






Mobile Energy Efficiency Services

E7.3. Report on IPR and Exploitation activities

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INDEX

1 Introduction	3
1.1 Motivation	3
1.2 Objectives	3
1.3 Main contributions	4
1.4 Document structure	4
2 Intellectual Property	5
3 Exploitation of Results	5
4 Dissemination	5
4.1 Publications and Public Presentations	5
4.2 Workshops	6
4.3 Demonstrators	8

1 Introduction

This section contains a brief introduction to the **Greenstamp** project, with its motivation and objectives. At the end of the section, one may find the description and objectives of the task being studied in this document. This general introduction aims to give the context of the project to new team members who participate in only one task.

The rest of the document contains the necessary sections for the research and development of the task being addressed.

1.1 Motivation

The importance that mobile devices have in our lives is such that it is difficult to imagine our daily activities without their use. The use of smartphones, tablets and, more recently, wearables such as smartwatches, has changed and simplified not only the way we communicate, but also the way we have fun, individually and collectively, or the way we work and do business. In fact, the number and scope of mobile apps seem limitless, but users still have increasing expectations about them. The distribution of such applications is highly facilitated by digital markets, which democratise the opportunity to market software to mobile devices. In 2017, the number of mobile applications installed was 178 billion, a figure estimated to grow to 258 billion in 2022.

While much of the app market is targeted at mobile devices, whose autonomy depends on the limited battery life, the fact is that today's markets do not provide any indication of the energy efficiency, absolute or relative, of the applications they offer. With this gap in mind, in the **GreenStamp** project we propose to investigate and develop innovative mechanisms for analysing and cataloguing the energy efficiency of mobile applications integrated into app store processes. Pedagogical recommendation systems for developers will also be studied, on how to improve the efficiency of their applications, and for users, of energy-efficient applications aligned with their profile. The objective is to reduce at least 20% of the energy consumed by applications that follow the technical recommendations proposed and, inherently, of the mobile devices where they are installed, thus contributing to a significant savings of resources consumed in the mobile market, particularly and immediately by the large user base of the company promoting this project (250 million unique users active in 2019).

1.2 Objectives

The **GreenStamp** project aims to investigate and develop techniques and technologies capable of analysing, cataloguing, and informing about the energy efficiency of mobile applications and how to optimise it, thus reducing the energy consumption of the mobile market. This goal is realised in direct impacts on the wide range of citizens who are consumers of apps, mobile application companies and app stores.

As for app consumers, the impact will be first and foremost on your satisfaction. This will come from the certainty that you can have energy-efficient applications that optimise your device's resources, rather than having applications that, in some cases you're usually unaware of at first, drain your

mobile device's limited energy resources with excessive and unnecessary battery consumption. This certainty will be achieved by providing information on the energy profile of applications at the time of their choice and installation, and through a system of recommendations to be investigated. Such knowledge will allow consumers to opt for energy-efficient solutions, as is currently the case in other markets (home appliances, automobiles, real estate, and others), thereby optimising the energy performance of their device and increasing the autonomy time of the device. Thus, a user who chooses efficient applications, will charge your device less often, will have a lower cost in your energy bill and reduce the risk of developing nomophobia, with the certainty that the energy consumption of your applications is great.¹

1.3 Main contributions

To achieve the strategic objective and impacts mentioned, this project aims to research and develop highly innovative techniques and technologies, unparalleled in the market. They are translated into the following technical-scientific objectives:

- Investigate and conceptualise new systems for the acquisition, processing and analysis of data related to the energy efficiency of mobile applications;
- Investigate and conceptualise innovative machine learning mechanisms and cataloguing energy consumption patterns of mobile applications based on static and dynamic data;
- Investigate and conceptualise ways to information to users about the energy efficiency of apps, and relevant recommendations related to this factor;
- Investigate and conceptualise models and mechanisms of technical and action-oriented recommendation to mobile application promoters, on how to optimise this parameter in their products, in an integrated way in their practice;
- Investigate and conceptualise a new interface to support decision and system management.

1.4 Document structure

Beginning with the "Introduction," we establish the project's context and significance, setting the stage for our objectives. The "Intellectual Property" section addresses our commitment to safeguarding innovative concepts and methodologies. "Exploitation of Results" explores practical applications, emphasizing real-world benefits, while the "Dissemination Activities" section outlines our knowledge-sharing strategy, ensuring engagement with stakeholders and broader awareness of our research's impact. This structure aims to deliver a holistic understanding of the project's objectives, achievements, and broader implications in a unified narrative.

¹ <https://www.infopedia.pt/dicionarios/lingua-portuguesa/nomofobia>

2 Intellectual Property

XXXXX

3 Exploitation of Results

XXXX

4 Dissemination

This section is structured into three interconnected sections ensuring a comprehensive overview of our outreach efforts.

1. **Publications and Public Presentations:** In this sub-section, we detail our commitment to knowledge dissemination through academic publications and public presentations. We highlight the significant research papers, articles, and presentations that have emanated from our project, showcasing our contributions to the scientific community and the broader public. These activities underscore our dedication to sharing our findings, insights, and innovative methodologies.
2. **Workshops:** This sub-section focuses on our engagement with workshops as a platform for knowledge exchange. We elaborate on our participation in and organization of workshops, emphasizing the interactive and collaborative nature of these events. By actively participating in workshops, we foster a dynamic environment for sharing ideas and expertise, thereby amplifying the impact of our research within the research community.
3. **Demonstrators:** In the final sub-section, we present a practical application of our research through demonstrators. These hands-on showcases illustrate the tangible results of the GreenStamp project, offering a glimpse into the real-world implications of our work. By creating and sharing demonstrators, we facilitate a deeper understanding of the project's potential in addressing real-world challenges related to energy-efficient mobile applications.

Through these three sub-sections, our "Dissemination" section ensures that our project's outreach efforts are comprehensive and interconnected, encompassing academic publications, interactive workshops, and practical demonstrators to maximize the dissemination of our research findings and the impact on both academic and practical audiences.

4.1 Publications and Public Presentations

The dissemination activities of the GreenStamp project have played a key role in sharing groundbreaking research findings and innovative approaches in the field of energy-efficient mobile app development. Through presentations at reputable conferences and the publication of research papers, the project has contributed significantly to the advancement of knowledge in this domain. Here are the key articles and their presentations at conferences:

1. E-APK: Energy Pattern Detection in Decompiled Android Applications

- a. Authors: Nelson Gregório, João Bispo, João Paulo Fernandes, Sérgio Queiroz de Medeiros
 - b. Presentation: 26th Brazilian Symposium on Programming Languages
2. Energy-Aware JPEG Image Compression: A Multi-Objective Approach
 - a. Authors: Seyed Jalaleddin Mousavirad, Luís A. Alexandre
 - b. Published in: Applied Soft Computing, 2023
3. A Metaheuristic-based Machine Learning Approach for Energy Prediction in Mobile App Development
 - a. Authors: Seyed Jalaleddin Mousavirad, Luís A. Alexandre
 - b. Status: Submitted, 2023
4. Metaheuristic-based Energy-aware Image Compression for Mobile App Development
 - a. Authors: Seyed Jalaleddin Mousavirad, Luís A. Alexandre
 - b. Status: Submitted, 2022
5. Analyzing the Resource Usage Overhead of Mobile App Development Frameworks
 - a. Authors: Wellington Oliveira, Bernardo Moraes, Fernando Castor, João Paulo Fernandes
 - b. Presentation: The International Conference on Evaluation and Assessment in Software Engineering [2023]
6. On Security and Energy Efficiency in Android Smartphones
 - a. Authors: João Ferreira, Bernardo Santos, Wellington Oliveira, Nuno Antunes, Bruno Cabral, João Paulo Fernandes
 - b. Presentation: 10th International Conference on Mobile Software Engineering and Systems [2023]
7. On Computation Offloading and Energy Efficiency on Android Devices
 - a. Authors: Gonçalo Carvalho, Karima Velasquez, Bruno Cabral, João Paulo Fernandes
 - b. Presentation: 2nd International Workshop on Green and Sustainable Networking [2023]
8. Ebserver: Automating Resource-Usage Data Collection of Android Applications
 - a. Authors: Wellington Oliveira, Bernardo Moraes, Fernando Castor, João Paulo Fernandes
 - b. Presentation: 10th International Conference on Mobile Software Engineering and Systems [2023]

These articles and presentations have been instrumental in advancing the understanding of energy-efficient mobile app development and have contributed to the ongoing dialogue in the research community. The GreenStamp project continues to drive innovation in this critical area, seeking sustainable solutions for mobile applications.

4.2 Workshops

Workshop: Analyzing Power Consumption on Mobile Devices

Date and Time: August 11, 2022, at 9:00 AM

Overview:

The GreenStamp Project is committed to advancing the field of energy-efficient mobile app development, and as part of its dissemination activities, it hosted an informative workshop on "Analyzing Power Consumption on Mobile Devices." This workshop brought together experts and enthusiasts in the domain of mobile computing to explore cutting-edge tools and techniques for understanding and mitigating power consumption challenges.

Speakers and Tools:

1. Rui Rua – PhD Student at the University of Minho, Portugal
 - a. Tool: PyAnaDroid
2. Magnus Cruz – PhD Student at the University of Coimbra, Portugal
 - a. Tool: BatteryHub
3. Wellington Oliveira – Doctor from the Federal University of Pernambuco, Portugal
 - a. Tool: Energy Dashboard

Workshop Highlights:

The workshop aimed to empower attendees with the knowledge and tools necessary to analyze and optimize power consumption in mobile devices, a critical aspect of modern software development. Each speaker presented their respective tool and shared insights into its applications and advantages. Participants had the opportunity to gain experience with these tools and study real-world scenarios related to energy-efficient mobile app development.

Key Takeaways:

1. PyAnaDroid: Rui Rua introduced PyAnaDroid, shedding light on how this tool can aid in analyzing power consumption in Android applications. Attendees learned about its features, capabilities, and practical use cases in the context of mobile app development.
2. BatteryHub: Magnus Cruz provided insights into BatteryHub, offering attendees a glimpse into how this tool can help developers gain better control over power consumption in mobile devices. The presentation highlighted its functionalities and benefits for app optimization.
3. Energy Dashboard: Wellington Oliveira discussed the Energy Dashboard, emphasizing its role in tracking and visualizing energy consumption patterns in mobile applications. Attendees discovered how this tool can facilitate data-driven decisions in app development.

Discussion:

The workshop served as a valuable forum for knowledge exchange, fostering discussions on best practices, challenges, and opportunities in the domain of energy-efficient mobile app development. Attendees gained practical insights into the use of powerful tools and learned how to apply them to real-world projects, ultimately contributing to the reduction of energy consumption in mobile devices.

By offering a platform for collaboration and learning, the GreenStamp Project continues to drive innovation in sustainable mobile app development, advancing the field and promoting eco-friendly practices in the digital landscape. This workshop marks a significant step toward creating a more energy-conscious mobile application ecosystem.

4.3 Demonstrators

The GreenStamp project has taken a significant step in its dissemination activities by launching a dedicated web page for the demonstration of its project results. This web page serves as a powerful tool to showcase the practical applications of the project's research and validate its core concepts.

Overview:

The centerpiece of this web page is a Demonstration Proof-of-Concept (PoC) application. This application embodies the innovative mechanisms that the GreenStamp project has been diligently working on. Its primary goal is to analyze and catalog the energy efficiency of mobile applications within the context of app store processes. Let's dive into the key aspects of this demonstration page:

1. Validation of Project Concepts:
 - a. The PoC application stands as a tangible representation of the project's core concepts. It serves as a living proof of the innovative ideas and methodologies developed by the GreenStamp project team.
2. Investigating Energy Efficiency:
 - a. The primary focus of the GreenStamp project is to investigate and understand the energy efficiency of mobile applications. By utilizing this PoC application, users can actively engage in the exploration of energy-related insights.
3. Search and Analysis:
 - a. Users are granted the ability to search for results related to energy efficiency. This feature enables them to access valuable data and insights derived from the project's research.
4. APK Submission:
 - a. The web page provides a user-friendly option to submit an APK (Android Application Package) for analysis. This functionality empowers users to actively participate in the project's ongoing research efforts.
5. APK Download for Testing:
 - a. Users are given the opportunity to download Android APKs, which can then be used to test the energy efficiency of their installed applications. This hands-on approach allows individuals to gain practical insights into the energy consumption of their apps.

Significance:

This web page plays a crucial role in bridging the gap between research and practical application. It not only showcases the GreenStamp project's dedication to addressing real-world challenges but

also invites active participation from users who are keen to understand and improve the energy efficiency of mobile applications.

In summary, the Demonstration Proof-of-Concept (PoC) application, as presented on this web page, symbolizes the culmination of the GreenStamp project's efforts. It is a testament to the project's commitment to advancing energy efficiency in the mobile app ecosystem. This initiative not only informs but actively involves users in the journey towards a more sustainable and efficient mobile application landscape.