Smart usage of context information for the analysis, design and generation of power-aware polices for mobile sensing apps

Presented by: Rafael Perez Torres

Thesis advisors:
PhD Cesar Torres Huitzil
PhD Hiram Galeana Zapien

Cinvestav Tamaulipas

Table of contents

Introduction

- There is a massive adoption of mobile devices by society in almost any daily activity [2].
  - Any-where, any-time connectivity
  - Possibility of installing new mobile applications
  - Increasing computing, memory, and sensing capabilities
- Sensing capabilities of smartphones improve interaction with user, turning mobile devices into *omni-sensors* able to *know* about their surrounding environment.

Introduction

- Hence, mobile devices have achieved a considerable degree of sensitivity that tries to mimic the sense of humans.
- In this way these devices have become *context-aware*, which is translated to an increasing level of understanding about user's activity and environment.
- *Context* refers to a four-dimensional space composed of *computing context*, *physical context*, *time context*, and *user context* [1].

Motivation

- Despite the increasing computing, storage and memory capabilities of smartphones, battery is not evolving at the same pace [3], growing only 5% each year [4].
- Each new generation of smartphones keeps improving and including new hardware embedded components, which imposes a higher energy demand.
- This resource constraint becomes more critical when continuous access to sensors' data is needed, which is the core requirement of **mobile sensing applications**.
- Then it is mandatory for any mobile sensing application development to consider the energy constraint and implement mechanisms or strategies to optimize battery duration.

Motivation

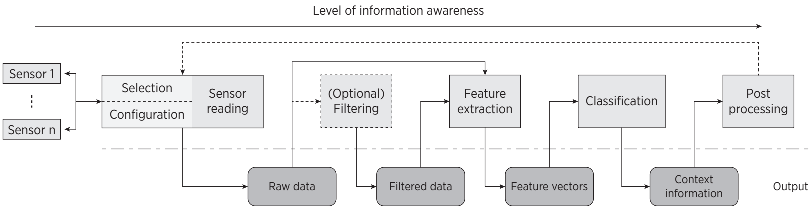

Figure: Stages of mobile sensing applications

- There is a tradeoff between the accuracy of context information retrieved and the associated energy consumption [6, 5].

Motivation

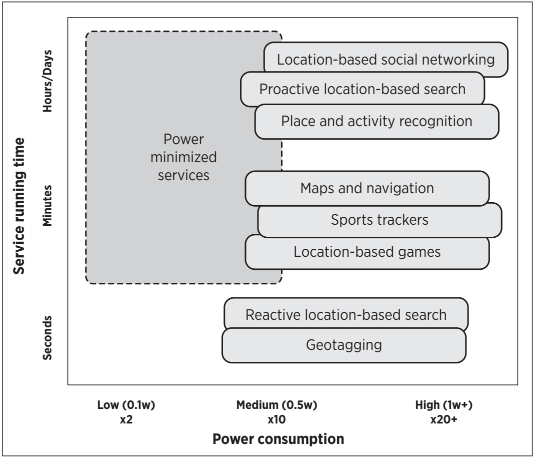

Figure: Location based services categorization based on running time and power consumption, as proposed by Kjærgaard [3]

Basic scenario

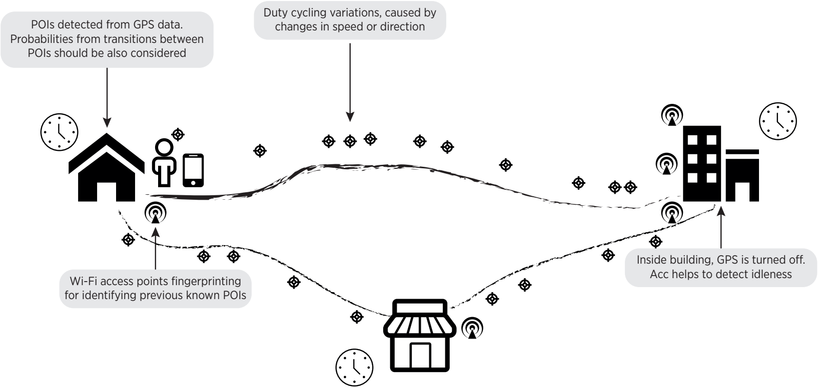

Figure: Basic scenario

Hypothesis

Hypothesis

Intelligent policies produced through context information built from sensors data can be employed to reduce the energy consumption in a mobile device when performing continuous sensor readings.

- An intelligent policy is a special rule that defines how sensors should be accessed in order to reduce the energy consumption and achieve the requirements of a mobile app. It is intelligent in terms of self-adaptness to changes detected in context information.
- This research work aims to employ data coming from GPS and inertial sensors (accelerometer) in order to obtain context information in the shape of user mobility that helps to adapt the usage of sensors and reduce energy consumption.

Problem statement

Problem statement: Mobility pattern identification

Given a set $V = \{v_1, v_2, \ldots, v_n\}$ of data values read from sensor S in the time interval $T \in [t_1, t_2]$, identify the current mobility pattern p_S that represents the activity of user.

$$\text{PatternIdentifier}(V) \longrightarrow p_S \in \mathit{Patterns} \tag{1}$$

Where *Patterns* is a set of patterns that represent an interesting state in user mobility, specifically the set $\{no\_movement, walking, running, vehicle\_transportation\}$.

Problem statement

Problem statement: Policy generation

Given the set of detected mobility patterns $\mathcal{P} = \{p_{S_1}, p_{S_2}, \ldots, p_{S_n}\}$ in data from sensors $\mathcal{S} = \{S_1, S_2, \ldots, S_n\}$, parameters for assigning weight to energy e and accuracy a, and physical constraints status c of a mobile device, find a policy that select the proper set of sensors $\mathcal{S}_{new}$ and its associated configuration $\mathcal{S}_{new_{conf}}$ while meeting application requirements.

$$\text{PolicyGeneration}(\mathcal{P}_{\mathcal{S}}, e, a, c) \longrightarrow \mathcal{S}_{new}, \mathcal{S}_{new_{conf}} \tag{2}$$

The $\mathcal{S}_{new_{conf}}$ configuration is referred as the *duty cycle* of associated sensor.

Interaction between problems

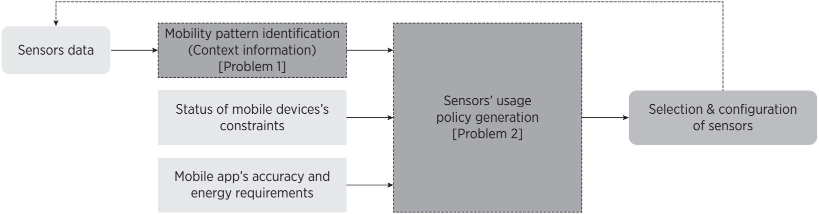

Figure: Interaction between the thesis work's problems

Objectives

Main objective

To reduce energy consumption in the mobile sensing apps, which perform continuous sensor readings, through self-adapting power-aware policies generated from context information obtained from sensors data.

Objectives

Particular objectives

- To identify mobility patterns from context information obtained from an inertial sensor (accelerometer) and location providers (GPS, WPS).
- To generate policies for a self-adapting sensors' usage from identified mobility patterns, accuracy and energy requirements of mobile application, and status of mobile device's constraints.
- To ease the development of mobile sensing applications that require user location tracking, i.e., LBS, isolating the complexity of sensors' access and the associated efficient energy management.

Methodology

1. Familiarization with state-of-art power-aware sensing related techniques
2. Formal definition and selection of mobility patterns to be identified
3. Research on pattern recognition algorithms focused on mobility patterns identification
4. Design of the Pattern Identification Element (PIE)
5. Research on and proposition of adaptive policies for energy efficient usage of sensors
6. Design of the Policy Generation Element (PGE)
7. Development of a middleware involving the PIE and PGE for the Android platform
8. Experimentation in terms of accuracy and energy efficiency

Schedule

		2014	2015			2016		
		3rd	1st	2nd	3rd	1st	2nd	3rd
	Step I							
1	State-of-art reading	■	■					
2	State-of-art works categorization		■	■				
3	Documentation of information found (committee request)			■				
	Step II							
4	Development of a mobile app for the Android platform that collects accelerometer and location data			■	■			
5	Analysis of data delivered by the mobile app				■			
6	Creation of the formal definition of mobility pattern				■			
7	Selection of the mobility patterns to be recognizable by the system				■	■		
	Step III							
8	Research on classification algorithms adequate to work with mobility patterns				■	■		
9	Definition of metrics for evaluating algorithms when executing on a mobile platform					■		
10	Implementation of algorithms (including proper adaptions towards running on a mobile platform) for evaluation					■	■	
11	Selection of best algorithms according to metrics						■	
	Step IV							
12	Definition and modeling of parameters needed by the PIE				■	■	■	■
13	Building of the PIE				■	■	■	■

Table: Schedule of activities (each column represents a four months period)

Schedule

		2016			2017		
		1st	2nd	3rd	1st	2nd	3rd
	Step V						
14	Creation of the formal definition of policy			■			
15	Research and evaluation of techniques for generation and adaption of policies			■	■		
16	Design and execution of experiments with techniques applied to use cases			■	■		
17	Selection of best techniques				■		
	Step VI						
18	Definition and modeling of parameters needed by the PGE					■	
19	Building of the PGE					■	
	Step VII						
20	Analysis of elements involved into software abstractions					■	
21	Research on Android API for specialized components					■	
22	Development of the middleware					■	

Table: Schedule of activities (each column represents a four months period)

Schedule

	Step VIII	2017 1st	2017 2nd	2017 3rd	2018 1st	2018 2nd
23	Definition of experiments targeting accuracy and energy consumption axes					
24	Development of needed sample mobile apps for running experimentation					
25	Execution of experimentation					
26	Results analysis					

Table: Schedule of activities (each column represents a four months period)

Schedule

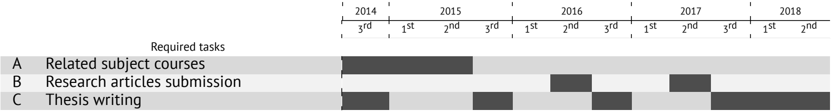

Table: Schedule of required activities

Contributions

- A mechanism for detecting mobility patterns from the data read by sensors of mobile devices (especifically GPS and accelerometer).
- A mechanism for generating policies for accessing sensors. The produced policies will allow to perform an intelligent usage of smartphone's sensing infrastructure in continuous sensor readings, reducing the energy consumption.
- A middleware implementing the previous power-aware mechanisms for easing the development of location based services.

Conclusions

In this talk:

- An introduction to the energy consumption issue in mobile sensing apps and its relevance has been presented.
- A description of the important components of our thesis work has been also given.
- An overview of the proposed methodology for solving the energy consumption issue has been provided.

Thank You
for your attention!

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[3] Mikkel Kjaergaard. Location-based services on mobile phones: Minimizing power consumption. *IEEE Pervasive Computing*, 11:67–73, 2012.

[4] Xiao Ma, Yong Cui, and Ivan Stojmenovic. Energy efficiency on location based applications in mobile cloud computing: A survey. In *Procedia Computer Science*, volume 10, pages 577–584, 2012.

[5] Kiran K Rachuri, Cecilia Mascolo, and Mirco Musolesi. *Mobile Context Awareness*. Springer London, London, 2012.

[6] Jaemun Sim, Yonnim Lee, and Ohbyung Kwon. Context-aware enhancement of personalization services: A method of power optimization. *Expert Systems with Applications*, 41(13):5702–5709, 2014.

Brief state of art revision

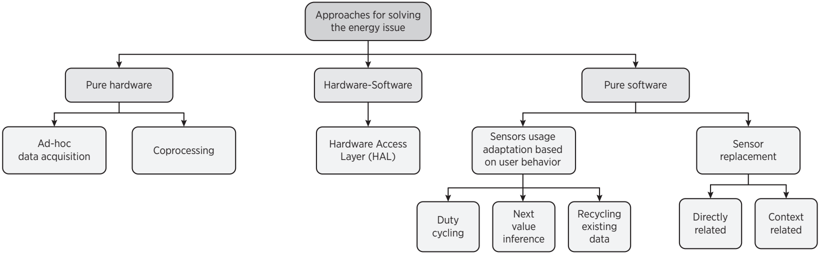

Figure: Taxonomy of solutions

Brief state of art revision

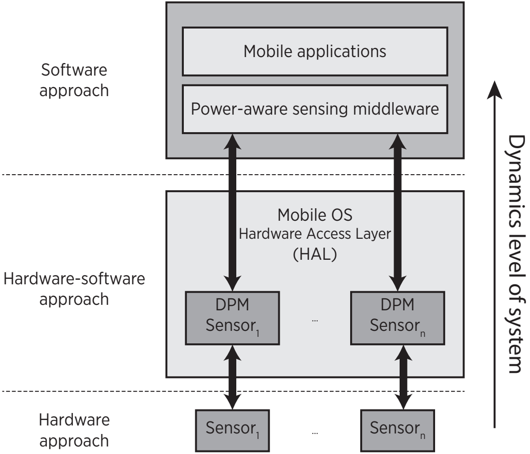

Figure: Distribution of approaches across mobile platform's layers

Proposed solution

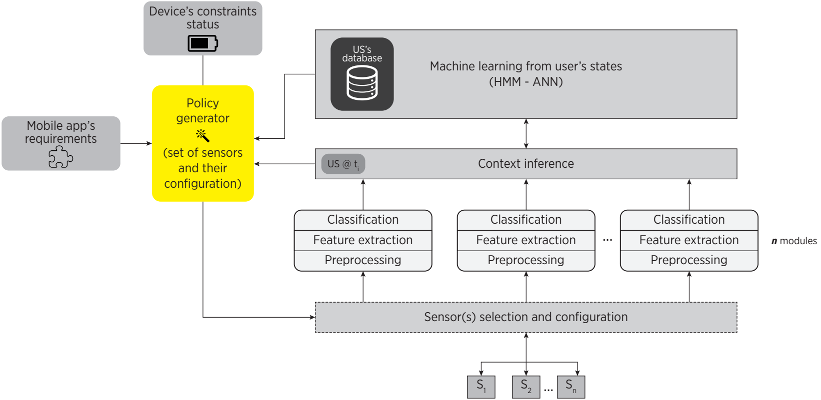

Figure: Overview of current solution