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► To cite this version:

Khalil Ibrahim Hamzaoui, Soufiane Dahmani, Pierre Boulet. ”Tour de France” data for the improvement of energy consumption in devices powered by limited energy sources. 2020. hal-02558636v1

HAL Id: hal-02558636

<https://hal.science/hal-02558636v1>

Preprint submitted on 29 Apr 2020 (v1), last revised 19 Jan 2021 (v2)

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“Tour de France” data for the improvement of energy consumption in devices powered by limited energy sources

HAMZAOUI Khalil Ibrahim,^{1,2,*}

DAHMANI Soufiane², BOULET Pierre¹

Abstract

In this article we propose a dataset about the energy consumption of mobile devices that was collected as part of a “Tour de France” with an electrical wheelchair. Part of these data were used to propose a mathematical model based on an experimental methodology of the energy consumed in smartphones.

Based on these precise measurements in a real environment, we have elaborated predictive models of energy consumption. The objective of this paper is to make accessible the data related to these publications to other researchers in several fields of science (computer science, telecommunications, meteorological science, artificial intelligence, statistics ...).

Keywords: Energy Consumption, Collection of Data, Internet of Things, Data Processing

*Corresponding author

Email addresses: hamzaoui.khalil@gmail.com (HAMZAOUI Khalil Ibrahim),
s.dahmani@ump.ac.ma (DAHMANI Soufiane), pierre.boulet@univ-lille.fr (BOULET Pierre)

URL: <https://pro.univ-lille.fr/pierre-boulet/> (BOULET Pierre)

¹Univ. Lille, CNRS, Centrale Lille, UMR 9189 - CRISTAL - Centre de Recherche en Informatique Signal et Automatique de Lille, F-59000 Lille, France

²Mohammed First University of Oujda, Morocco

Specifications table

Subject	Computer Science, Computational Theory and Mathematics
More specific subject area	Improvement of energy consumption in devices powered by limited energy sources
Type of data	Text (csv file)
How data was acquired collection	These experimental data were collected during a 33 day long “Tour de France” with an electrical wheelchair: https://www.youtube.com/watch?v=0NwU2yU_xnE The data were collected on the basis of several scenarios in different places (3006 kilometers(Km)). These measures were operated out in a real environment.
Parameters for data	Tablet HP Pro Slate 8 (Snap Dragon), Trepn Profiler V6.2s [1], Cpu Frequency, Cronoid 3.5.1 [2]
Data format	Table
Description of data collection	Scientific data was collected on the basis of several scenarios in different places. These measures were operated out in a real environment and confronted with the consumption measures carried out beforehand in a controlled environment. After each experiment, the obtained data is stored in a csv file with a large number of parameters and data retrieved.
Data source location	Cities : Lille, Amiens, Rouen, Le Havre, Caen, Rennes, Nantes, La Rochelles, Bordeaux, Toulouse, Montpellier, Avignon, Grenoble, Lyon, Dijon, Troyes, Paris, Valenciennes. Country: France.

Specifications table**(continued)**

Data accessibility	The dataset is available at https://zenodo.org/record/3739472 with a Creative Commons Attribution 4.0 International license
Repository name	Zenodo : “Tour de France” data for the improvement of energy consumption in devices powered by limited energy sources.
Related research article	Author’s name: Khalil Ibrahim HAMZAOU, Mohammed BERRAJAA, Mostafa AZIZI, Giuseppe LIPARI, Pierre BOULET Title: Measurement-based methodology for modelling the energy consumption of mobile devices Journal: International Journal of Reasoning based Intelligent Systems DOI: https://doi.org/10.1504/IJRIS.2020.105007 [3]

Value of the data:

- The presented experimental data are useful to measure several metrics related to the energy variation in a mobile device.
- The data are beneficial for all the scientists who are exploring energy consumption in devices powered by limited energy sources as a knowledge resource.
- The data can be used to analyze the load of the Central Processing Unit (CPU) and the Graphics Processing Unit (GPU) as well as to make a more detailed follow-up of the energy variation on other type of mobile environment.
- The provided data can be used for further analysis in order to define models to improve energy handling in mobile devices, to study other types

of scenarios given the large size of the data measured during the collection, or to optimize our methodology (based on part of the dataset [4, 3]).

15 1. Data description

The presented research is part of the development of mathematical models, for modeling and evaluating the energy cost in mobile environments.

Our study focused on the Android system. The main objective of the data collection was to model the energy consumption of a particular application running on a mobile device.

The data collection made possible to develop a specific mathematical model of energy consumption for monitoring the energy consumption of playing a local video, remote video streaming as well as in the case of navigating with a GPS by acting on the following parameters:

- 25 • Processor frequency,
- Initial battery level,
- Dissipated energy.

This study is focused on the development and measurement of energy costs. Our work focused on monitoring energy consumption based on several experimental scenarios.

Scientific data was collected on the basis of several scenarios in different places. These measures were operated out in a real environment and confronted with the consumption measures carried out beforehand in a controlled environment.

35 Collecting and analyzing massive data in a real environment and diversifying it in a reasonable time creates a scientific challenge. The objective of the carried out study is to model the energy consumption of a particular application running on a mobile device.

2. Experimental design, materials, and methods

40 2.1. Methodology

Our work is used to model the energy consumption of one or more specific applications in a mobile device [5, 6, 7, 8]. On the one hand, it allows the monitoring of energy consumption according to the frequency and the total number of operations, on the other hand, to put into practice our proposed
45 methodologies through several concrete case studies.

To identify the parameters of the model, our methodology must determine the type of correlation between the number of total operations and the elementary energy dissipated at a previously defined frequency. The total number of operations is calculated by summing the active clock cycles of each processor per
50 measurement interval. This active clock cycle number is the load of the CPU multiplied by the measurement interval duration and by the CPU frequency. The dissipated energy during a measurement interval is the product between the battery power and the measurement interval duration.

The average consumption per clock cycle can be expressed as follows:

$$E_{\text{clock cycle}} = \text{Regression}\left(\sum_{i=1}^4 \text{Load}_i, E_{\text{dissipated}}\right)$$

55 $E_{\text{clock cycle}}$ shows the total energy per clock cycle, Load_i the load of CPU i and $E_{\text{dissipated}}$ corresponds to the dissipated energy measured experimentally.

Our methodology consists in establishing a regression of energy per measurement interval as a function of the total number of operations. The research presented proposes a methodology to evaluate and modeling the energy costs of
60 mobile devices.

The proposed methodology is developed in three stages:

- data collection,
- data preparation,
- energy consumption modelling.

65 The aim of this work is to monitor energy consumption by acting on the following parameters:

- frequency of the processors,
- initial level of the battery,
- energy dissipated by the clock cycle.

70 2.2. Energy Consumption Modelling

In the case of offline mode study, a linear regression is enough to build a good model. The connected mode case is better managed by a polynomial regression [3].

In the case of variable frequencies, the same methodology can be applied
75 by filtering the rows of the measurement table recorded by group of identical frequencies.

3. Experimental context

The purpose of our study is to provide detailed monitoring of the main sources of energy consumption. In the first case study, only the Global Mobile
80 Communications system (GSM) is active. The other communication networks (third generation of mobile wireless telecommunications (3G), fourth generation of mobile wireless telecommunications (4G), Wireless Fidelity (Wi-Fi) and Global Positioning System (GPS)) remain inactive throughout the different experiences.

85 The second case study aims at evaluating and measuring the energy consumed in connected use cases. Sources related to the data communications are activated completely (3G/4G or Wi-Fi) or partially (GPS) depending on the scenarios of the experiment. Another mobile device was present to serve as an access point for sharing the Wi-Fi connection.

90 To collect the data, a “Tour de France” was carried out using an electrical wheelchair to perform measurements in a diversified environment based on sev-

eral scenarios. Figure 1 details the route of the measurement sites (33 days and 3006 km).



Figure 1: Route of the scientific “Tour de France” [4]

The tool used for all the experiments is a tablet (HP ProSlate 8) which was previously rooted. This choice was linked to the capacity of the battery which
95 allows a large number of tests for each charge cycle, as well as the architecture

of the processor (Snapdragon 800) for its performance, minimal power use and temperature. The full characteristics of the tablet are given in Table 1.

Table 1: Characteristics of the experimental equipment [4]

Type of Product	Tablet
Operating system	Android 4.4.4 (KitKat)
Processor	QUALCOMM Snapdragon 800
Max. CPU frequency	2.3 GHz
Number of cores	4
Sensors	Accelerometer, ambient light, proximity, compass, barometer, gyroscope, Hall effect
Number of batteries	1
Technology	Lithium polymer
Autonomy	Up to 13.75 h
Operating temp mini	0°C
Operating temp maxi	40°C
Storage temp mini	-20°C
Storage temp maxi	60°C

3.1. Data Collection

100 The tools used to develop our study are [9]:

1. Trepn Profiler, a diagnostic tool for profiling performance and power consumption of Android applications. All tests of this experimentation were processed by version V6.2s. Trepn profiler provides information on system status, network status, graph performance, speed, processor frequency etc.
- 105 2. Cronoid, an automation tool that allows performing tasks on a regular basis (like cron). It also enables automatic task running when the status of the terminal changes. The version used for our work is Cronoid-3.5.1.

3. CPU Frequency, a tool that allows the user to change the CPU frequency setting to save energy or to achieve better performance.

110 The data collection stage of our methodology is based on the following steps:

- Preparation of the test platform (CPU frequency management based on the governor) in order to have the rights to fix the frequencies of the CPU with the CPU Frequency tool.
- The role of the Cronoid tool is to automate tasks in order to minimize
115 interaction with the user.

3.2. Data Preparation

The measurement file is represented in the two tables 2 and 3 which present the data collected from a 45-minute measurement experiment. The obtained data is stored in a csv file.

Table 2: Sample of measured data (part1) [4]

Time [ms]	Cpu1 Freq [kHz]	Cpu1 Load [%]	Cpu2 Freq [kHz]	Cpu2 Load [%]	Cpu3 Freq [kHz]	Cpu3 Load [%]	Cpu4 Freq [kHz]	Cpu4 Load [%]
0	652800	85	729600	80	729600	60	729600	71
100	652800	88	729600	82	729600	66	729600	80
200	652800	73	729600	81	729600	83	729600	60
300	652800	100	729600	82	729600	75	729600	75
400	652800	80	729600	83	729600	75	729600	83
500	652800	83	729600	88	729600	83	729600	80
...
27000	300000	90	883200	90	729600	80	729600	80

Table 3: Sample of measured data (part 2) [4]

Time [ms]	Memory Usage [kb]	Screen Brightness	Battery Power [μ W]	Battery Remaining [%]	GPU Load [%]	CPU Load [%]
0	1800004	255	875708	3665025	45	89
100	1800376	255	866186	3665076	45	86
200	1800516	255	831271	3665121	45	83
300	1800648	255	880999	3665165	45	76
400	1800896	255	868302	3665230	45	76
500	1801152	255	890521	3665275	45	77
...
27000	1802410	255	883200	3665404	47	82

120 *Meaning of the columns of Table 2:*

- Time [ms]: The interval of measurements in milliseconds (ms),
- Cpu1 Freq [kHz]; Cpu2 Freq [kHz]; Cpu3 Freq [kHz]; Cpu4Freq [kHz]:
The respective frequencies of the 4 Central Processing Units (CPUs) in kiloHertz [kHz].
- 125 • Cpu1 Load, Cpu2 Load, Cpu3 Load, Cpu4 Load: Percentages of respective loads of the 4 CPUs [%].

Meaning of the columns of Table 3:

- Time [ms]: The interval of measurements in milliseconds (ms),
- Memory Usage [Kb]: Memory used per measurement interval in Kilobyte
130 [Kb],
- Screen Brightness: Screen brightness state,

- Battery Power* [μ W]: Power consumption per measurement interval in microwatt(μ W),
- Battery Remaining [%]: Remaining battery capacity,
- 135 • GPU Load [%]: Total Graphics Processing Unit load,
- CPU Load [%]: Total CPU load.

4. Results

We have developed a methodology based on the processor frequency parameters, the dissipated energy and the initial level of the battery [3]. To this end, part of the collection of the produced experimental data was analyzed by statistical tools. To validate our model, we compared our results with other existing models.

We have presented a methodology to build a model of energy consumption of applications on mobile devices. This methodology begins with recording precise measurements of energy consumption when using the applications. The strong point of our methodology is in the technique of processing recorded data which leads to a precise model. The proposed solution can be used to define an optimal frequency for one or more applications in order to provide a better experience for users with reduced energy consumption.

150 For the implementation of our methodology, we selected the following parameters, obtained by Trepp Profiler:

- Total load per CPU,
- Memory usage,
- CPU frequency,
- 155 • Battery level,
- Battery power.

4.1. Disconnected mode case

The measurements of the dissipated energy were carried out according to the number of total operations at a fixed frequency. Figure 2 shows examples of experimentation by setting the processor frequencies at 1 GHz, 1.7 GHz and 2.2 GHz.

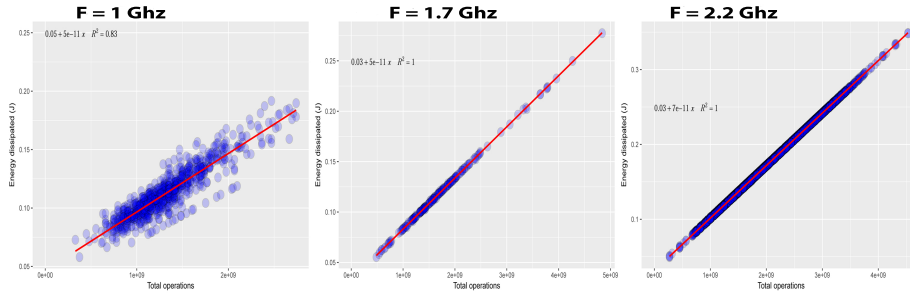


Figure 2: LVFF frequencies = 1 GHz, 1.7 GHz, 2.2 GHz [3]

4.2. Connected mode case [3]

The aim of this section is to study energy consumption by activating Wi-Fi. To stay in the same context, the remote video was identical to that used in disconnected mode. We determine the type of correlation between energy consumption and the number of total operations, then we compare the obtained result with those in offline mode.

Figure 3 shows an example of experimentation by fixing the frequency of the processor at 1.7 GHz for a remote video in navigation mode with fixed frequency (NFF). In this study, we have treated the different types of dependencies between energy dissipation and the frequency of several cases in disconnected mode (LVFF, LVVF) and connected mode (NFF, NVF).

The difference between the types of regressions can be explained in part by the variability of the signal strength received for GPS and Wi-Fi (for connected mode). On the other hand, the scenarios concerned in connected mode require the activation of other parameters, which increases the rate of inputs / outputs which are partly responsible for the additional energy cost.

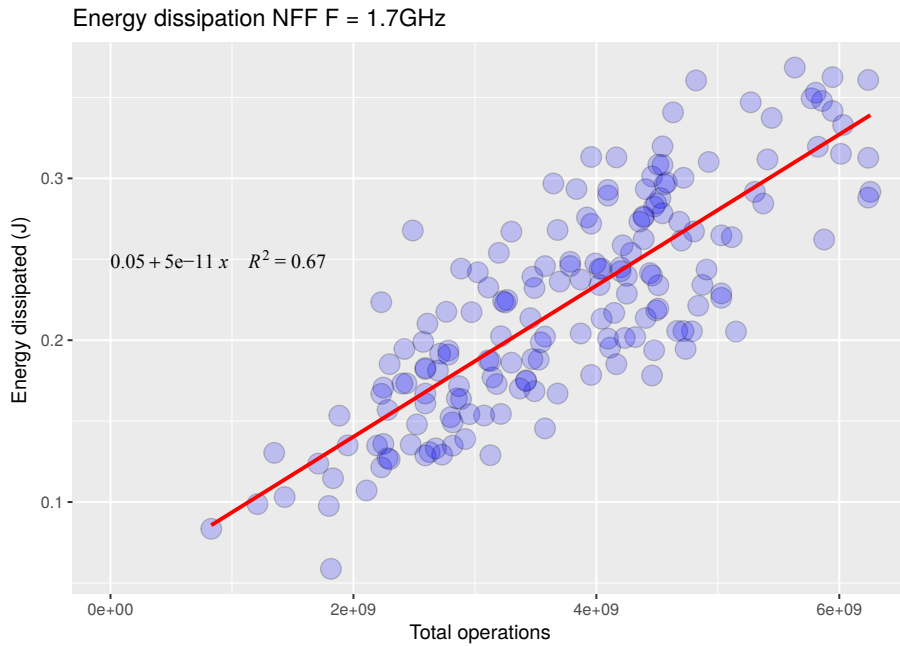


Figure 3: Energy dissipation for NFF scenario, Frequency=1.7GHz [3]

5. Description by classification of data

In the rest of our paper, we will base ourselves on two types of case studies:

- 180 • The disconnected mode in which all the measurements were carried out in the presence of only the GSM network,
- Connected mode where all connection techniques have been activated (3G, 4G, Wi-Fi, GPS, etc.) depending on the chosen scenario .

The raw data are stored in text files (csv file). they are divided into four
 185 main groups depending on the chosen scenarios . Table 4 presents the different characteristics of the group of scenarios used for the evaluation of our study.

Each file is named in a unique way to facilitate use, the files are named as follows:

`scenario_name_freq_GHz_[Option]_[departure_city]_[arrival_city]`

Table 4: Characteristics of the reference scenarios [4].

Model name	Meaning	Mode	Description
LVFF	Local Video with fixed frequency	Disconnected	Monitoring the energy behavior of a local video under a fixed frequency
LVVF	Local Video with variable frequency	Disconnected	Monitoring of energy behavior by of a local video at a variable frequency
NFF	Navigation with fixed frequency	Connected	Monitoring of the energy behavior by launching navigation via GPS under a fixed frequency
NVF	Navigation with variable frequency	Connected	Monitoring of the energy behavior by launching navigation via GPS at a variable frequency

190 Tables 5 and 6 show respectively some examples of measurement files for disconnected and connected modes for all treated scenarios.

For convenience, each measurement file is divided into two sub-files: The first one contains the list of measurements made during the experiment. The second one have the same name with the suffix "_info" which gives information about active applications during the experiment. The average number of accesses per application and statistics on the sensors (table 7), the "_info" file contains also information about the percentage of use of CPU resources, the average use of virtual memory per application, the maximum use of virtual memory per application, average real memory usage per application and maximum real memory usage per application.

200 All this information are detailed in table 8.

Table 5: Description of the disconnected scenario filenames

File name	Meaning
Scenario	
LVFF_freq0.3GHz _Caen_Domfront.csv	Measurement with the LVFF scenario by setting the frequency at 0.3GHz between Caen (departure city) and Domfront (arrival city).
LVFF_freq0.3GHz _Caen_Domfront_info.csv	Information about present applications during the experiment, Percentage of use of CPU resources, Average of use of virtual memory per application, Average use of real memory per application, Maximum use of real memory per application, statistics of the active sensors between Caen and Domfront.
LVVF_default_freq _Lille_Amiens.csv	Mesurement with LVVF scenario with variable frequency (the default frequency) between Lille and Amiens.
LVVF_default_freq _Lille_Amiens_info.csv	Information about present applications during the experiment, Percentage of use of CPU resources, Average of use of virtual memory per application, Average use of real memory per application, Maximum use of real memory per application, statistics of the active sensors between Lille and Amiens.

Table 6: Description of the connected scenario filenames

File name	Meaning
Scenario	
NFF_freq1.0GHz_GPS _facebook_Provins_Paris.csv	Mesurement with NVF scenario with variable frequency (the default frequency) between Provins and Paris.
NFF_freq1.0GHz_GPS _facebook_Provins_Paris_info.csv	Information about present applications during the experiment, Percentage of use of CPU resources, Average of use of virtual memory per application, Average use of real memory per application, Maximum use of real memory per application, statistics of the active sensors between Provins and Paris.
NVF_default_freq_GPS _facebook_Provins_Paris.csv	Mesurement with NVF scenario with variable frequency (the default frequency) between Provins and Paris.
NVF_default_freq_GPS _facebook_Provins_Paris_info.csv	Information about present applications during the experiment, Percentage of use of CPU resources, Average of use of virtual memory per application, Average use of real memory per application, Maximum use of real memory per application, statistics of the active sensors between Provins and Paris.
NVF_Optimal_Freq_GPS _facebook_Lyon_Tournus.csv	Mesurement with NVF scenario with variable frequency, choosed by tool of mesurement (Optimal frequency) between Lyon and Tornus.
NVF_Optimal_Freq_GPS _facebook_Lyon_Tournus_info.csv	Information about present applications during the experiment, Percentage of use of CPU resources, Average of use of virtual memory per application, Average use of real memory per application, Maximum use of real memory per application, statistics of the active sensors between Lyon and Tournus.

Table 7: Sensor statistics [4]

Sensors Application	Type Application	Average
200	Mobile Data State	0.0
205	Battery Remainin %	47.63441680465886
206	Battery Status	0.0
328	Memory Usage	1772465.436876518
331	Screen Brightness	247.38371006912013
332	Battery Power	989798.485167196
400	GPU Frequency	226874.2200635158
401	GPU Load	32.80052307117504
600	CPU Load	75.21363721277788
1000	CPU1 Frequency	856941.4085559499
1001	CPU2 Frequency	664897.7395852793
1002	CPU3 Frequency	812255.0943396227
1003	CPU4 Frequency	860962.047450028
1096	CPU1 Load	76.48867924528302
1097	CPU2 Load	68.41748552213711
1098	CPU3 Load	73.45888286941901
1099	CPU4 Load	74.58380347468709

Table 8: System resource allocation [4]

Applications	CPU [%]	Average Virtual Memory Size [MB]	Max Virtual Memory Size [MB]	Average Resident Set Size [MB]	Max Resident Set Size [MB]
Facebook	0.18	1784.41	1794.03	26.99	34.0
GsmaService	0.0018	1483.33	1485.60	5.79	6.09
Clock	0.006	257.32	1493.86	1.42	8.37
CPU Frequency	5.51E-5	606.2	1489.42	2.79	7.64
Google Play Store	0.004	15.80	1545.80	8.33	9.59
Launcher3	0.004	1589.49	1589.49	12.08	13.789
Services Google Play	0.34	4096.29	6540.66	34.89	60.18
Google Partner	5.04E-4	24.55	1486.86	0.09	5.97
Configuration					
Play-Fi	0.0017	1483.88	1483.88	5.05	5.69
Personal Dictionary	0.007	99.57	1491.23	0.52	7.94
YouTube	20.51	1966.10	1985.42	42.51	48.83
Cron Tasker Free	0.06	1330.37	1492.48	7.004	8.63
Gmail	0.050	893.47	1834.24	12.28	33.15
Google Application	0.032	3084.76	3091.49	16.81	19.653
Cronoid	0.62	1507.74	1520.84	7.97	8.94
Power Battery	0.47	1682.2	3114.73	10.07	29.05
Hangouts	0.05	19.82	1665.26	0.18	21.22
Google+	0.031	64.793	1545.664	0.487	12.356
Google keyboard	0.078	1548.13	1607.44	11.58	14.71
Mobile Network	0.28	3034.45	3035.91	14.26	16.59
Configuration					
SmartcardService	0.006	2987.34	2991.18	13.007	14.622
System Interface	0.25	1727.72	1805.57	41.59	51.07
Messenger	0.14	1871.18	1910.15	46.07	56.89
SVI Settings	3.46	9172.51	9217.14	55.79	64.84
Multimedia Storage	0.002	277.25	1495.03	1.28	7.613

Acknowledgements

The authors wish to acknowledge the following institutions for their help in collecting this data and their financial support:

- University of Lille France,
- 205 • CNRS : National Center for Scientific Research (CNRS France),
- The Research Institute for Software and Hardware Components for Information and Advanced Communication (IRCICA Lille, France),
- Association of the Paralyzed in France (APF),
- City of Villeneuve d'Ascq, France.

210 Conflict of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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