Power Consumption Analysis of a Modern Smartphone

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Abstract. This paper presents observations about power consumption of a latest smartphone. Modern smartphones are powerful devices with different choices of data connections and other functional modes. This paper provides analysis of power utilization for these different operation modes. Also, we present power consumption by vital operating system (OS) components.

Keywords: smart phone, power, consumption, analysis, operating system

1 Introduction

Smartphones saw their advent some 16 years ago with the introduction of Nokia Communicator series. Growth of smartphones only started increasing exponentially in recent years. According to Strategy Analytics, total number of smartphones in the world has reached to one billion. It is expected to hit two billion in three years.

This shows how much part smartphones are playing, and will play, in our daily lives. Latest smartphones are handy, powerful and are equipped with various functionalities.

1.1 Power in Smartphones

With these advantages, some constraints come along in the form of power consumption. It is normal to recharge (or replace) smartphone batteries at least once or more times a day. Similarly, smartphone battery appears to drain over night, when smartphone is partially or fully idle.

All smartphone companies are taking this issue seriously, as we can notice bigger batteries with newer models of smartphones. Extra features like flight mode, automatic and manual power save modes are also included in smartphones to save energy.

Modern smartphones are capable of using more than one data networks. Also, smartphones have certain features and modes that claim to save power consumption thus increasing the battery usage hours.
1.2 Our Contributions

In this report, we will try to analyze power consumption of a modern smartphone while it uses LTE and WiFi data network connections. Moreover, power consumption of the smartphone in some important modes, namely flight and power-save modes, are computed. Along with these observations, power utilization of smartphone for normal usage and while it is in sleep mode is also measured. We believe this paper will provide a baseline for further analysis in the works related to power consumption in modern smartphones.

2 Device Under Test (DUT)

We used SHV-E120S, also known as Samsung Galaxy S2 HD LTE, for our tests. Platform, display and battery specifications of the tested phone are given below.

2.1 DUT Specifications

Following table lists some notable specifications of our DUT.

| Table 1: Specifications of DUT |
|-------------------------------|
| **Network**                  | GSM 850 / 900 / 1800 / 1900 |
| 2G Network                  | HSDPA 850 / 900 / 1900 / 2100, HSDPA 900 / 2100 |
| 3G Network                  | LTE 800 / 1800 / 2600 |
| 4G Network                  | LTE, HSDPA, 21 Mbps |
| Data Speed                  | Wi-Fi 802.11 a/b/g/n, DLNA, Wi-Fi Direct, Wi-Fi hotspot |
| Data                         | LTE, HSDPA, 21 Mbps |
| WLAN                        | Wi-Fi 802.11 a/b/g/n, DLNA, Wi-Fi Direct, Wi-Fi hotspot |
| Others                      | GRPS, EDGE, BluetoothWednesday |
| Display Screen              | Super AMOLED capacitive touchscreen, 16M colors |
| Size                        | 720 x 1280 pixels, 4.65 inches |
| Battery Capacity            | Li-Ion 1850 mAh |
| Stand-by                    | Up to 320 h (2G) / Up to 290 h (3G) |
| Talk time                   | Up to 12 h 40 min (2G) / Up to 5 h 50 min (3G) |
| Platform OS                 | Android OS, v2.3 (Gingerbread) |
| Chipset                     | Qualcomm MSM8660 Snapdragon |
| CPU                         | Dual-core 1.5 GHz Scorpion |
| GPU                         | Adreno 220 |
| Sensors                     | Accelerometer, gyro, proximity, compass |
| Messaging                   | SMS (threaded view), MMS, Email, Push Mail, IM, RSS |
| Browser                     | HTML, Adobe Flash |
| Radio                       | No |
| GPS                         | Yes, with A-GPS support |
2.2 Operating System Specifications

Factors related to power consumption are not limited to hardware alone; operating systems (OS) components also contribute to battery drainage.

In this section, we briefly describe some OS fragments that seem to affect power more than other OS parts.

1. **Android System**

   Android system performs most of functions of OS, and consumes more power than other components of OS. Android system includes, more importantly, service manager, sensor manager, com.android.settings, tvoutserver, dmbserver etc.

   (a) **Service manager**

   Android runtime uses the ServiceManager to add services, and to find them, but the ServiceManager itself is accessed via a Binder. It manages, lists and add all service that are running in the system. A Service is an application component representing either an application’s desire to perform a longer-running operation while not interacting with the user or to supply functionality for other applications to use.

   (b) **Sensor manager**

   Modern day smartphones have many interesting sensors available to enhance user experience, by providing novel applications. Sensors provide accurate information about device positioning, orientations and environmental conditions.

   Sensor manager is responsible for managing the operations of these sensors. Some of the sensors available in our device are:

   i. **Accelerometer**

   Measures the acceleration force in m/s² that is applied to a device on all three physical axes (x, y, and z), including the force of gravity.

   ii. **Gyroscope**

   Measures a device’s rate of rotation in rad/s around each of the three physical axes (x, y, and z).

   iii. **Magnetic field**

   Measures the ambient geomagnetic field.

   iv. **Orientation**

   Measures degrees of rotation that a device makes around all three physical axes (x, y, z).

   (c) **Others**

   Other notable parts of OS are Tvoutserver, DMBserver, com.android.settings and com.android.fatorysettings.

2. **OS Kernel**

   Kernel in OS links facilitates the communication between hardware and software layers. Kernel includes drivers, scripts, security modules and firmware to name a few. Kernel keeps consuming power regardless of whether they
are operating at any moment or not.

3. **Android core apps**
   They are basically applications which are installed by default with Android OS. Email service i.e. Gmail, keyboard, Internet Voice calling, clock, calendar and alarm etc. are some of the core apps available in Gingerbread 2.3.

4. **Microbes**
   Microbes is live wallpaper application available in Gingerbread 2.3.

5. **Mediaserver**
   Mediaserver in Android accesses gallery, audio and video files available on device and plays them.

6. **Google services framework**
   Google services framework allows the device to communicate with Google for various purposes i.e. application licensing, AdMob ads, In-App billing. Firm upgrade, accessing Google cloud and Google maps are also handled with this framework.

7. **Anti-virus**
   Anti-virus program may run on smartphone at all times to ensure security.

8. **Misc. services**
   Other important Android, Google or stand-alone services running on devices are email synchronization program, message, store, dictionary etc.

9. **Other common apps**
   Most commonly used applications such as Facebook, Twitter, Skype and mobile messaging service KakaoTalk were installed on DUT. Android OS comes with some already installed applications i.e. Youtube, Google Store, Maps, Navigation to name a few.

### 2.3 Test Equipment

We used power monitor by Monsoon Solutions Inc. for our measurements. Exact output voltage can be determined by considering the resistances, internal resistance of test equipment and source channel resistance.

\[
V_{\text{exact}} = V_{\text{output}} (I_{\text{drawn}} \times R)
\]

Normally, the resistance of 20 gauge wire is 0.012 \( \Omega/\text{ft} \). The length of cable used for testing was about two feet. According to above equation, setting the output voltage \( V_{\text{out}} \) at 3.76 V provides us 3.7 V as real output voltage. Specifications including the accuracy of the current for USB channel are given in Table 2.
Table 2: USB channel specs of test equipment

| Component                        | Min   | Max   |
|----------------------------------|-------|-------|
| Input voltage range              | 2.1 V | 5.4 V |
| Continuous current               | -     | 1.0 A |
| Fine current scale - range       | -     | 40 mA |
| Fine current scale - resolution  | 2.86 uA | -   |
| Fine current scale - accuracy    | +/- 1% or +/- 50 uA (whichever is greater) | -   |
| Coarse current scale - range     | 30 mA | 4.5 A |
| Coarse current scale - resolution| 286 uA | -   |
| Coarse current scale - accuracy  | +/- 1% or +/- 1 mA (whichever is greater) | -   |
| VBUS capacitance to GND          | 22uF +/- 20% | -   |

3 Modes of Operation

We will compare power performance of DUT under various scenarios. In this section, we describe some of these situations.

1. Data Networks
   LTE and Wi-Fi data networks are both used during experimentation. We analyze both networks during their normal and sleep mode.

2. Normal Operation
   During normal operation, users use their smartphones in a typical way. Different users utilize their smartphones differently. Though based on average current consumption, some optimized criteria can be set. Thus, we took many samples in order to make certain the lower and upper bounds of power consumption. Average of these samples is presented in this work.

3. Sleep
   Sleep mode is inactive mode of normal operation. Users perform no activity of any kind with their smartphones. It is equivalent to the passive mode of smartphones at night. We started calculations after initial power surges subsided.

4. Flight Mode
   Generally flight mode in phones disables data connection i.e. no data enters or leaves the phone. Only native applications can be used in this mode.

5. Power Save Mode
   Latest smartphones include this mode to enhance the battery life by taking steps needed to decrease the current consumption. We will also analyze the effect of this mode in practical in next section.
Table 3. depicts functionalities of smartphone which are activated or de-activated during different modes of DUT.

| Activity                             | LTE | Wi-Fi | Flight mode | Power-save mode |
|--------------------------------------|-----|-------|-------------|-----------------|
|                                      | Normal | Sleep | Normal | Sleep | Normal | Sleep | Normal | Sleep | Normal | Sleep |
| Network (LTE or Wi-Fi)               | Yes  | Yes   | Yes      | No    | No     | Yes   | Yes    | Yes   |
| GPS                                  | Yes  | Yes   | Yes      | No    | No     | No    | No     |
| Bluetooth                            | Yes  | Yes   | Yes      | No    | No     | No    |
| Notifications                        | Yes  | Yes   | Yes      | No    | No     | Yes   |
| Email synchronization                | Yes  | Yes   | Yes      | No    | No     | No    |
| Apps running in background           | Yes  | Yes   | Yes      | No    | No     | Yes   |
| CPU power optimization               | No   | No    | No       | No    | No     | Yes   | Yes    |
| Brightness intensity optimization    | No   | No    | No       | No    | No     | Yes   | Yes    |

4 Observations

In this section, we present results and analysis of power consumption for the scenarios we defined in the previous section. Results are based on more than 7.5 million samples collected during the testing. Table 4. lists power consumed under different conditions. Here, the observations about the power consumption are presented in graphical form for ease of analysis.

At sleep mode, WiFi network seems to be consuming more energy than others. Flight mode is more energy efficient. In normal operation, however, WiFi shows better performance in regard to energy consumed. Power-save mode does not help in saving energy, as shown in Figure 1.

In Figure 2, average power consumption shows the same behavior as that of consumed energy. WiFi network shows better power performance at sleep mode, but perform oppositely in normal functioning. Similarly, power-save mode does not shows better performance.
In Figure 3., average current for sleep and normal mode depicts the same observations as depicted in previous figures. Average current consumption for LTE network is far lower than WiFi and power-save mode. This is true for both sleep and normal mode.

In Figure 4., based on the analysis, smartphone in flight mode will save more power thus extending the battery life. LTE networks show better performance than WiFi network and power-save mode in sleep.

Fig. 1: Consumed energy in Sleep and Normal mode
Fig. 2: Average power in Sleep and Normal mode

Fig. 3: Average current in Sleep and Normal mode
Fig. 4: Battery life in Sleep and Normal mode

Table 5. shows the share of important Android components, defined briefly in Section 3, in overall power consumption.

Figure 5. shows the power consumed in normal mode, whereas Figure 6. shows the power consumed in sleep mode.

Fig. 5: Consumed energy in Normal mode
### Table 5: Functions operating in different modes

| Activity                  | LTE  | Wi-Fi | Flight mode | Power-save mode |
|---------------------------|------|-------|-------------|-----------------|
|                           | Normal | Sleep | Normal | Sleep | Normal | Sleep | Normal | Sleep |
| Android system level      | 18.4 | 24.4  | 20      | 19.9  | 8.7    | 28.3  | 21.0   | 21.8  |
| Kernel                    | 4.2  | 6.4   | 4.0     | 4.2   | 1.4    | 6.8   | 3.5    | 5.2   |
| Android core apps         | 2.6  | 4.9   | 2.1     | 2.3   | 58.1   | 4.4   | 3.3    | 2.9   |
| Google services           | -    | 1.5   | 0.9     | 1.3   | 0.3    | 2.3   | 1.3    | 3.8   |
| Anti-virus program        | 3.1  | 6.8   | 9.6     | 26.2  | 12.2   | 9.0   | 13.8   | 18.9  |
| Facebook                  | 4.6  | 3.5   | 4.2     | 0.9   | 0.6    | 4.1   | 10.1   | 3.7   |
| Internet                  | 11.6 | -     | 23.7    | -     | -      | -     | 6.3    | -     |
| Microbes                  | 3.0  | 4.0   | 3.2     | 7.2   | 1.5    | 8.1   | 2.5    | 9.0   |
| Kakaotalk                 | 0.7  | 1.2   | 2.1     | 9.8   | -      | 3.9   | 2.4    | 4.8   |
| Google maps               | 0.3  | 1.1   | 0.9     | 2.6   | 0.9    | 1.8   | 0.9    | 1.4   |
| Dialer                    | 2.6  | 1.5   | 0.6     | 0.8   | -      | 1.4   | 0.8    | 1.3   |
| System mediaserver        | -    | -     | 1.0     | -     | 0.3    | -     | 0.7    | 0.4   |
| Google Play               | 0.2  | -     | -       | 0.5   | -      | 0.8   | 0.4    | 0.8   |
| Media                     | -    | -     | -       | -     | -      | -     | 0.4    | 0.5   |
| Email and messages        | -    | 1.1   | -       | -     | -      | 0.4   | -      | -     |

![Fig. 6: Consumed energy in Sleep mode](image)
5 Conclusion

In this paper, we analyzed power consumption of a latest smartphone for different working modes. This study showed that some modes that are meant for saving power i.e. power-save mode, are not that efficient in saving power. In sleep, putting our smartphones in flight mode can help us in saving most of its energy, and thus extend its battery consumption. LTE, although a new network, performs better in sleep mode. In normal operation, however, it is still expensive for power.

We also analyzed OS-level power consumption of a latest smartphone for different working modes. This work may form the basis for further in-depth analysis on power consumption in smartphones. Furthermore, power optimization can also benefit from this work.

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