7429	3330272	2990829	3831927	2414727	2855732
7529	3233586	3231045	3707608	2503671	2939179
7631	3225180	3322957	3694148	2481217	2909983
7729	3049834	3165800	3796180	2363719	2938947
7830	3211011	3213886	3715615	2410852	2899249
7936	2996719	3233011	3709577	2328076	2803346
8031	2845768	4259640	3899249	2697881	2643790
8131	3014146	3876571	3808911	2349136	2666653
8232	2676871	3614787	3885607	2262916	2633323

8333	3327151	3477830	3836352	2351964	2664284
8432	2618393	3727321	3549591	2368001	2664873
8532	2474420	3619137	3638968	2320536	2649699
8651	2730608	3116755	3827060	2340508	2560449
8733	2995018	3763714	3812779	2399206	2655214
8837	2524785	3624679	3834980	2521971	2550724
8935	2898787	3562708	3794061	2608798	2509396
9037	3013238	4155640	3963198	2933227	2426385
9135	2989053	3522696	3876497	2640103	2454181
9241	2375214	4122160	3760470	2588973	2505655
9337	2812494	3187604	4030687	2275774	2820030
9437	2919584	3200123	3203965	2320242	2441817
9537	2756602	3585922	4129493	2336017	2429674
9638	2755459	3659060	4147856	2320242	2434602
9737	2769926	3538812	3937040	2379758	2723821
9837	2815618	3527875	3942245	2349079	2536789
9939	2845237	3626099	3755446	2272261	2505379
10039	2447549	3604123	4108823	2686475	2595552
10139	2642995	3471580	3487099	2320463	2668432
10240	2613241	3645167	3515991	2231620	2611080
10339	2721086	3702020	3738449	2347220	2642921
10440	2665551	3621542	3747715	2347761	2602105
10541	2612042	3728846	3863710	2254205	2498466
10640	2600917	3614918	3826936	2603639	2574165
10741	3538190	3657603	3757275	2583078	2747234
10842	3261550	3685597	3705134	2540361	2505786
10942	3350155	3702436	3790782	2495199	2564819
11042	3053179	3644415	3664285	2983821	2449635
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44974	1989003	2958359	3279006	3184133	2516665
45083	2089446	2970498	4237825	3154269	2480459
45165	2371097	2942467	3860675	3192611	2474358

A.2 System Test Results

Time [ms]	Battery Power [uW] powersave Governor Test	Battery Power [uW] Red Filter	Battery Power [uW] Low Min and Max Freq	Battery Power [uW] Full Brightness	Battery Power [uW] Default Governor and CPU Frequency
75	911000	2772000	743000	2949000	1298000
134	911000	2772000	743000	2949000	1298000
246	911000	2772000	743000	2949000	1298000
334	1442000	2772000	743000	2949000	1298000
439	1442000	2772000	743000	2949000	1298000
541	1442000	2933000	743000	2949000	1298000
631	1442000	2933000	743000	2949000	1356000
731	1442000	2933000	1067000	2949000	1356000
839	1442000	2933000	1067000	2949000	1356000
935	1442000	2933000	1067000	2949000	1356000
1034	1442000	2933000	1067000	2828000	1356000
1165	1442000	2933000	1067000	2828000	1356000
1255	1442000	2933000	1067000	2828000	1356000
1340	1209000	2933000	1067000	2828000	1356000
1437	1209000	2933000	1067000	2828000	1356000
1538	1209000	2326000	1067000	2828000	1356000
1638	1209000	2326000	1067000	2828000	1044000
1739	1209000	2326000	955000	2828000	1044000
1841	1209000	2326000	955000	2828000	1044000
1943	1209000	2326000	955000	2828000	1044000
2038	1209000	2326000	955000	2514000	1044000
2145	1209000	2326000	955000	2514000	1044000
2243	1209000	2326000	955000	2514000	1044000
2343	1905000	2326000	955000	2514000	1044000
2447	1905000	2326000	955000	2514000	1044000
2544	1905000	3551000	955000	2514000	1044000
2643	1905000	3551000	955000	2514000	2002000
2747	1905000	3551000	891000	2514000	2002000
2845	1905000	3551000	891000	2514000	2002000
2946	1905000	3551000	891000	2514000	2002000
3049	1905000	3551000	891000	3298000	2002000
3149	1905000	3551000	891000	3298000	2002000

3248	1905000	3551000	891000	3298000	2002000
3351	1038000	3551000	891000	3298000	2002000
3450	1038000	3551000	891000	3298000	2002000
3549	1038000	2726000	891000	3298000	2002000
3653	1038000	2726000	891000	3298000	1544000
3751	1038000	2726000	951000	3298000	1544000
3851	1038000	2726000	951000	3298000	1544000
3955	1038000	2726000	951000	2925000	1544000
4054	1038000	2726000	951000	2925000	1544000
4155	1038000	2726000	951000	2925000	1544000
4277	1038000	2726000	951000	2925000	1544000
4360	820000	2726000	951000	2925000	1544000
4464	820000	2726000	951000	2925000	1544000
4562	820000	2273000	951000	2925000	1544000
4728	820000	2273000	951000	2925000	1102000
4770	820000	2273000	777000	2925000	1102000
4882	820000	2273000	777000	2925000	1102000
4965	820000	2273000	777000	3786000	1102000
5085	820000	2273000	777000	3786000	1102000
5165	820000	2273000	777000	3786000	1102000
5287	820000	2273000	777000	3786000	1102000
5391	2293000	2273000	777000	3786000	1102000
5484	2293000	2273000	777000	3786000	1102000
5567	2293000	2103000	777000	3786000	1102000
5679	2293000	2103000	876000	3786000	3129000
5769	2293000	2103000	876000	3786000	3129000
5880	2293000	2103000	876000	3786000	3129000
5971	2293000	2103000	876000	2470000	3129000
6088	2293000	2103000	876000	2470000	3129000
6177	2293000	2103000	876000	2470000	3129000
6282	2293000	2103000	876000	2470000	3129000
6373	2673000	2103000	876000	2470000	3129000
6473	2673000	2103000	876000	2470000	3129000
6572	2673000	2076000	876000	2470000	3129000
6688	2673000	2076000	820000	2470000	3083000
6810	2673000	2076000	820000	2470000	3083000
6876	2673000	2076000	820000	2470000	3083000
6986	2673000	2076000	820000	2198000	3083000
7073	2673000	2076000	820000	2198000	3083000
7190	2673000	2076000	820000	2198000	3083000
7276	2673000	2076000	820000	2198000	3083000
7436	2884000	2076000	820000	2198000	3083000
7502	2884000	2076000	820000	2198000	3083000
7611	2884000	2787000	820000	2198000	3083000
7686	2884000	2787000	781000	2198000	2268000
7803	2884000	2787000	781000	2198000	2268000
7891	2884000	2787000	781000	2198000	2268000
8003	2884000	2787000	781000	2375000	2268000
8088	2884000	2787000	781000	2375000	2268000
8185	2884000	2787000	781000	2375000	2268000
8288	2884000	2787000	781000	2375000	2268000

8392	2797000	2787000	781000	2375000	2268000
8488	2797000	2787000	781000	2375000	2268000
8593	2797000	4735000	781000	2375000	2268000
8693	2797000	4735000	824000	2375000	1696000
8793	2797000	4735000	824000	2375000	1696000
8907	2797000	4735000	824000	2375000	1696000
8997	2797000	4735000	824000	3244000	1696000
9099	2797000	4735000	824000	3244000	1696000
9194	2797000	4735000	824000	3244000	1696000
9308	2797000	4735000	824000	3244000	1696000
9426	1381000	4735000	824000	3244000	1696000
9500	1381000	4735000	824000	3244000	1696000
9600	1381000	4567000	824000	3244000	1696000
9755	1381000	4567000	1066000	3244000	1800000
9809	1381000	4567000	1066000	3244000	1800000
9924	1381000	4567000	1066000	3244000	1800000
10010	1381000	4567000	1066000	2605000	1800000
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10213	1381000	4567000	1066000	2605000	1800000
10312	1381000	4567000	1066000	2605000	1800000
10439	1799000	4567000	1066000	2605000	1800000
10522	1799000	4567000	1066000	2605000	1800000
10618	1799000	3600000	1066000	2605000	1800000
10721	1799000	3600000	1982000	2605000	1294000
10815	1799000	3600000	1982000	2605000	1294000
10914	1799000	3600000	1982000	2605000	1294000
11018	1799000	3600000	1982000	4029000	1294000
11116	1799000	3600000	1982000	4029000	1294000
11216	1799000	3600000	1982000	4029000	1294000
11332	1799000	3600000	1982000	4029000	1294000
11419	1116000	3600000	1982000	4029000	1294000
11559	1116000	3600000	1982000	4029000	1294000
11622	1116000	2649000	1982000	4029000	1294000
11733	1116000	2649000	1624000	4029000	2216000
11820	1116000	2649000	1624000	4029000	2216000
11938	1116000	2649000	1624000	4029000	2216000
12082	1116000	2649000	1624000	2895000	2216000
12157	1116000	2649000	1624000	2895000	2216000
12189	1116000	2649000	1624000	2895000	2216000
12275	1116000	2649000	1624000	2895000	2216000
12392	2162000	2649000	1624000	2895000	2216000
12476	2162000	2649000	1624000	2895000	2216000
12592	2162000	3774000	1624000	2895000	2216000
12682	2162000	3774000	1073000	2895000	2007000
12789	2162000	3774000	1073000	2895000	2007000
12882	2162000	3774000	1073000	2895000	2007000
12984	2162000	3774000	1073000	3305000	2007000
13128	2162000	3774000	1073000	3305000	2007000
13182	2162000	3774000	1073000	3305000	2007000
13313	2162000	3774000	1073000	3305000	2007000
13381	1767000	3774000	1073000	3305000	2007000

13488	1767000	3774000	1073000	3305000	2007000
13582	1767000	2857000	1073000	3305000	2007000
13683	1767000	2857000	1002000	3305000	1023000
13779	1767000	2857000	1002000	3305000	1023000
13882	1767000	2857000	1002000	3305000	1023000
13986	1767000	2857000	1002000	3305000	1023000
14088	1767000	2857000	1002000	3747000	1023000
14184	1767000	2857000	1002000	3747000	1023000
14290	1767000	2857000	1002000	3747000	1023000
14385	1141000	2857000	1002000	3747000	1023000
14489	1141000	2857000	1002000	3747000	1023000
14589	1141000	3875000	1002000	3747000	1023000
14687	1141000	3875000	997000	3747000	1736000
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14937	1141000	3875000	997000	3747000	1736000
14988	1141000	3875000	997000	3747000	1736000
15121	1141000	3875000	997000	4033000	1736000
15213	1141000	3875000	997000	4033000	1736000
15325	1141000	3875000	997000	4033000	1736000
15409	777000	3875000	997000	4033000	1736000
15507	777000	3875000	997000	4033000	1736000
15605	777000	3216000	997000	4033000	1736000
15731	777000	3216000	2377000	4033000	1736000
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15913	777000	3216000	2377000	4033000	1624000
16012	777000	3216000	2377000	4033000	1624000
16133	777000	3216000	2377000	2666000	1624000
16227	777000	3216000	2377000	2666000	1624000
16317	777000	3216000	2377000	2666000	1624000
16436	1052000	3216000	2377000	2666000	1624000
16517	1052000	3216000	2377000	2666000	1624000
16637	1052000	2234000	2377000	2666000	1624000
16720	1052000	2234000	2199000	2666000	1624000
16821	1052000	2234000	2199000	2666000	907000
16916	1052000	2234000	2199000	2666000	907000
17016	1052000	2234000	2199000	2666000	907000
17169	1052000	2234000	2199000	2964000	907000
17229	1052000	2234000	2199000	2964000	907000
17322	1052000	2234000	2199000	2964000	907000
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17621	1633000	2102000	2199000	2964000	907000
17725	1633000	2102000	1658000	2964000	907000
17823	1633000	2102000	1658000	2964000	1680000
17922	1633000	2102000	1658000	2964000	1680000
18026	1633000	2102000	1658000	2964000	1680000
18124	1633000	2102000	1658000	3588000	1680000
18225	1633000	2102000	1658000	3588000	1680000
18326	1633000	2102000	1658000	3588000	1680000
18426	766000	2102000	1658000	3588000	1680000
18525	766000	2075000	1658000	3588000	1680000

18629	766000	2075000	1658000	3588000	1680000
18728	766000	2075000	2378000	3588000	1680000
18827	766000	2075000	2378000	3588000	1824000
18929	766000	2075000	2378000	3588000	1824000
19028	766000	2075000	2378000	3588000	1824000
19129	766000	2075000	2378000	3986000	1824000
19234	766000	2075000	2378000	3986000	1824000
19332	766000	2075000	2378000	3986000	1824000
19433	763000	2075000	2378000	3986000	1824000
19533	763000	2075000	2378000	3986000	1824000
19643	763000	2074000	2378000	3986000	1824000
19742	763000	2074000	1613000	3986000	1824000
19836	763000	2074000	1613000	3986000	2340000
19969	763000	2074000	1613000	3986000	2340000
20043	763000	2074000	1613000	3986000	2340000
20146	763000	2074000	1613000	3681000	2340000
20246	763000	2074000	1613000	3681000	2340000
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20449	713000	2074000	1613000	3681000	2340000
20552	713000	2046000	1613000	3681000	2340000
20652	713000	2046000	1613000	3681000	2340000
20785	713000	2046000	2114000	3681000	2340000
20856	713000	2046000	2114000	3681000	1868000
20960	713000	2046000	2114000	3681000	1868000
21065	713000	2046000	2114000	3681000	1868000
21208	713000	2046000	2114000	3080000	1868000
21264	713000	2046000	2114000	3080000	1868000
21368	713000	2046000	2114000	3080000	1868000
21521	812000	2046000	2114000	3080000	1868000
21567	812000	2117000	2114000	3080000	1868000
21671	812000	2117000	2114000	3080000	1868000
21769	812000	2117000	2217000	3080000	1868000
21873	812000	2117000	2217000	3080000	1688000
21974	812000	2117000	2217000	3080000	1688000
22073	812000	2117000	2217000	2139000	1688000
22176	812000	2117000	2217000	2139000	1688000
22274	812000	2117000	2217000	2139000	1688000
22384	812000	2117000	2217000	2139000	1688000
22477	2033000	2117000	2217000	2139000	1688000
22572	2033000	2683000	2217000	2139000	1688000
22675	2033000	2683000	2217000	2139000	1688000
22774	2033000	2683000	2019000	2139000	1688000
22873	2033000	2683000	2019000	2139000	1853000
22982	2033000	2683000	2019000	2139000	1853000
23075	2033000	2683000	2019000	2086000	1853000
23174	2033000	2683000	2019000	2086000	1853000
23280	2033000	2683000	2019000	2086000	1853000
23379	2033000	2683000	2019000	2086000	1853000
23476	892000	2683000	2019000	2086000	1853000
23583	892000	3433000	2019000	2086000	1853000
23690	892000	3433000	2019000	2086000	1853000

23778	892000	3433000	2266000	2086000	1853000
23908	892000	3433000	2266000	2086000	2287000
23990	892000	3433000	2266000	2086000	2287000
24088	892000	3433000	2266000	3345000	2287000
24179	892000	3433000	2266000	3345000	2287000
24292	892000	3433000	2266000	3345000	2287000
24382	892000	3433000	2266000	3345000	2287000
24486	1471000	3433000	2266000	3345000	2287000
24583	1471000	3529000	2266000	3345000	2287000
24638	1471000	3529000	2266000	3345000	2287000
24800	1471000	3529000	2032000	3345000	2287000
24840	1471000	3529000	2032000	3345000	2348000
24953	1471000	3529000	2032000	3345000	2348000
25036	1471000	3529000	2032000	4167000	2348000
25152	1471000	3529000	2032000	4167000	2348000
25237	1471000	3529000	2032000	4167000	2348000
25340	1471000	3529000	2032000	4167000	2348000
25435	1843000	3529000	2032000	4167000	2348000
25535	1843000	3400000	2032000	4167000	2348000
25737	1843000	3400000	2032000	4167000	2348000
25791	1843000	3400000	1364000	4167000	2348000
25891	1843000	3400000	1364000	4167000	2179000
25997	1843000	3400000	1364000	4167000	2179000
26091	1843000	3400000	1364000	3562000	2179000
26203	1843000	3400000	1364000	3562000	2179000
26291	1843000	3400000	1364000	3562000	2179000
26403	1843000	3400000	1364000	3562000	2179000
26490	2105000	3400000	1364000	3562000	2179000
26592	2105000	3835000	1364000	3562000	2179000
26723	2105000	3835000	1364000	3562000	2179000
26794	2105000	3835000	1004000	3562000	2506000
26893	2105000	3835000	1004000	3562000	2506000
27018	2105000	3835000	1004000	3562000	2506000
27055	2105000	3835000	1004000	3262000	2506000
27153	2105000	3835000	1004000	3262000	2506000
27293	2105000	3835000	1004000	3262000	2506000
27358	2105000	3835000	1004000	3262000	2506000
27461	1026000	3835000	1004000	3262000	2506000
27556	1026000	3480000	1004000	3262000	2506000
27676	1026000	3480000	1004000	3262000	2506000
27752	1026000	3480000	1092000	3262000	2506000
27862	1026000	3480000	1092000	3262000	2263000
27954	1026000	3480000	1092000	3262000	2263000
28067	1026000	3480000	1092000	3636000	2263000
28154	1026000	3480000	1092000	3636000	2263000
28272	1026000	3480000	1092000	3636000	2263000
28354	1026000	3480000	1092000	3636000	2263000
28462	2068000	3480000	1092000	3636000	2263000
28563	2068000	3360000	1092000	3636000	2263000
28662	2068000	3360000	1092000	3636000	2263000
28758	2068000	3360000	1178000	3636000	2263000

28868	2068000	3360000	1178000	3636000	1932000
28961	2068000	3360000	1178000	3636000	1932000
29065	2068000	3360000	1178000	3347000	1932000
29160	2068000	3360000	1178000	3347000	1932000
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29359	2068000	3360000	1178000	3347000	1932000
29462	1990000	3360000	1178000	3347000	1932000
29559	1990000	3454000	1178000	3347000	1932000
29662	1990000	3454000	1178000	3347000	1932000
29786	1990000	3454000	993000	3347000	1932000
29869	1990000	3454000	993000	3347000	2572000
29965	1990000	3454000	993000	3347000	2572000
30068	1990000	3454000	993000	3739000	2572000
30164	1990000	3454000	993000	3739000	2572000
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30369	1990000	3454000	993000	3739000	2572000
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30564	1205000	3670000	993000	3739000	2572000
30668	1205000	3670000	993000	3739000	2572000
30767	1205000	3670000	1009000	3739000	2572000
30867	1205000	3670000	1009000	3739000	2560000
30972	1205000	3670000	1009000	3739000	2560000
31068	1205000	3670000	1009000	3393000	2560000
31167	1205000	3670000	1009000	3393000	2560000
31270	1205000	3670000	1009000	3393000	2560000
31370	1205000	3670000	1009000	3393000	2560000
31470	751000	3670000	1009000	3393000	2560000
31572	751000	2824000	1009000	3393000	2560000
31670	751000	2824000	1009000	3393000	2560000
31770	751000	2824000	1060000	3393000	2560000
31908	751000	2824000	1060000	3393000	2203000
31973	751000	2824000	1060000	3393000	2203000
32076	751000	2824000	1060000	3563000	2203000
32177	751000	2824000	1060000	3563000	2203000
32280	751000	2824000	1060000	3563000	2203000
32374	751000	2824000	1060000	3563000	2203000
32483	1559000	2824000	1060000	3563000	2203000
32576	1559000	2061000	1060000	3563000	2203000
32690	1559000	2061000	1060000	3563000	2203000
32793	1559000	2061000	969000	3563000	2201000
32877	1559000	2061000	969000	3563000	1695000
32995	1559000	2061000	969000	3563000	1695000
33081	1559000	2061000	969000	3370000	1695000
33198	1559000	2061000	969000	3370000	1695000
33286	1559000	2061000	969000	3370000	1695000
33385	1559000	2061000	969000	3370000	1695000
33485	2022000	2061000	969000	3370000	1695000
33603	2022000	2066000	969000	3370000	1695000
33685	2022000	2066000	969000	3370000	1695000
33795	2022000	2066000	989000	3370000	1695000
33882	2022000	2066000	989000	3370000	1127000

33986	2022000	2066000	989000	3370000	1127000
34083	2022000	2066000	989000	3370000	1127000
34185	2022000	2066000	989000	3898000	1127000
34296	2022000	2066000	989000	3898000	1127000
34389	2022000	2066000	989000	3898000	1127000
34487	1680000	2066000	989000	3898000	1127000
34591	1680000	2081000	989000	3898000	1127000
34690	1680000	2081000	989000	3898000	1127000
34787	1680000	2081000	957000	3898000	1127000
34888	1680000	2081000	957000	3898000	1561000
34988	1680000	2081000	957000	3898000	1561000
35087	1680000	2081000	957000	3898000	1561000
35190	1680000	2081000	957000	3477000	1561000
35288	1680000	2081000	957000	3477000	1561000
35389	1680000	2081000	957000	3477000	1561000
35492	766000	2081000	957000	3477000	1561000
35590	766000	2044000	957000	3477000	1561000
35690	766000	2044000	957000	3477000	1561000
35793	766000	2044000	992000	3477000	1561000
35892	766000	2044000	992000	3477000	1912000
35994	766000	2044000	992000	3477000	1912000
36095	766000	2044000	992000	2432000	1912000
36196	766000	2044000	992000	2432000	1912000
36303	766000	2044000	992000	2432000	1912000
36398	766000	2044000	992000	2432000	1912000
36515	781000	2044000	992000	2432000	1912000
36608	781000	2085000	992000	2432000	1912000
36721	781000	2085000	992000	2432000	1912000
36801	781000	2085000	934000	2432000	1912000
36903	781000	2085000	934000	2432000	1846000
37002	781000	2085000	934000	2432000	1846000
37105	781000	2085000	934000	2066000	1846000
37208	781000	2085000	934000	2066000	1846000
37312	781000	2085000	934000	2066000	1846000
37404	781000	2085000	934000	2066000	1846000
37507	2040000	2085000	934000	2066000	1846000
37605	2040000	2061000	934000	2066000	1846000
37708	2040000	2061000	934000	2066000	1846000
37810	2040000	2061000	945000	2066000	1846000
37904	2040000	2061000	945000	2066000	2237000
38007	2040000	2061000	945000	2066000	2237000
38105	2040000	2061000	945000	2046000	2237000
38206	2040000	2061000	945000	2046000	2237000
38315	2040000	2061000	945000	2046000	2237000
38411	2040000	2061000	945000	2046000	2237000
38516	1473000	2061000	945000	2046000	2237000
38611	1473000	3210000	945000	2046000	2237000
38709	1473000	3210000	945000	2046000	2237000
38810	1473000	3210000	992000	2046000	2237000
38914	1473000	3210000	992000	2046000	1690000
39010	1473000	3210000	992000	2046000	1690000

39110	1473000	3210000	992000	2805000	1690000
39212	1473000	3210000	992000	2805000	1690000
39312	1473000	3210000	992000	2805000	1690000
39412	1473000	3210000	992000	2805000	1690000
39514	918000	3210000	992000	2805000	1690000
39613	918000	2629000	992000	2805000	1690000
39713	918000	2629000	992000	2805000	1690000
39816	918000	2629000	917000	2805000	1690000
39914	918000	2629000	917000	2805000	2195000
40013	918000	2629000	917000	2805000	2195000
40117	918000	2629000	917000	2982000	2195000
40230	918000	2629000	917000	2982000	2195000
40321	918000	2629000	917000	2982000	2195000
40419	918000	2629000	917000	2982000	2195000
40524	1135000	2629000	917000	2982000	2195000
40620	1135000	2158000	917000	2982000	2195000
40724	1135000	2158000	898000	2982000	2195000
40821	1135000	2158000	898000	2982000	2195000
40928	1135000	2158000	898000	2982000	2674000
41019	1135000	2158000	898000	2982000	2674000
41125	1135000	2158000	898000	3458000	2674000
41221	1135000	2158000	898000	3458000	2674000
41329	1135000	2158000	898000	3458000	2674000
41420	1135000	2158000	898000	3458000	2674000
41526	2077000	2158000	898000	3458000	2674000
41623	2077000	2085000	898000	3458000	2674000
41724	2077000	2085000	898000	3458000	2674000

A.3 Homeless Kernel Test Results

Time [ms]	Battery Power [uW] Homeless Kernel
85	826000
139	826000
242	1422000
339	1422000
444	1422000
545	1422000
646	1422000
744	1422000
848	1422000
948	1422000
1046	1422000
1150	1422000
1250	1095000
1351	1095000
1450	1095000
1553	1095000
1650	1095000
1751	1095000
1851	1095000
1983	1095000

2150	1095000
2201	1095000
2285	845000
2399	845000
2496	845000
2605	845000
2701	845000
2792	845000
2891	845000
2993	845000
3163	845000
3220	845000
3305	750000
3402	750000
3507	750000
3601	750000
3708	750000
3819	750000
3915	750000
4020	750000
4115	750000
4230	750000
4321	746000
4414	746000
4524	746000
4628	746000
4727	746000
4861	746000
4940	746000
4983	746000
5084	746000
5183	746000
5298	750000
5385	750000
5487	750000
5588	750000
5690	750000
5789	750000
5890	750000
5992	750000
6148	750000
6250	750000
6388	738000
6458	738000
6520	738000
6617	738000
6715	738000
6827	738000
6909	738000
7011	738000
7112	738000

7209	738000
7325	940000
7419	940000
7525	940000
7617	940000
7723	940000
7818	940000
7918	940000
8019	940000
8124	940000
8220	940000
8318	1540000
8429	1540000
8522	1540000
8618	1540000
8719	1540000
8825	1540000
8933	1540000
9024	1540000
9126	1540000
9223	1540000
9324	1125000
9428	1125000
9529	1125000
9625	1125000
9727	1125000
9848	1125000
9943	1125000
10046	1125000
10148	1125000
10264	1125000
10354	940000
10482	940000
10557	940000
10653	940000
10762	940000
10873	940000
10975	940000
11062	940000
11169	940000
11271	940000
11378	776000
11498	776000
11602	776000
11705	776000
11795	776000
11893	776000
11998	776000
12098	776000
12208	776000
12295	776000

12409	787000
12535	787000
12628	787000
12704	787000
12814	787000
12898	787000
13004	787000
13105	787000
13207	787000
13306	787000
13415	806000
13516	806000
13614	806000
13725	806000
13829	806000
13937	806000
14015	806000
14111	806000
14220	806000
14318	806000
14422	848000
14525	848000
14625	848000
14755	848000
14810	848000
14883	848000
14980	848000
15092	848000
15215	848000
15294	848000
15396	776000
15504	776000
15587	776000
15697	776000
15785	776000
15885	776000
15986	776000
16087	776000
16189	776000
16290	776000
16391	1373000
16493	1373000
16590	1373000
16692	1373000
16795	1373000
16898	1373000
16997	1373000
17095	1373000
17199	1373000
17300	1373000
17396	1706000

17496	1706000
17595	1706000
17697	1706000
17797	1706000
17898	1706000
17999	1706000
18106	1706000
18201	1706000
18302	1706000
18402	869000
18503	869000
18607	869000
18724	869000
18837	869000
18907	869000
19012	869000
19111	869000
19208	869000
19311	869000
19413	1758000
19528	1758000
19614	1758000
19727	1758000
19816	1758000
19952	1758000
20020	1758000
20117	1758000
20219	1758000
20320	1758000
20419	1576000
20524	1576000
20622	1576000
20725	1576000
20830	1576000
20927	1576000
21024	1576000
21136	1576000
21234	1576000
21331	1576000
21425	1522000
21531	1522000
21630	1522000
21729	1522000
21830	1522000
21933	1522000
22031	1522000
22139	1522000
22254	1522000
22359	1522000
22439	1753000
22540	1753000

22642	1753000
22744	1753000
22846	1753000
22950	1753000
23057	1753000
23154	1753000
23249	1753000
23343	1753000
23445	2310000
23548	2310000
23647	2310000
23747	2310000
23851	2310000
23951	2310000
24053	2310000
24152	2310000
24261	2310000
24356	2310000
24463	1937000
24562	1937000
24664	1937000
24763	1937000
24864	1937000
24966	1937000
25066	1937000
25166	1937000
25278	1937000
25372	1937000
25483	2069000
25569	2069000
25672	2069000
25773	2069000
25889	2069000
25975	2069000
26075	2069000
26176	2069000
26279	2069000
26377	2069000
26480	1464000
26606	1464000
26679	1464000
26778	1464000
26881	1464000
27005	1464000
27086	1464000
27195	1464000
27296	1464000
27385	1464000
27494	1840000
27596	1840000
27644	1840000

27742	1840000
27846	1840000
27944	1840000
28057	1840000
28154	1840000
28263	1840000
28356	1840000
28449	2328000
28553	2328000
28660	2328000
28756	2328000
28855	2328000
28960	2328000
29060	2328000
29166	2328000
29271	2328000
29366	2328000
29476	1946000
29575	1946000
29674	1946000
29778	1946000
29883	1946000
29978	1946000
30083	1946000
30211	1946000
30282	1946000
30383	1946000
30484	2044000
30584	2044000
30684	2044000
30788	2044000
30890	2044000
30988	2044000
31096	2044000
31198	2044000
31290	2044000
31396	2044000
31491	1637000
31592	1637000
31692	1637000
31797	1637000
31899	1637000
31999	1637000
32099	1637000
32199	1637000
32313	1637000
32400	1637000
32507	1604000
32617	1604000
32706	1604000
32807	1604000

32909	1604000
33021	1604000
33111	1604000
33213	1604000
33310	1604000
33439	1599000
33514	1717000
33616	1717000
33717	1717000
33818	1717000
33922	1717000
34018	1717000
34122	1717000
34222	1717000
34330	1717000
34444	1722000
34526	1521000
34627	1521000
34731	1521000
34833	1521000
34928	1521000
35034	1521000
35156	1521000
35236	1521000
35344	1521000
35433	1521000
35536	1438000
35634	1438000
35735	1438000
35837	1438000
35938	1438000
36049	1438000
36162	1438000
36245	1438000
36341	1438000
36443	1438000
36549	1312000
36644	1312000
36753	1312000
36846	1312000
36947	1312000
37049	1312000
37148	1312000
37265	1312000
37349	1312000
37452	1312000
37549	1196000
37650	1196000
37749	1196000
37850	1196000
37962	1196000

38010	1196000
38112	1196000
38210	1196000
38307	1196000
38418	1196000
38511	2359000
38617	2359000
38711	2359000
38830	2359000
38920	2359000
39024	2359000
39123	2359000
39224	2359000
39323	2359000
39425	2359000
39524	2240000
39625	2240000
39724	2240000
39823	2240000
39923	2240000
40026	2240000
40128	2240000
40232	2240000
40329	2240000
40429	2240000
40529	1862000
40629	1862000
40730	1862000
40829	1862000
40937	1862000
41032	1862000
41135	1862000
41234	1862000
41334	1862000
41434	1862000
41536	1464000
41638	1464000
41741	1464000
41837	1464000
41936	1464000
42037	1464000
42144	1464000
42240	1464000
42345	1464000
42493	1462000
42553	1379000
42655	1379000
42754	1379000
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42965	1379000
43061	1379000

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