

# Method for Saving Energy Battery Based in Context for Android Phones

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## Abstract

*Nowadays, the main problem we found in most smartphones is the poor battery life when using applications that make an intensive use of connectivity services. This becomes a serious problem in specific applications such as telemedicine; where services such as WiFi and 3G connection are the largest consumers of energy, but are essential for the transfer of data required by these applications. This paper examines different energy consumption studies on mobile devices via WiFi and 3G. After this analysis, we propose and test a method for choosing the network with lower energy consumption based on the characteristics of the data transfer context that the application requires.*

## 1. Introduction

Each day mobile devices show us more capabilities and services at our disposal; however, developments in battery capacity doesn't occur at the same rate [1] [2] [3] [4]. Especially with connectivity services, which are the biggest battery consumers and the most used in applications that pursue user being always "connected". Thus the main problem we found in most smartphones is the poor battery life when using applications that make an intensive use of connectivity services.

The problem worsens in specific applications such as telemedicine, where the use of WiFi and 3G services, although they are the largest energy consumers, are essential to the operation of these applications, because they must have data transfer functions that goes from simple temperature data until tomography images; i.e. require a wide range of data [5].

One of the first steps for optimizing the use of energy is to know under what conditions the WiFi and 3G services are consuming battery. For this task, we analyzed several studies of energy consumption of networking services on mobile devices.

This analysis led to the design of a networking strategy choice. When the telemedicine application will perform a data transfer, the strategy chooses the network with the lower energy consumption. This choice is based on four transfer characteristics: connection status, signal strength, data size and transfer time.

In section III we present an analysis of previous works about energy consumption of interfaces WiFi and 3G. In section IV we proposed the design and implementation of the networking strategy choice. In section V we show our

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experiments with the method. Finally in section VI we discuss the conclusions and future work.

## 2. Related Work

Rahmati and Zhong analyzes the different energy consumptions for each phases of connection for the network interfaces [5]. The paper proposes to use the complementary strengths of each network to automatically select the most efficient according to background information of the network for Windows Mobile. They work in this problem from a statistical point of view.

Chong, Gaber, Krishnaswamy and Loke proposes the development of a framework called CAS: Context Awareness in Sensing Enviroments, which objective is the energy conservation in sensors for wireless networks [6]. According to a set of rules the framework activates the most saving sensors. This work was made especially for the sensors of a PDA.

Zahid, Ali y Nassr develops and evaluates an Android service called ASPSS: Android Smart Power Save Service for the energy saving oriented to the user, tries to use the smartphone idle times to stop the technologies and applications with the most energy consumption according to the preferences of the user [3].

Kim, Min, Gupta, Mohapatra and Singh implements a system for Android smartphones that uses user motion information obtained through low battery sensors to outline the network information, and finally includes adaptive algorithms for WiFi detection that makes use of these profiles, in order to conserve battery power by enabling the detection phase when there is more possibilities that is a WiFi network available [7].

## 3. Consumption Analysis wifi and 3g

Compared to wired networks (Ethernet), wireless networking WiFi and 3G consume more energy. Based on minimum power for Ethernet, transmit data via WiFi incurs in an energy expenditure of 11.33% higher, while the use of 3G connection is 44% higher. Its expends are higher because the transmission medium is air, which has a higher attenuation condition, as well as other circumstances like multipath or interference [8]. However, the devices could not connect to the Internet without using them.

Works and experiments conducted suggest us that WiFi and 3G, are the largest energy consumers of battery, and they also present various solutions to reduce this consumption [9]

[10] [11]. Among the solutions they proposed one of the simplest ways to save energy is use the most saving network and turn off the rest, so that the application is in low energy states as much as possible [12] [13] [14]. But how do you know which network saves more energy? There are various issues that need to be analyzed, and are present below.

Although we tend to think that 3G consumes more than WiFi because its range of action covers large areas or its number of potential users [8]. Actually, the energy consume between WiFi and 3G is similar, but each one has its own energy characteristics at the different phases of connection: Establishing a connection, maintaining a connection, data transfer [11] [15] [16] [14]. In Rahmati, we can find a detailed study of the energy costs of WiFi and 3G connection [5]. Keep in mind if the connection is already turned on, it doesn't incur in an energy expense. This case can be seen in Table I on 3G.

**Table 1. Network Energy Consumption [5]**

	3G	WiFi
Checking for availability/establishing a connection	0	5J
Maintaining a connection	1-6 J/min	20-60 J/min
Energy per MB transfer	Upload: 95-125 J Download: 40-50J	Upload: 7-11 J Download: 5-7 J

Another aspect to consider in connection energy expenses is the *vertical handoff*, the energy cost of switching from one network to another, which must also be taken into account for the final calculation of the network energy cost. Petander indicates that the *vertical handoff* from 3G to WiFi consumes more energy than the 3G itself, and recommended switch to WiFi when the data size is greater than 0,12 – 0,9 Mb [18].

Also other factors to measure the connection energy cost, are studied [5] [15] [16] [17] [19]. Transmit data consumes more energy that receive it [8].The data size to be transferred is a decisive factor, in 3G the larger the data size the greater the consumption we have, therefore studies show that is better using WiFi for large amount of data. In Kalic et al. they present mathematical models to estimate energy consumption according to the data size to transfer, these models were specially designed for Android devices [20].

**Table 2. Energy Consumption Functions in respect to the amount of Transferred Data [17]**

	Download	Upload
WiFi	$y=17.01x-0.93$	$y=17.31x-2.28$
3G	$y=31.74x+2.15$	$y=71.27x-0.03$

Together with the size data, the transfer time could be a factor too. As seen above in connection phases, while WiFi consumes more energy in maintaining the connection, save

more energy in the data transfer, entirely contrary to 3G; when the data size is small the time transfer cost is negligible. Kalic also presents a mathematical model in respect to the transfer time [20].

**Table 3. Energy Consumption Functions in respect to the transfer Time [17]**

	Download	Upload
WiFi	$y=18.09x+0.17$	$y=21.24x-2.68$
3G	$y=20.59x-1.09$	$y=15.31x+2.67$

Another factor is the signal strength, especially WiFi that has availability more varied than 3G, the stronger the signal lower the energy cost. Even as the signal strength is decreasing the energy expense increases by a percentage.

To check the consumptions of WiFi and 3G, tests were performed in a Smartphone Samsung Y Duos with Android 2.3. The Smartphone remained turn on for about an hour and a half, in daily use. The measurements were made using the application PowerTutor, this application generates an estimated energy consumption model [21].

**Table 4. Energy Measurements Android Applications [Source: Own Elaboration]**

Applications	WiFi	3G
Media Server	43,9 J	17,6 J
Internet	18,1 J	18,3 J
Google Play Store	9,7 J	16,0 J
Google+	4,4 J	18,2 J
Maps	4,3 J	17,7 J
Youtube	3,0 J	19,4 J
Sincronización de Contactos	1,4 J	38,3 J
Noticias & Clima	834,0 mJ	9,2 J
WhatsApp	342,0 mJ	30,4 J

As seen in Table IV the applications that transfer a large amount of data save more energy using WiFi, although their connection remain connected for a longer time. And however there are cases, e.g. the application media server, in which despite of being active all the time, save more energy using 3G, because de data size to be transfer was lower.

In the experiments, we didn't take into account the *vertical handoff* consumption, because the tests turn on one connection at a time.

## 4. Design and Implementation

### 4.1. Design

In this paper we present the design of a method for choosing the network with lower energy consumption for an application. We develop this solution as an auxiliary service for a central telemedicine application with sending data functions.

The proposal divides basically in two modules, as it can be seen in Figure I, a most saving network choice module and a prediction module to improve the method performance.

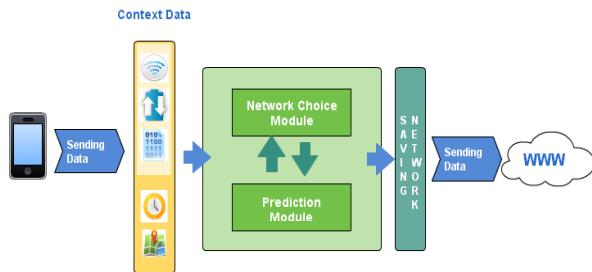


Figure 1. Overview of the Solution [Source: Own Elaboration]

### 4.2. Network Choice Module

This module is in charge of obtain which network interface, between WiFi and 3G, is the one with lower energy consumption for sending data according to the connectivity context of the moment. This module is divided in 3 submodules that can be seen in Figure II.

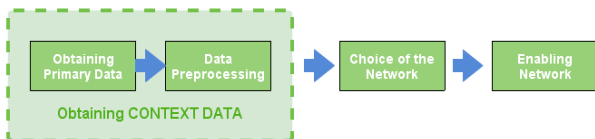


Figure 2. Network Choice Module [Source: Own Elaboration]

**4.2.1. Obtaining Context Data:** This module gets the environment information and the upcoming transfer information, the context. Some context data will be use for the algorithm choose network, that from this point on we will refer as connectivity context. The other part of the data will be used for the learning in the prediction module.

This is a list of the primary data necessary to define the context:

**Location:** Refers to the user location at the moment of sending the data and choice a network interface. We didn't use GPS location because is one of the largest battery consumers, so we use other locations strategies like Cell-ID and WiFi.

**Day of the week:** refers to the day of the week at the moment of sending the data and choice a network interface.

**Time slot:** refers to the time space of half an hour (for example 9:00- 9:30) in which the user sends data and the method choose a network interface.

**Availability:** refers if the network is available for the location, day of week and time slot given at the time of transfer. It is possible to connect to a network interface. For example there are locations where there is availability of a modem or access point to connect to WiFi.

**Connection Speed:** refers to the speed of the network interface link, it's necessary for the algorithm choose network.

**Packet size:** refers to the size of the data for an upcoming transfer, it means the size of the data before sending it by Internet. It's necessary for the algorithm choose network.

**Signal Strength:** refers to the signal strength of the network interface, it's necessary for the algorithm choose network.

Based in some of these data we obtained two additional data:

**Energy expense x Time Transfer:** Calculate based in the model of Kalic with the data size and the connection speed [20].

**Energy expense x Data Size:** This model is estimated using primary data of the data size.

**4.2.2. Choice of the Network:** This submodule contains the algorithm for choose the most energy saving network interface. This choice is given according to the features of each connectivity context of the network in the given time. For the elaboration of this algorithm an analysis was made about the connectivity factors that impact in the energy consumption.

**4.2.3. Enabling Network:** This submodule executes the the election given by the previous submodule. Basically activates and connects the network interface chosen by the algorithm of choice, and off the other network.

### 4.3. Algorithm Choose Network

This algorithm bases its decision on the aspects seen in the consumption analysis of the previous section. This algorithm is divided into steps, each step represent an energy aspect to be evaluated.

In Figure 3, we show the pseudocode for this algorithm, and later we explain step by step, the aspects we are taking into account for the evaluation and later decision of the most saving network.

```

Procedure ChooseNetwork (ContextWiFi, Context3G)
If 3GConected() Then
    If PacketSize() > 150Kb Then
        If TmTransfWiFi() < TmTransf3G() Then
            TurnOff3G();
            TurnOnWiFi();
        End if
    End if

```

```

//If not we are still connected to 3G
End If

Else If WifiConected() Then
EvWiFi ← TmTransfWiFi() + SizeWiFi();
Ev3G ← TmTransf3G() + Size3G();
If EvWiFi > Ev3G Then
TurnOffWiFi();
TurnOn3G();
End If

Else Then
EvWiFi ← TmTransfWiFi() + SizeWiFi();
Ev3G ← TmTransf3G() + Size3G();
If EvWiFi > Ev3G Then
TurnOn3G();
Else Then
TurnOffWifi();
End If
End If

End Procedure

```

**Figure 3. Algorithm Choose Network [Source: Own Elaboration]**

**4.3.1. Step 1: This network is active?:** The scan and activation of a network involved an energy cost, which is why the first aspect to be taken into account is to check which of the two networks is active. If the WiFi is active, we will make an additional evaluation of signal strength because this is an important aspect in this interface.

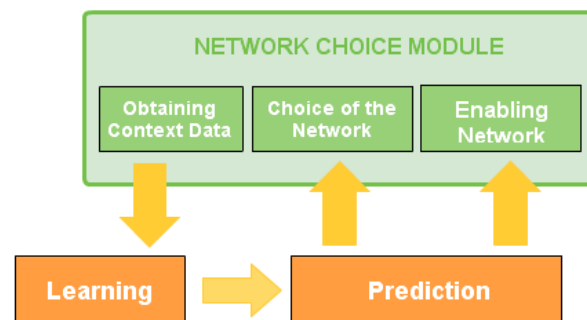
**4.3.2. Step 1.5 : How good is the signal strength?:** If the WiFi signal is in a range of 75% - 100% signal strength, it isn't an additional energy cost to the total [18]. Then one can proceed to evaluate de data size and the transfer time. Instead, if the signal strength is less than 75% is appropriate to add a penalty energy cost that is consistent with the decrease in the signal strength.

**4.3.3. Step 2: Data Size Evaluation:** WiFi saves more energy while the packet size is large. But according to what number we began to considerate that the size is large and we need to use WiFi? A measure obtained empirically and intuited by the work of Rahmati and Petander, brings us the approximate number of 150 Kb, which also fit well with the energy cost of a vertical handoff from 3G to WiFi [5] [18].

In the case of WiFi and the additional penalties of signal strength, it's calculated with the formulas show in Table II.

**4.3.4. Step 3: Transfer Time Evaluation:** If the data size is small immediately choose 3G otherwise we have one more evaluation: the transfer time for large data. The transfer time can be calculated from the packet size and the speed of each connection. Once obtained this time is calculated with the energy cost of maintaining a connection. We compare the energy costs and choose the one that saves more energy.

## 4.4. Prediction Module



**Figure 4. Prediction Module [Source: Own Elaboration]**

According to a previous research, although we had a saving in the battery energy when using the algorithm of choice network, the algorithm incurred in an energy expenditure having to activate the two interfaces for getting the context data [22]. Thus this second module is devised to improve this weakness.

Being our solution developed at an application level we have limitations giving by Android system itself. Among them that in order to get the data from each network connectivity, this had to be active anyway. However, it was a chance to learn from previous choices given by the first module in a given context. Thus, if it has a context which already has made choices of network interface, we can learn from these choices and predict the most saving network without turning on the 2 interfaces, only by making use of previous cases. And that is precisely the function of the prediction module.

This module records the data context and the choice of network interface given by the algorithm for a period of time. With this information we generated a transition matrix for each context with records, the previous choices. We use Markov chains of Order one  $O(1)$  with stationary transition matrix.

As it can be seen in the Figure IV, this module has a strong connection with the network choice module. This module is divided into two other sub-modules:

**4.4.1. Learning:** This submodule records the network choices made for a determined context, and after a time of learning, a transition matrix is obtained for each context.

**4.4.2. Prediction Network Interface:** This submodule is executed whenever there is a transition matrix for the context. If there is no matrix or record of previous choices it proceeds to execute the algorithm. Once we have the transition matrix for a context we don't need to keep learning for this context.

So when we try sending data we consult if the context has a transition matrix, presenting two situations:



- There is a matrix for the context: Based in this matrix we predict which network to choose according to previous experiences. Once the decision is made we use the enabling network submodule for turn on the interface.
- There is not matrix for the context: Which means we don't have previous experiences and is a new context. In this case we need to use the algorithm.

#### 4.5. Learning

From the context data records the submodule generated the transition matrix. The context consists of the day of the week, time slot and location. In this context some data transfers are made, where previously the most saving network was chosen according to the connectivity context that was presented at that time. This context with the respective choice forms a training data record for the subsequent creation of a transition matrix.

So the training data has the following components: the day of the week, time slot, location, network choice at the moment and the previous network choice, as we work with Markov Chain of Order one  $O(1)$  is necessary the record of the previous choice for a determined context. With the actual choice and the previous choice we generated a transition matrix and generated a training data. In Figure V we can see an example of a training data with the transition matrix generated.

TUESDAY				
...	9:00 - 9:30	9:30 - 10:00	10:00 - 10:30	...
	Loc1	Loc1	Loc2	
		%WW %WG		
		%GW %GG		

**Figure 5. Example Training Data with transition matrix [Source: Own Elaboration]**

This learning develops in a time given by the user, but as in any other learning with more data training we can have a better accuracy in our predictions. Once the user indicates the end of the learning data, we proceed to the automatic creation of the transition matrix. In Figure VI we can see the model of the matrix.

The transition matrix consists of 4 probabilities:

- WW: Probability to choose the WiFi network interface when the previous choice was WiFi.
- WG: Probability to choose the 3G network interface when the previous choice was WiFi.
- GW: Probability to choose the WiFi network interface when the previous choice was 3G.
- GG: Probability to choose the 3G network interface when the previous choice was 3G.

	WiFi	3G
WiFi	%WW	%WG
3G	%GW	%GG

**Figure 6. Model Transition Matrix [Source: Own Elaboration]**

### 5. Experiments

#### 5.1. Measurement Tool: PowerTutor

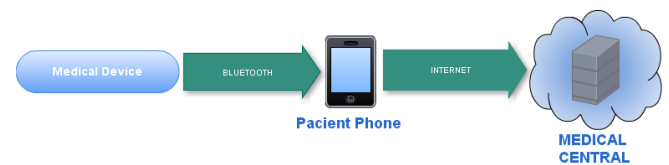
PowerTutor is an application for Android phones that displays the power consumed by system components such as CPU, network interface, display, and GPS [21]. The application allows seeing the impact on power efficiency and battery life.

PowerTutor uses a power consumption model built by direct measurements during careful control of device power management states. This model generally provides power consumption estimates within 5% of actual values. It displays the power consumption history and also provides a text-file containing detailed results. One can use PowerTutor to monitor the power consumption of any application.

#### 5.2. Study Case

The present work focuses in telemedicine applications which have almost indispensable functions for sending data, this is because medical data taken by a device must be verified by a specialist and should be store in a central database.

We develop a testing application that simulates the flow of data in a common application of telemedicine, as it can be seen in Figure VII, where data form a medical device is saved in a phone and the sent via Internet to a central server.



**Figure 7. Flow data telemedicine application [Source: Own Elaboration]**

Medical data are generated within the application, following the format of data: submission date, value of the data, unit, date, data type, sub data type, login, Medical Device ID, Mobile Device ID.

Usually such applications presents several scenarios under which it works, the most common are:

- Personal Use: A person has their own devices and makes use of them to send his/her data to the medical central.

- **Shared Device:** A medical device is shared by multiple users to control and monitor the health.
- **Doctor visits:** Specialized medical staff recorded the control and monitoring of patients whom they make appointments, their work is sent as an entire block to the medical central.

To simulate these work scenarios we sent 3 sizes of data: sending a measurement, sending a series of measurements and sending a picture (since its size is large enough to represent a data set). In the case of simple measures are randomly generated. The mechanics of the application is to send some data every 10 minutes to the server.

### 5.3. Initial Experiments

The initial experiments are the tests made during the development of the solution to test it and see if there is actually a saving with the implemented solution.

We test the method in a smartphone Motorola XT914 Razr D1 with operating system Android 4.1 JellyBean, additionally it has the technical specifications of the Table V.

**Table 5. technical specification – initial experiments**  
[Source: Own Elaboration]

2G	Bandas 850 / 900 / 1800 / 1900 MHz Tecnología GSM / GPRS / EDGE
3G	Bandas 850 / 1900 / 2100 MHz Tecnología UMTS/ HSDPA / HSUPA
Battery	Duración 5.8 hrs Modelo de Batería HW4X Tiempo de Carga 4 hrs Tipo de Batería Li-Ion de 1785 mAh
Memory	Capacidad 4 GB Memoria RAM 1 GB
Processor Speed	1 GHz
Operating System	Android Versión 4.1 – JellyBean

As one can see we used a mid-range smartphone, with average characteristics. It is expected that if the solution works properly on this phone it will work equally good for phones with similar or even better characteristics.

**5.3.1. Network Choice Module Test:** The objective of this test was to verify that indeed the use of the network choice module saves a percentage of energy battery. This verification of the effectiveness of the algorithm is given but we returned to do the tests with the enhancements and changes made to the programming level algorithm for this work [22].

For the testing, three tests were performed, one using the energy saving solution and the other two using the WiFi network and the 3G network. For each test the battery was charged to 100% and the demo application was active for 5 hours. In this period we didn't use the smartphone for other activities.

To measure energy costs over this period the PowerTutor application was activated and the battery level

decreases were seen in the detailed file that provides PowerTutor.

The results were compared and shown that effectively the method chooses the most saving network. By using WiFi the energy cost was 5358.08 J equivalents to 28% of spent battery and 3G use an energy cost of 6698.6 J equivalents to a 35%. If we see the cost of the solution was 4405.04 J equivalents to 23%. So an energy saving is achieved compared to using only the WiFi interface or 3G network. Savings of approximately 5% compared to WiFi and about 13 % compared to 3G.

### 5.4. Prediction Module Test

While the choice network module has an energy saving, according to our design we can have a better saving by using training data. As this is an experiment we used hard coded training data and thus also avoid the learning time because is not the main objective of this test.

For this test, there will be the same conditions than the previous tests: charge the phone to 100%, enable the continuous transmission of data for 5 hours and use PowerTutor. Only that, this time, the prediction module was used.

In this test the energy cost was 4114.6 J about 21% of battery consumption. Compared with the results of the choice network module, applying a learning process can achieve better energy savings.

**5.4.1. Users Experiments:** In this section we present the results of the method validation given by expert users, people with some experience or knowledge in the problem area.

First we define an expert profile with the competences needed for this research. Which are the followings:

- Attitude Review
- Fairness Opinions
- Possess knowledge of the Android operating system.
- Possess basic knowledge of programming.
- Possess knowledge of mobile network or WiFi and 3G data.

Also other conditions were also established, necessary to perform the validation.

- Count with a device with Android 2.3 or higher operating system.
- This device must be connected to the network interfaces: WiFi and 3G.
- The person is capable to enable and disable network interfaces from the system settings.

### 5.5. Energy Saving Test

We realized the test for our solution on 10 different expert users. The mechanic of the test was the following.

We install in their phones the measurement tool PowerTutor and the telemedicine application demo. This tests phase was divided in 3 parts:

- **Day Zero:** In this test the users had to have their battery at 100% of the capacity. And activate the continuous transmission of data during 5 hours; the schedule was election of each user it could be in the morning or in the afternoon. They had to continue their normal routine.
- **Learning Time:** In the beginning of this test, usually the next day after day zero, the user activates our saving energy method. In the GUI is only enabling a check. And in the same way that day zero they has to have the battery at 100% and activate the continuous transmission in the same schedule.
- **Final Day:** To avoid the users having to make additional settings, past the learning time automatically the learning stops and wait a moment because the transition matrices are created. Users should proceed in the same manner as the other days.

With this procedure we have information on the energy cost of using networks without the solution and after it is implemented.

## 5.6. Devices Specifications

In the Table VI we present the list of the used phones of each user and their most important characteristics which are the model and manufacturer, version of the operating system, battery capacity in milliampere-hours and the mobile operator, the provider for mobile internet.

**Table 6. List of Device Specifications**  
[Source: Own Elaboration]

Usuario	Modelo Smartphone	Versión S.O. Android	Capacidad Batería (mAh)	Operador móvil
U01	MotoSmart XT914	4.1 JellyBean	1700	Movistar
U02	MotoSmart XT389	2.3 Gingerbread	1390	Movistar
U03	Samsung Galaxy Y	2.3 Gingerbread	1200	Movistar
U04	Samsung Galaxy Y Duos	2.3 Gingerbread	1300	Claro
U05	Airis TM400	4.0.4 Ice CreamSandwich	1700	Movistar
U06	Airis TM520	4.2 JellyBean	2000	Movistar
U07	Samsung Galaxy Y	2.3 Gingerbread	1200	Claro
U08	Samsung Galaxy Ace	2.3 Gingerbread	1350	Claro
U09	Samsung Galaxy S3 mini	4.1 JellyBean	1500	Movistar
U010	Samsung Galaxy S3	4.1 JellyBean	2100	Movistar

## 5.7. Results

The Table VII shows us the energy consumption of each device with and without the solution. These results are the measurements made by the application PowerTutor. This Table shows the results according to the Level of Energy Consumed x Time of Use in Joules.

**Table 7. Energy Consumed Results**  
[Source: Own Elaboration]

User	Day Zero	Final Day
	Energy consumed J	Energy consumed J
U01	7982,2	6330,7
U02	2121,2	1811
U03	2922	1588,7
U04	879,5	1420
U05	6055,5	4679,25
U06	6881,3	5780,7
U07	2853	2678
U08	1894	1488
U09	2283	2595
U010	2284	1632,6

The Table VIII shows us the percentage of battery spent of each device with and without the solution. These results were calculated with the measurements of the previous Table made by the application PowerTutor and the battery specification of each device. This Table shows the results according to the Percentage Battery Usage x Time of Use.

**Table 8. Energy Consumed Results**  
[Source: Own Elaboration]

User	Day Zero	Final Day
	%Battery Spent	%Battery Spent
U01	29%	23%
U02	34%	28%
U03	28%	19%
U04	13%	21%
U05	22%	17%
U06	25%	21%
U07	26%	24%
U08	28%	22%
U09	22%	25%
U010	26%	19%

To summarize we present the Table IX where one can see the measurements that have been made for both the "Level of Energy Consumed x Time of Use" as to "Percent Battery Usage By Time of Use". These two indicators show us the saving battery power of an Android device.

It is from this table where one can compare more clearly the results of the tests when the user did not have the solution and continued his/her routine, and when the user uses the solution on his/her smartphone.

**Table 9. Summarized Results**  
[Source: Own Elaboration]

User	Day Zero		Final Day	
	Energy consumed J	% Battery Spent	Energy consumed J	% Battery Spent
U01	7982,2	29%	6330,7	23%
U02	2121,2	34%	1811	28%
U03	2922	28%	1588,7	19%
U04	879,5	13%	1420	21%
U05	6055,5	22%	4679,25	17%
U06	6881,3	25%	5780,7	21%
U07	2853	26%	2678	24%
U08	1894	28%	1488	22%
U09	2283	22%	2595	25%
U010	2284	26%	1632,6	19%

As can be seen by comparing the percentages of spent battery from day zero and the last day, it can be seen that each user can save the phone battery using the method in a different level. All except the user U04 at first sight it seems that was not the case, but further review to detail was observed that on day zero the mobile application was not sending the amount of data that must be sent in time because at some point the user disabled the network connection, whereas the method automatically provided to activate an available network. Then, on day zero percentage is lower for this user because it had fewer data submissions.

## 6. Conclusions

In the initial experiments, the energy expenses in which incur the different network interfaces WiFi and 3G vary according to several factors such as data size, transfer time and energy costs of each interface. Thereby determining that each interface can be the most saving network according to the context at a given time.

The method for choosing a network presented in this paper allows battery saving using a set of rules considered by previous works and a later prediction, proposing the use of the network that has lower power consumption according to a preliminary evaluation and turn off the other networks.

This strategy allows the mobile to save battery according to a preliminary evaluation. But for this evaluation, we need to activate each network, which incurs in an additional cost. So for this weakness we design learning and prediction approach that avoids these unnecessary activations and improve the percentage of saving energy as it can be seen in the tests we realized in the present paper.

For future works we plan to add the 4G network interface in the solution, for this we need to do its own consumption analysis. Additional to this we plan to add a new evaluation feature also, that is the monetary cost of the use of mobile data.

## 7. Acknowledgment

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