Energy-Efficiency in Mobile Software

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THE UNIVERSITY OF BRITISH COLUMBIA

Mobile Applications

- More than 2 billion smartphones in use
  - More than desktop computers
  - Plus smart watches, glasses, cameras, TVs, in-car navigation, and messaging
- More than 3 million mobile apps in official app stores
  - … and much more apps in hundreds of alternative stores
- ~2.3 million active mobile developers worldwide
  - 760,000 people in Asia
  - 680,000 people in North America
  - 680,000 people in Europe

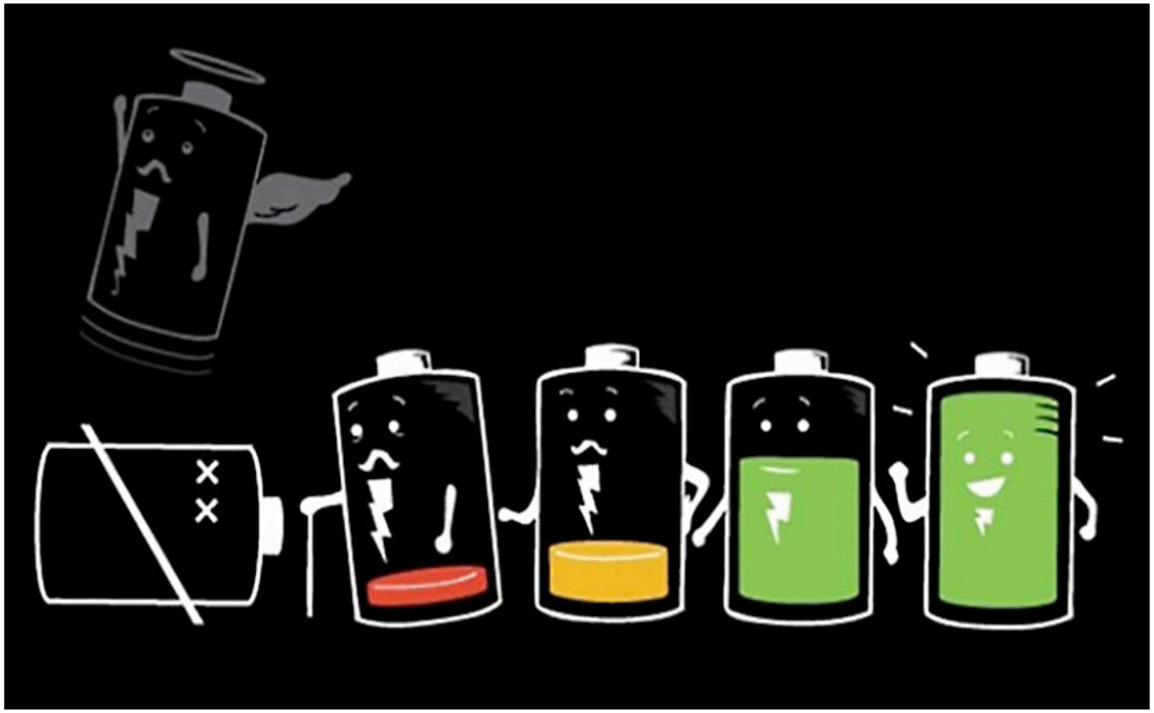
[https://blog.newrelic.com/2014/06/13/mobile-app-development-trends-worldwide-need-know/]
[Developer Economics Q3 2014]

Mobile Application Developers

Lack knowledge, tools, and incentives to deal with:

- Security
- Privacy
- **Energy-efficiency**

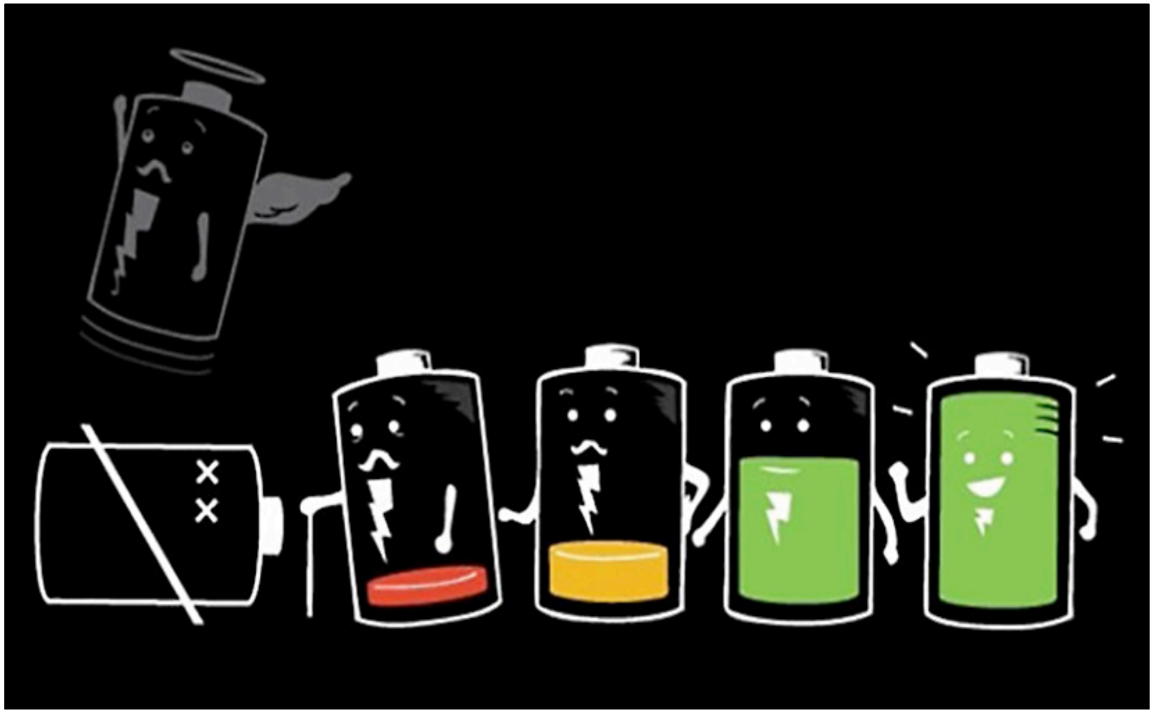
What Can Go Wrong?



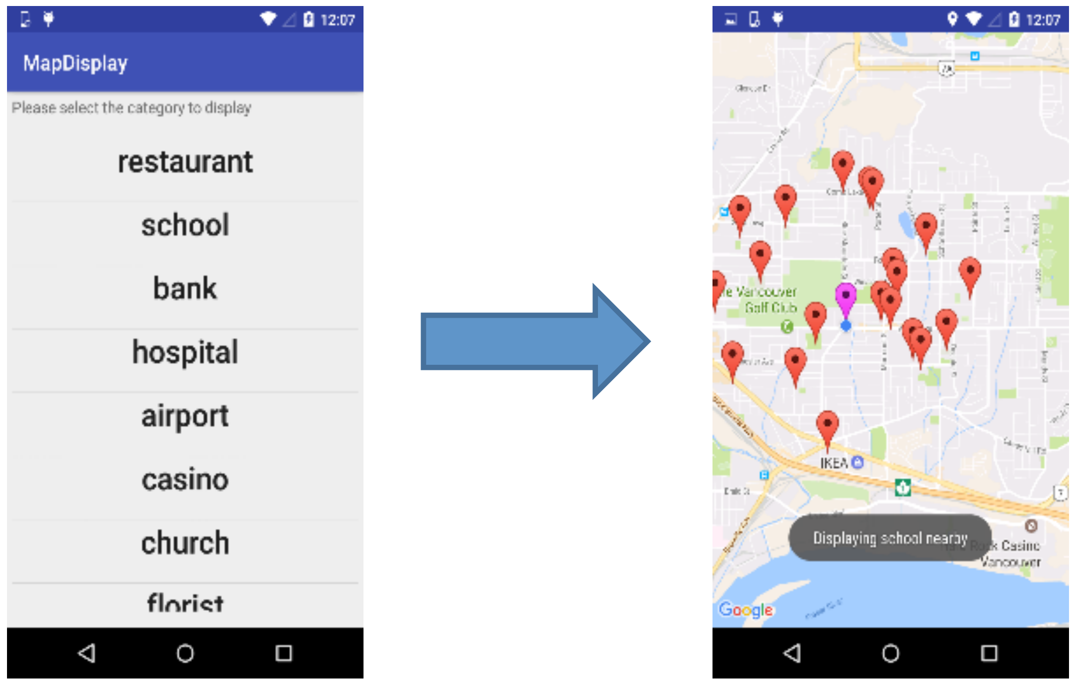
What Can Go Wrong?

Major consumers of energy:
Screen, WiFi, GPS, Sensors, Camera, CPU

[Pathak et al., EuroSys'12, Banerjee et al., FSE'14]

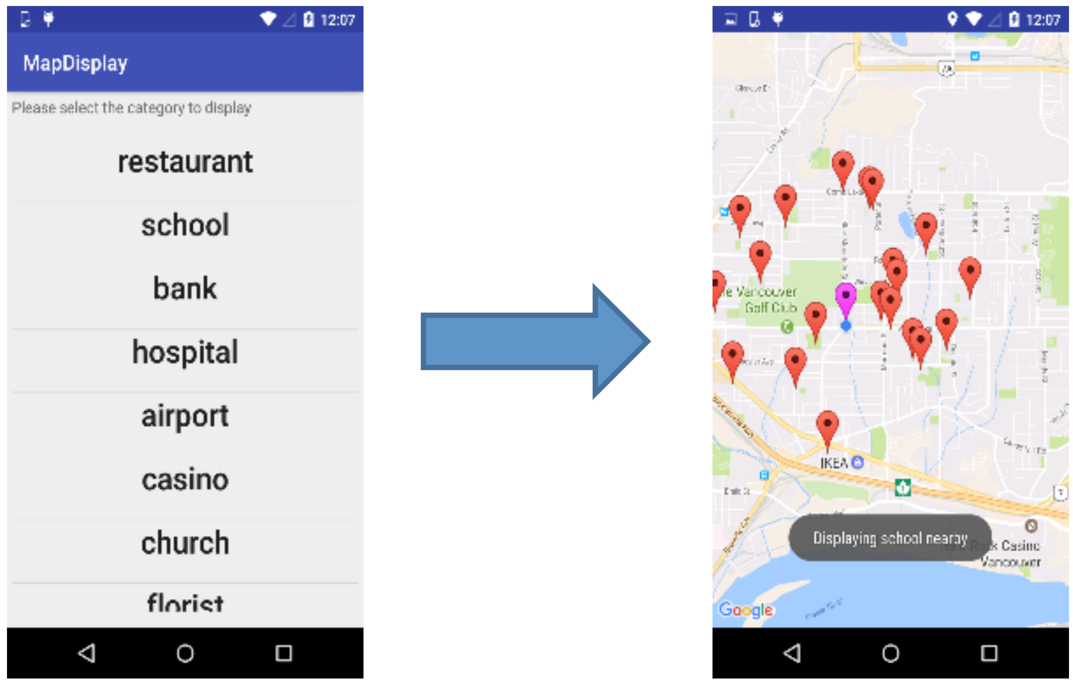


Example App



GPS location used

Example App



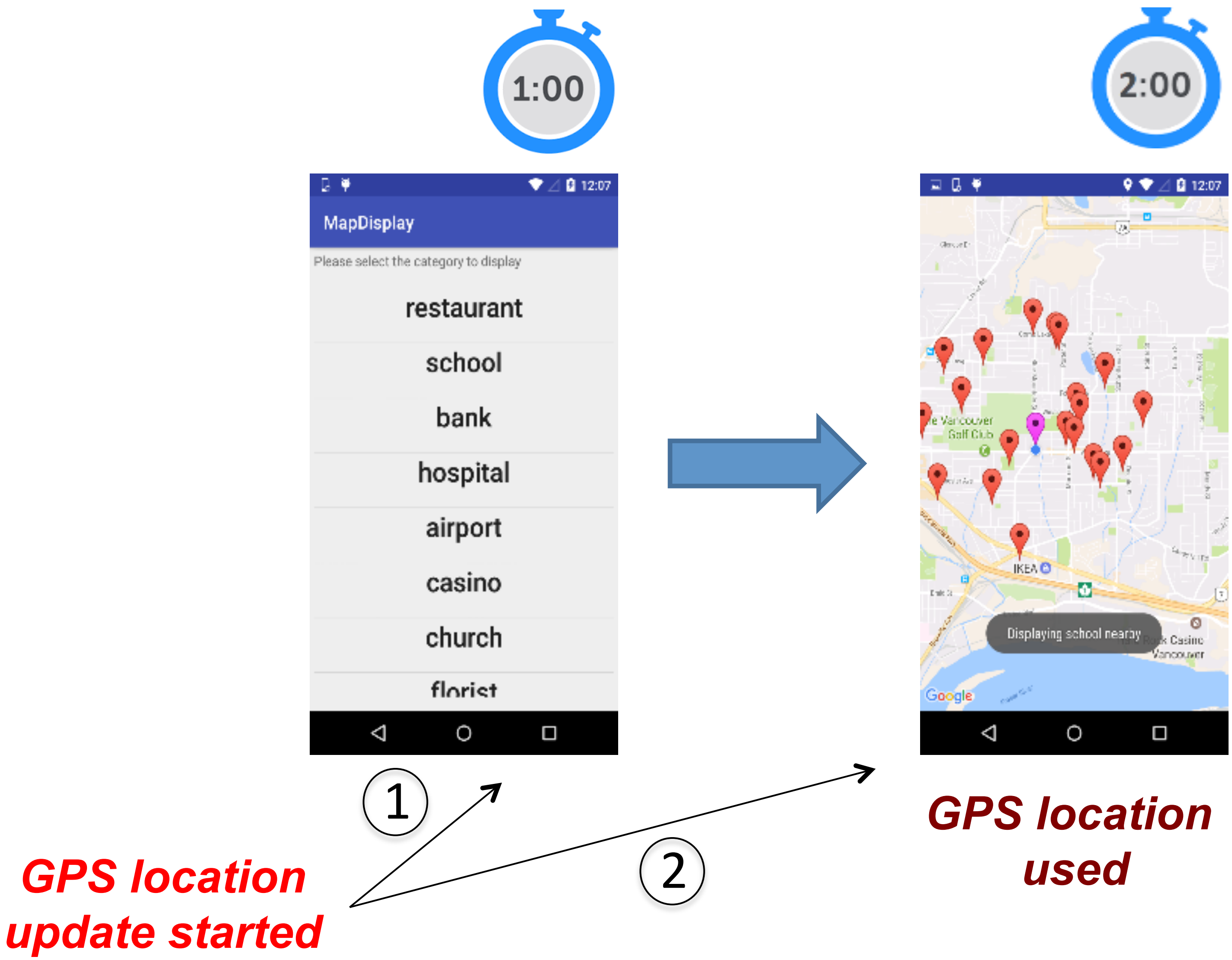
1

2

GPS location update started

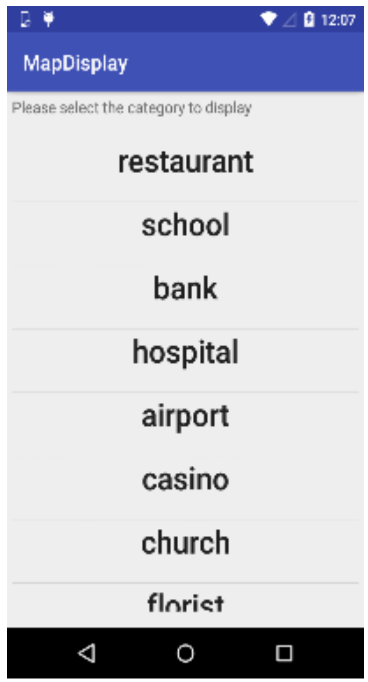
GPS location used

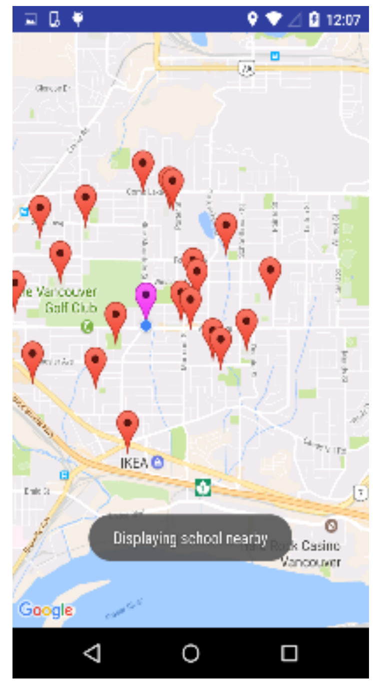
Example App



1:00
2:00
MapDisplay
Please select the category to display
restaurant
school
bank
hospital
airport
casino
church
florist
Displaying school nearby
IKEA
Google
1
2
GPS location update started
GPS location used

Example App





1 47% more energy

1

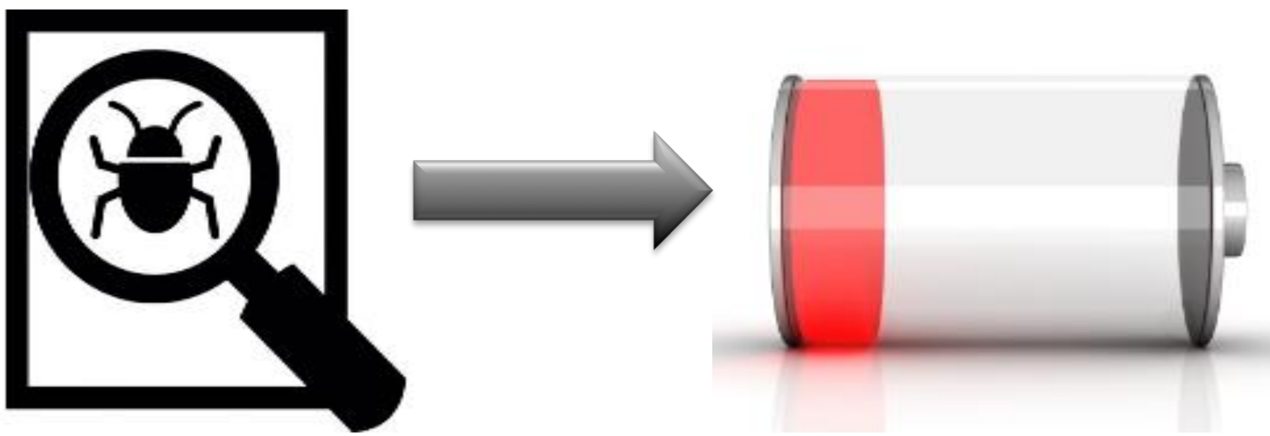
2

GPS location update started

GPS location used

Energy Bugs

An error in the system that causes an unexpected amount of high energy consumption



[Pathak et al., HotNets'11]

Energy Bugs and Hotspots

An application consumes an abnormally high amount of battery power …

- … even *after it has completed execution* → ***Bug***
- … even though the utilization of its hardware resources is low → ***Hotspot***

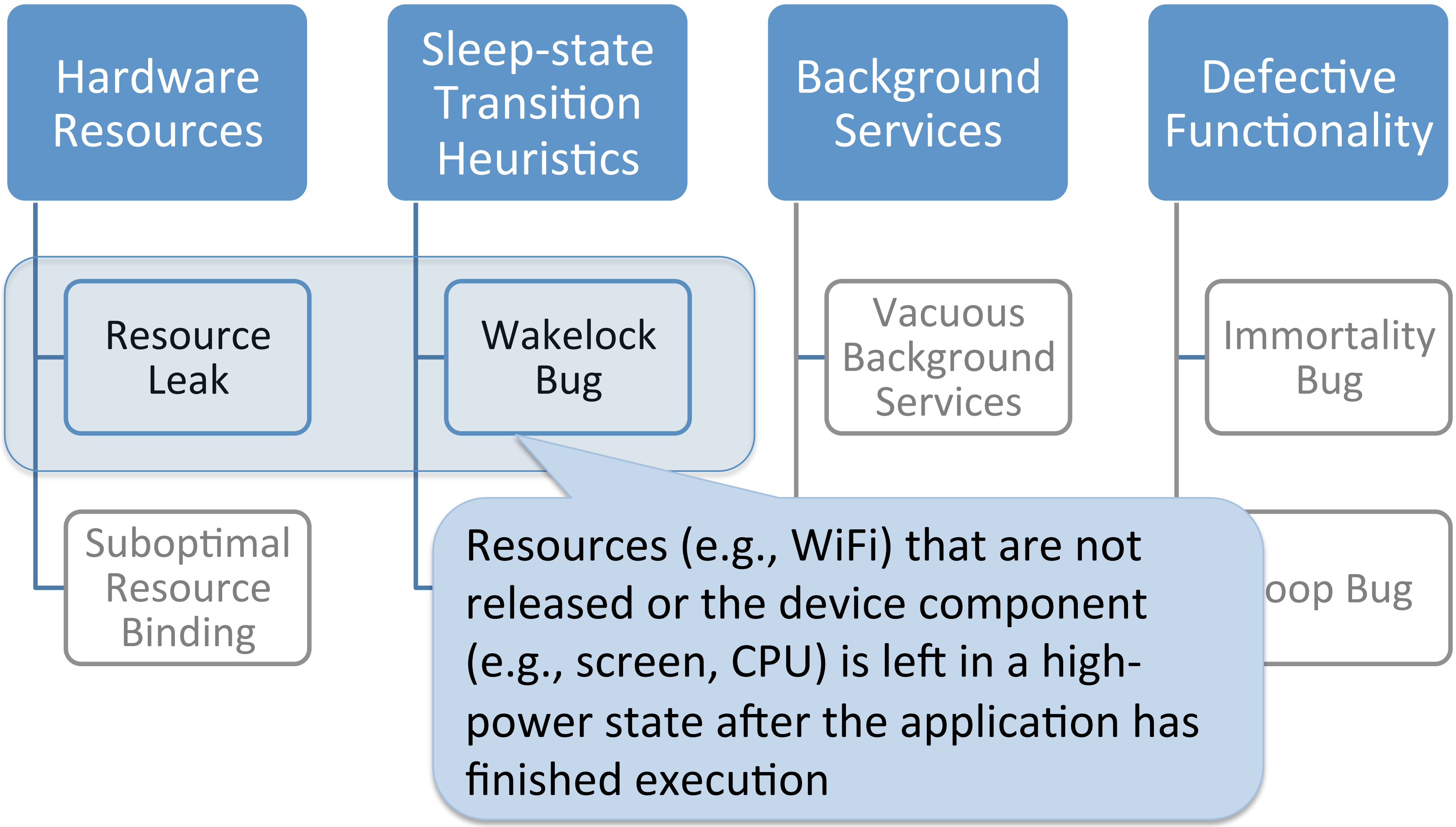
[Banerjee et al., FSE'14]

Taxonomy of Energy Bugs and Hotspots

- Hardware Resources
  - Resource Leak
  - Suboptimal Resource Binding
- Sleep-state Transition Heuristics
  - Wakelock Bug
  - Tail Energy Hotspot
- Background Services
  - Vacuous Background Services
  - Expensive Background Services
- Defective Functionality
  - Immortality Bug
  - Loop Bug

[Banerjee et al., FSE'14]

Taxonomy of Energy Bugs and Hotspots



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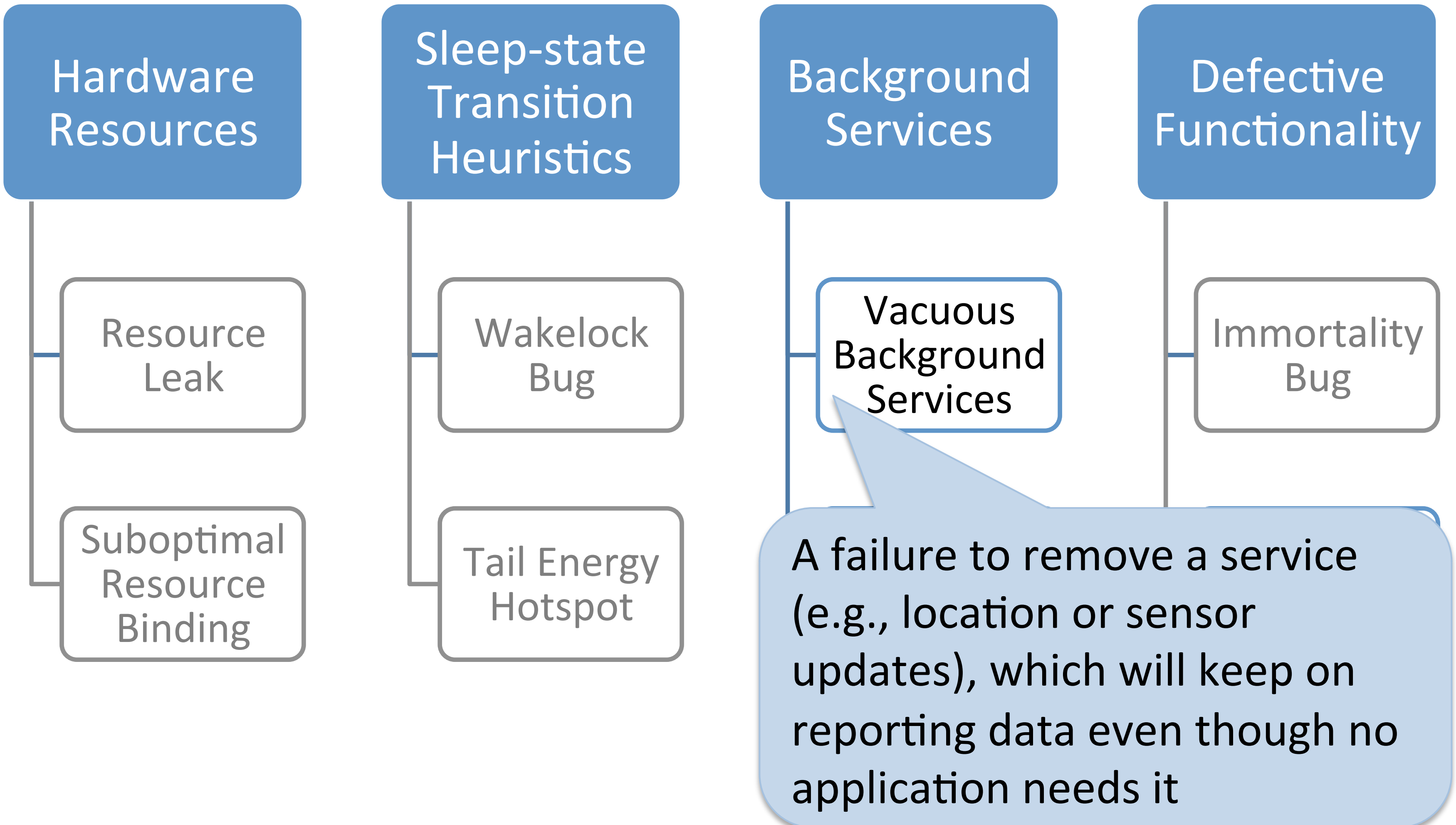

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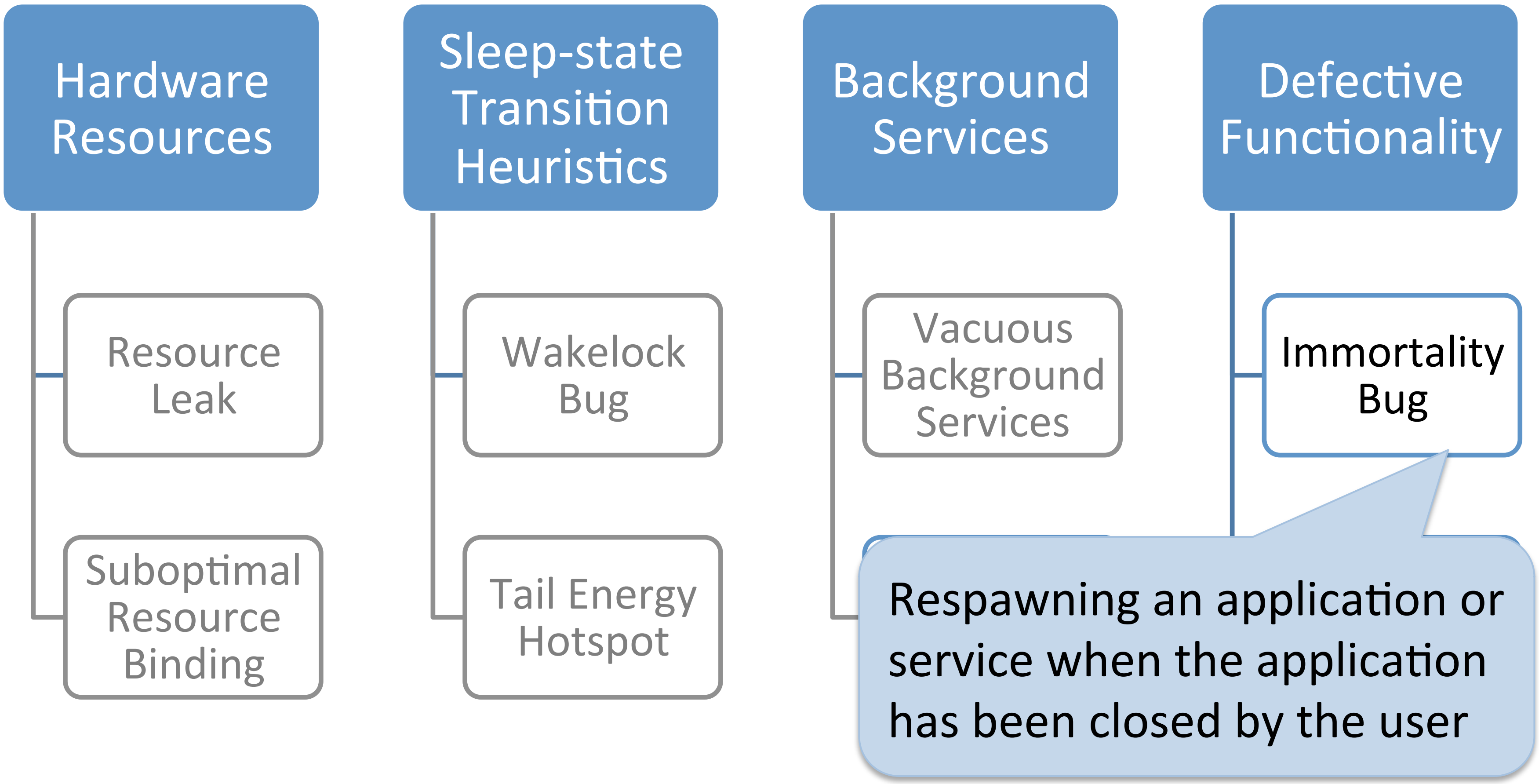

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Binding resources too early or releasing them too late

[Banerjee et al., FSE'14]

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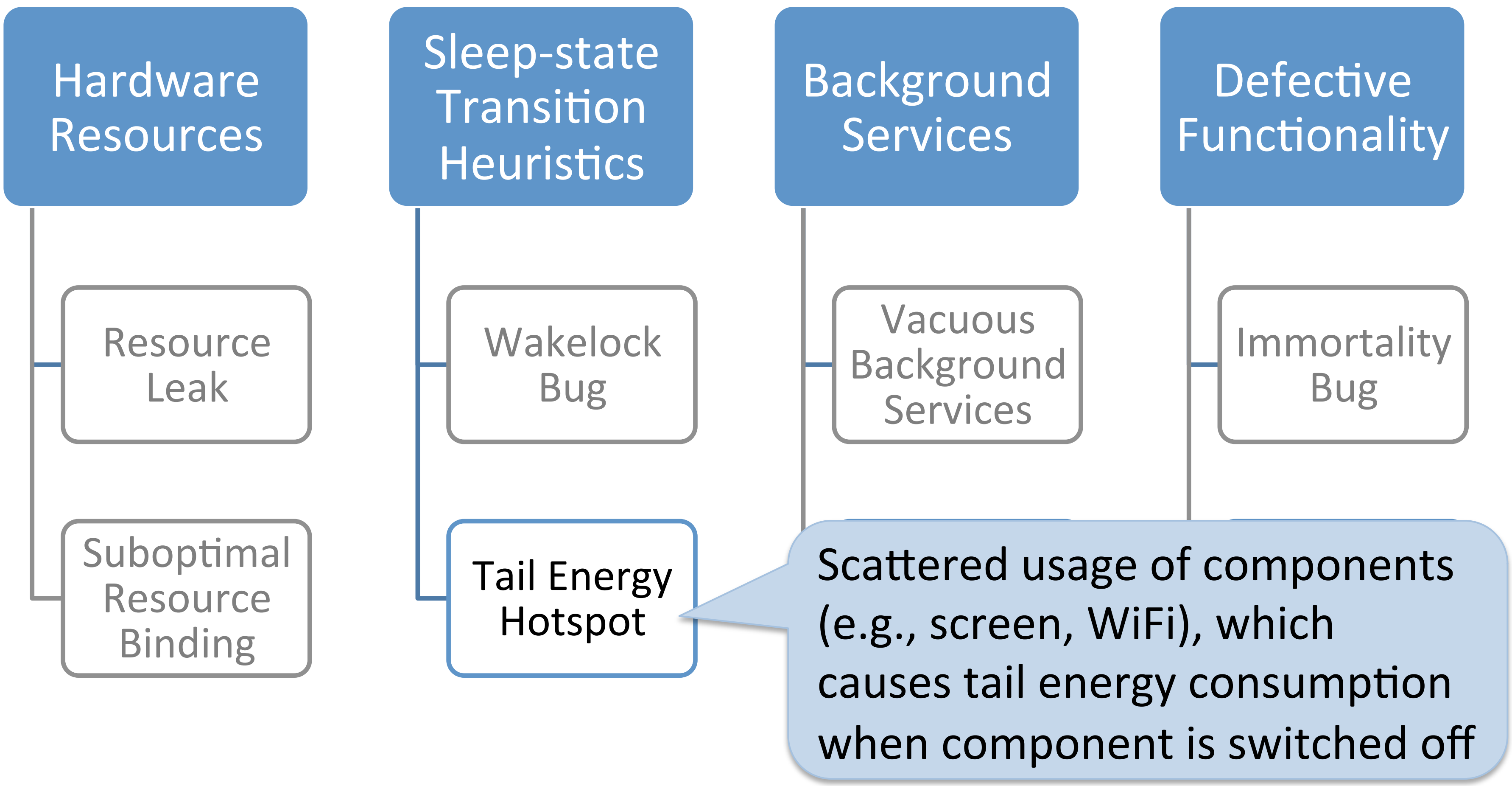

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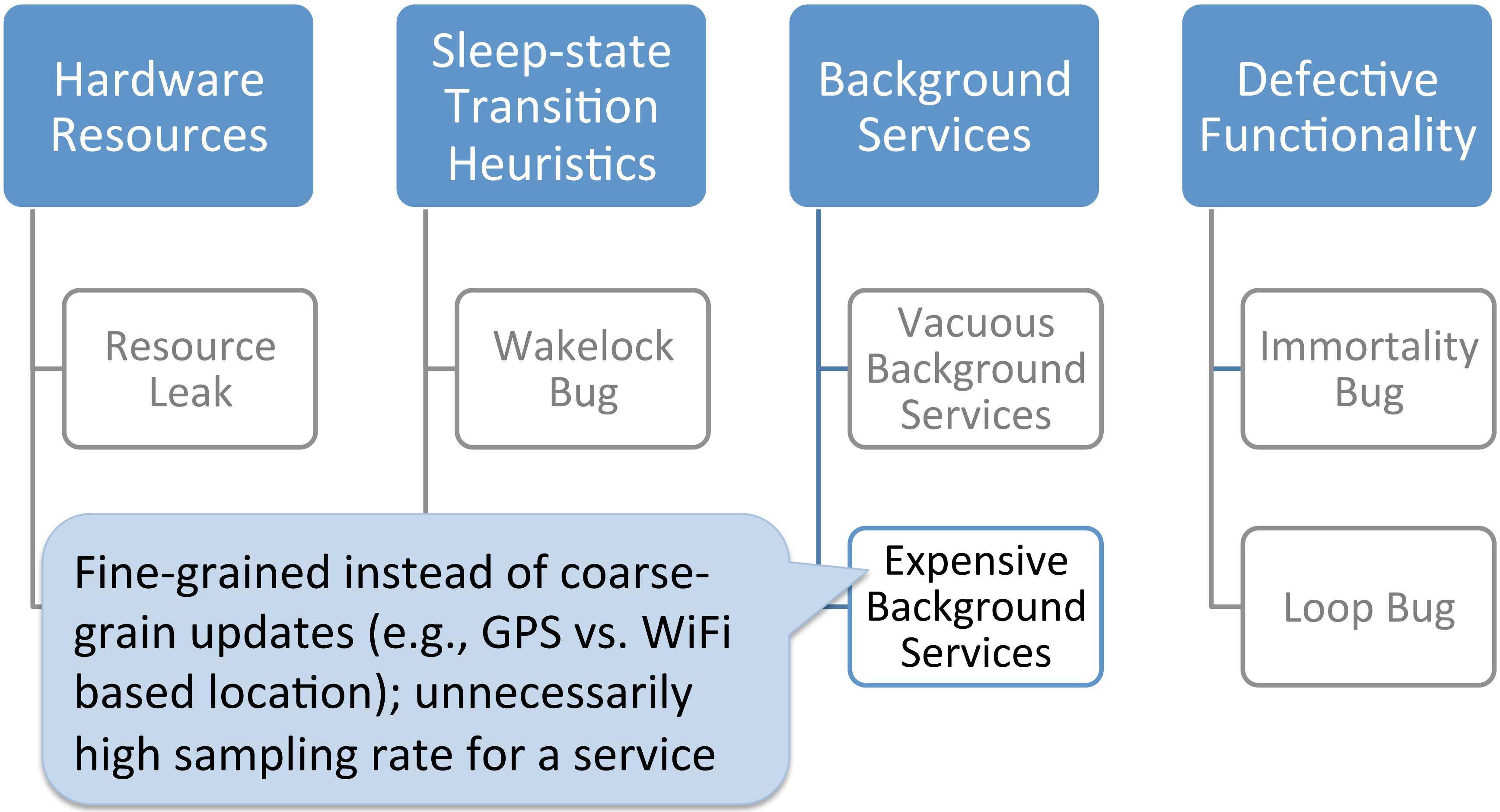

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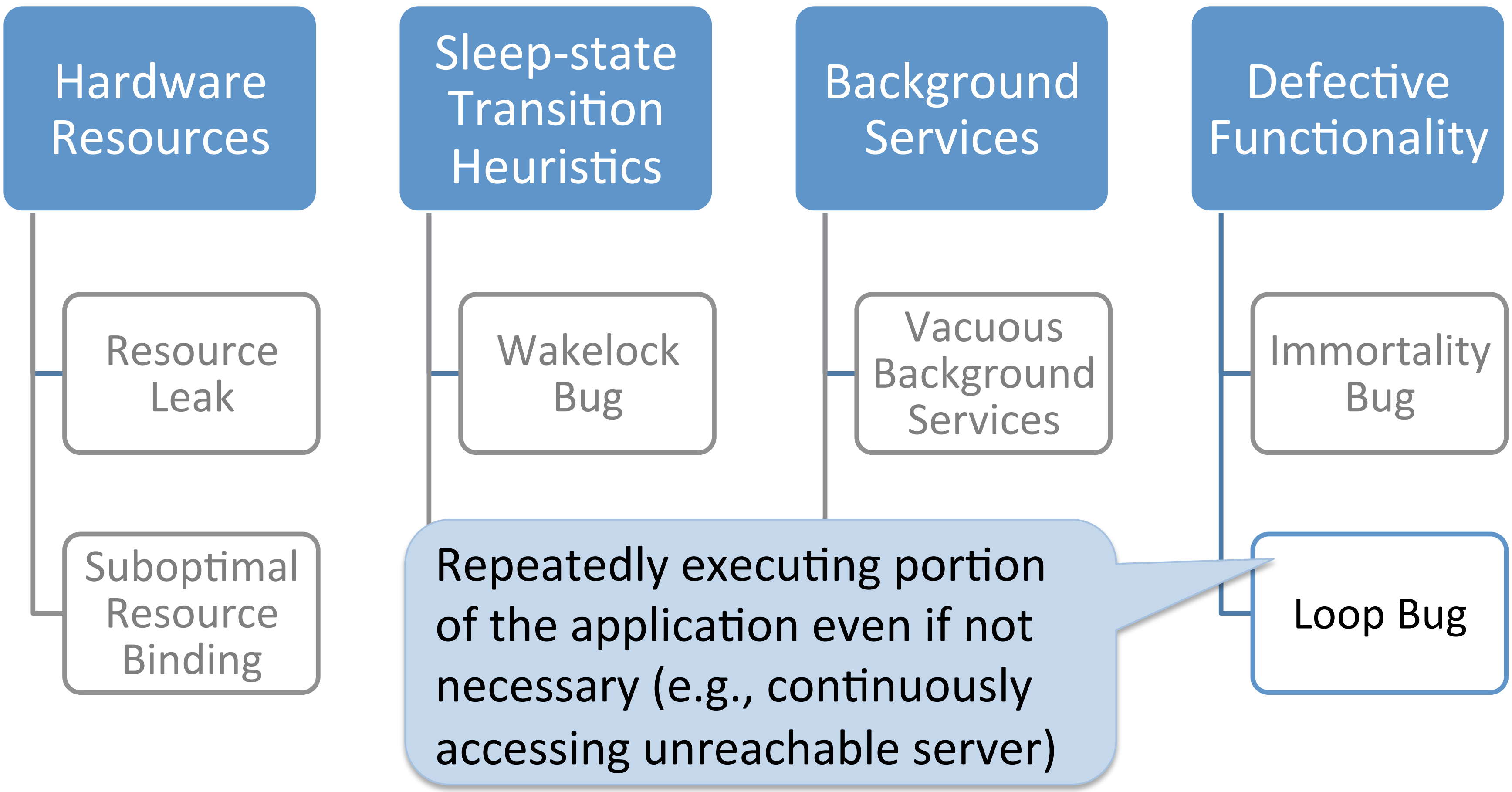

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- *Pathak et al., MobiSys'12*:
  static analysis to find definitions (resource acquisition) that are not killed (released)
- *Guo et al., ASE'13 (Relda)*:
  builds a Function Call Graph (callbacks and resource-related operations) to check which resources are not released

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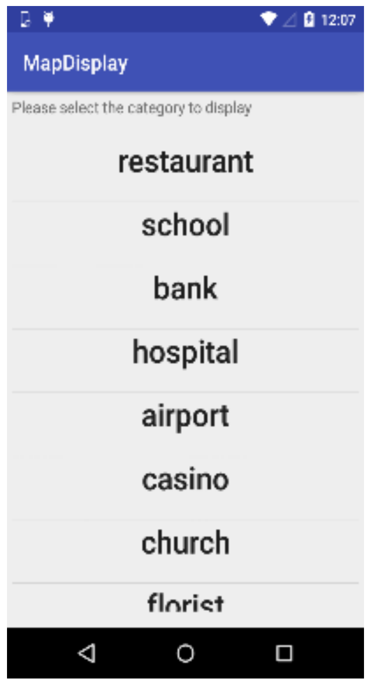
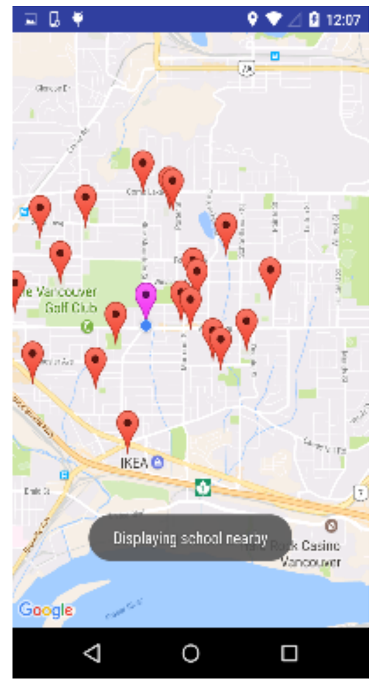
- *Liu et al., PerCom'13 (GreenDroid):* calculates utilization ratio by using dynamic taint analysis
- *Banerjee et al., MobileSoft'16*: improves binding location by matching defect and design expressions

Example App

1 47% more energy





1

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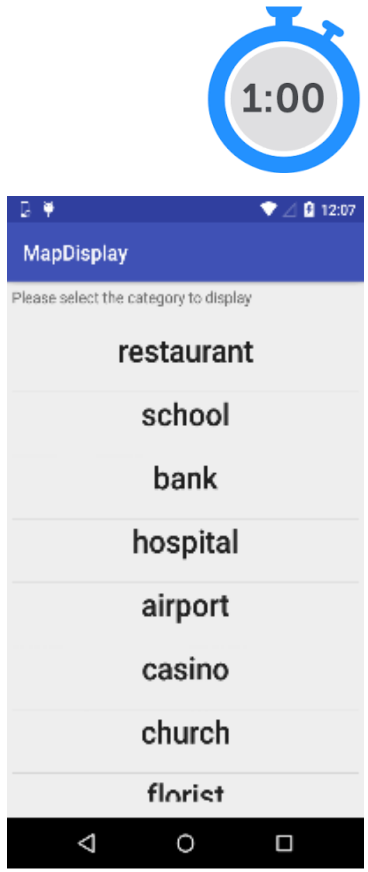
GPS location used

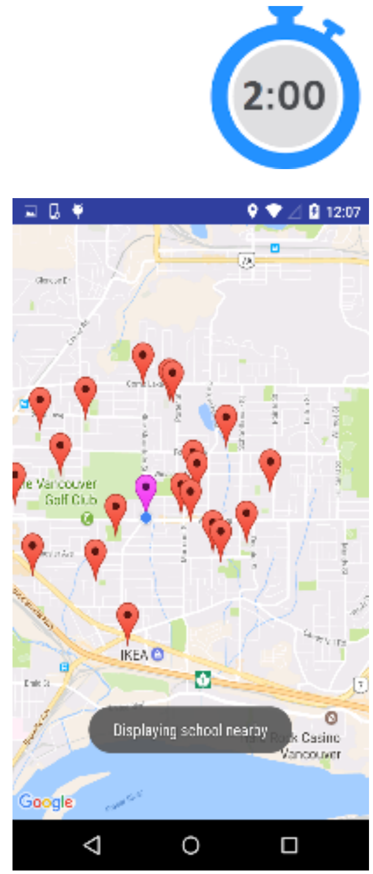
Example App

1 47% more energy

?

2 visibly slower





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QoS Considerations

"For best location accuracy, you might choose to start listening for location updates ***when users begin creating the content or even when the application starts***, <…>"

"You might need to consider ***how long*** a typical task of creating the content takes and judge if this duration allows for efficient collection of a location estimate."

[https://developer.android.com/guide/topics/location/strategies.html]

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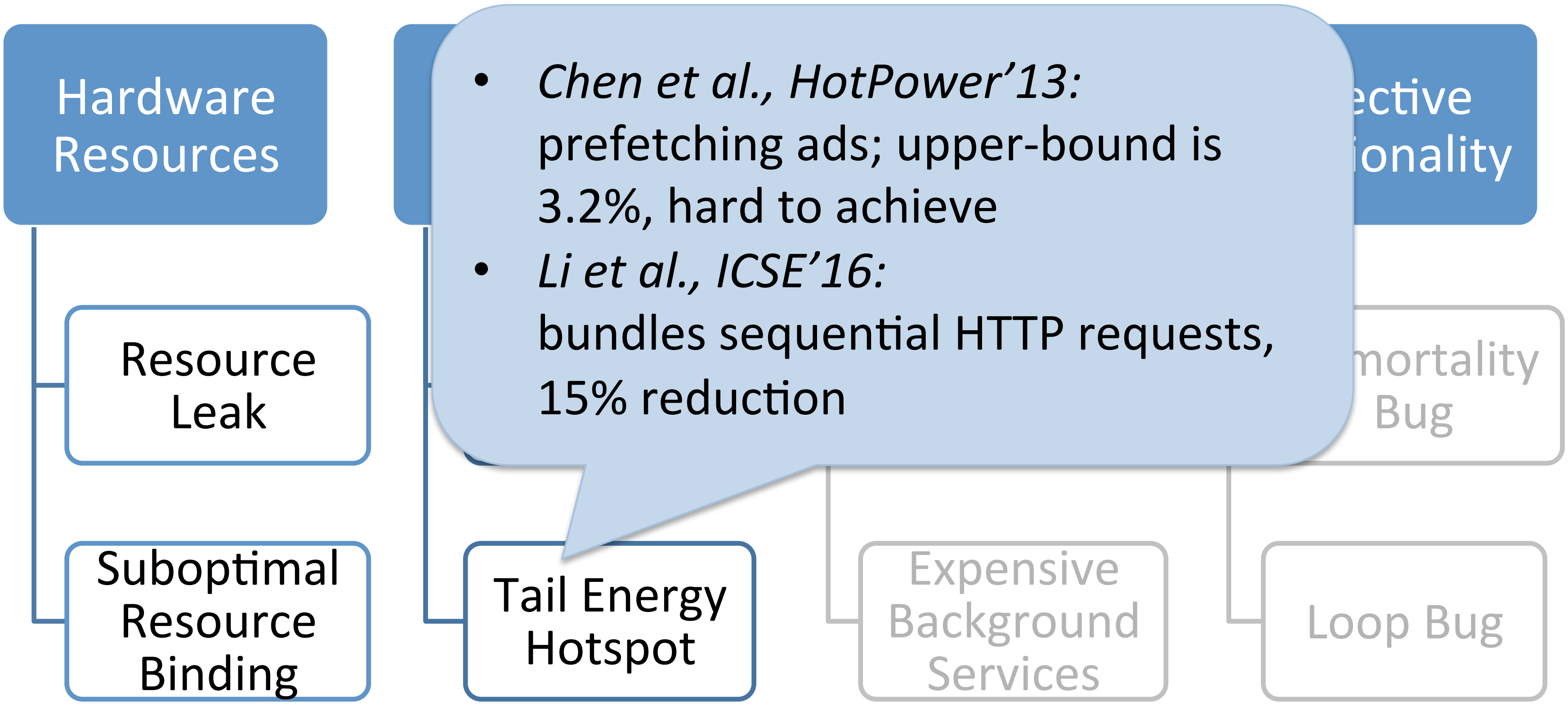

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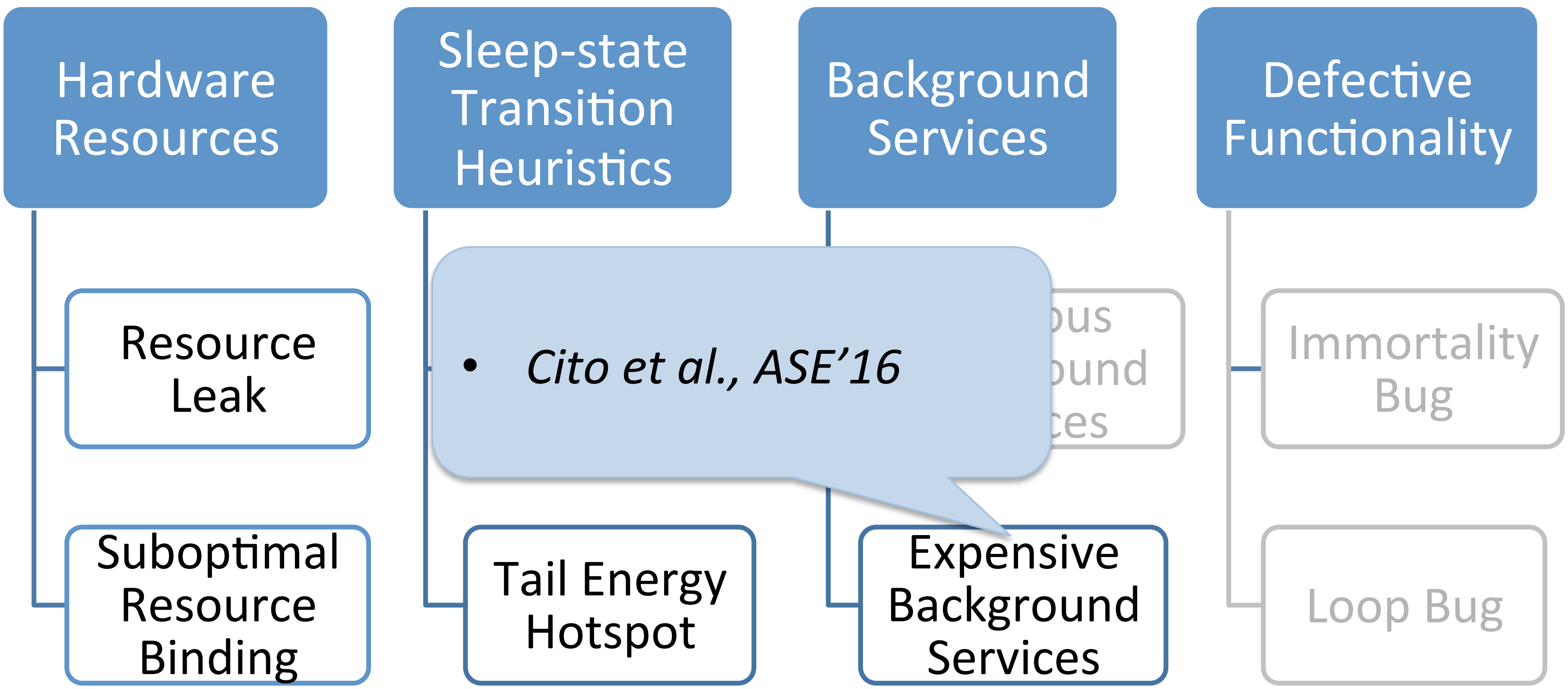


Advertising and Analytics (A&A)

- At least 3 third-party libs in an app [Rubin at al., ASE'15]
- Consume 65%-75% of energy [Pathak et al., EuroSys'12]
- More than 40% of HTTP connections do not contribute to user-observable behavior [Rubin at al., ASE'15] – Analytics
- Advertising consumes 16% of energy (plus 48% more CPU time and 79% more network data) [Gui et al., ICSE'15]

Photo Credit "Mobile Users": https://flic.kr/p/nJMbfu Kyle Spradley

Mobile Users

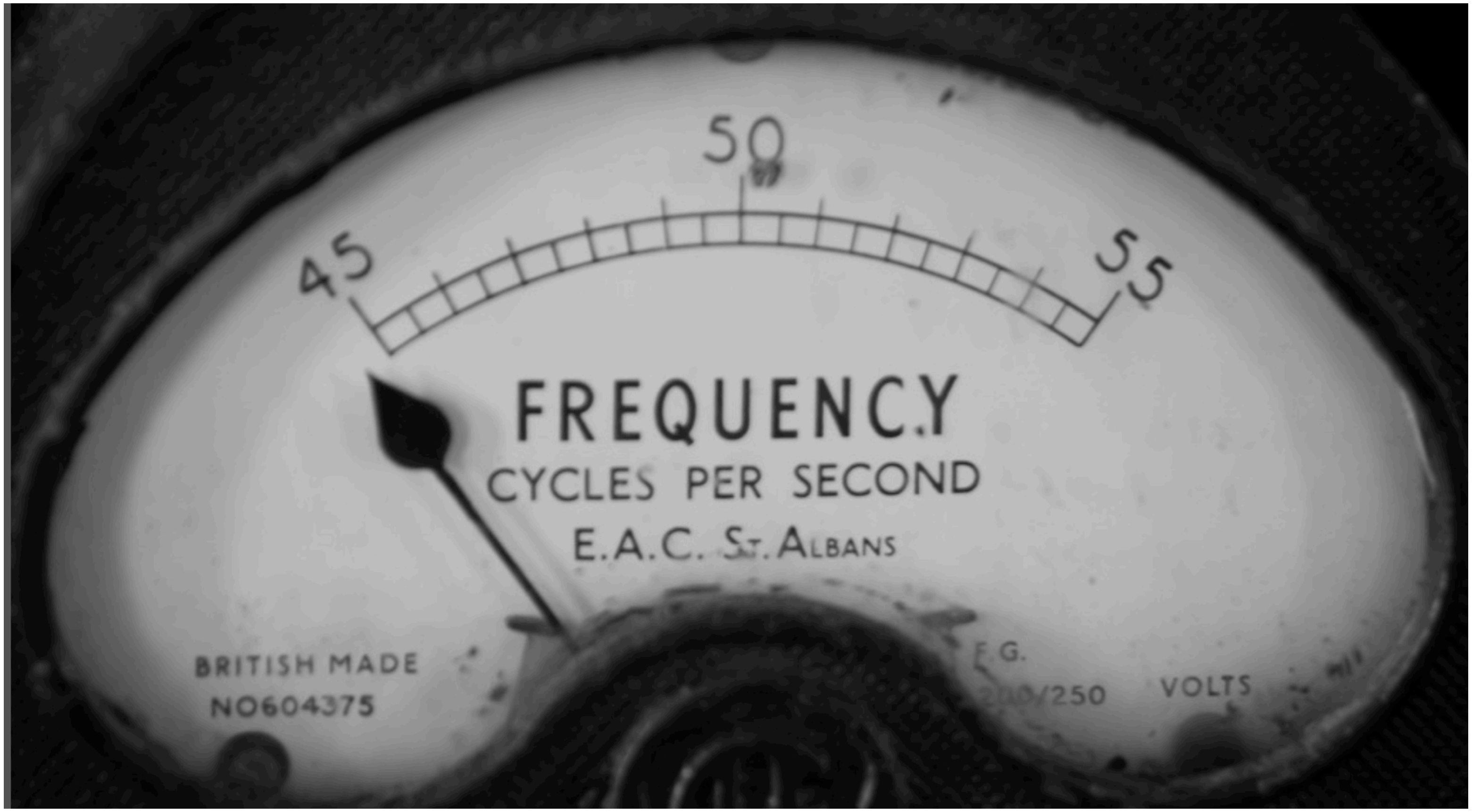
Mobile Developers

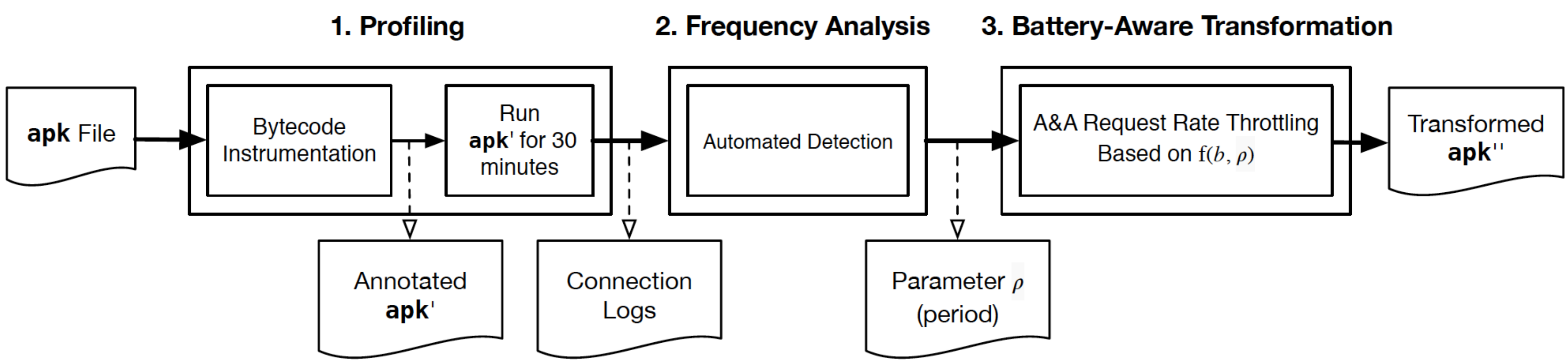
Goal
Maximize Battery Life
Minimize Energy Consumption

Goal
Maximize Revenue (Ads)
Maximize App Insight (Analytics)

Main Idea

Automatically identify ***recurrent A&A requests*** and ***adapt their frequency*** to the current battery state.




1. Profiling
2. Frequency Analysis
3. Battery-Aware Transformation
apk File
Bytecode Instrumentation
Run apk' for 30 minutes
Automated Detection
A&A Request Rate Throttling Based on f(b, ρ)
Transformed apk''
Annotated apk'
Connection Logs
Parameter ρ (period)

Battery Aware Transformation

Based on

- ρ – period of the recurrent requests
- b – battery status

add a delay before recurrent A&A requests

Linear adaptation:

$$f_{linear}(b,\rho) = \frac{\rho * c}{b}$$

Low power mode
(at 20% battery status):

$$f_{LowPowerMode}(b,\rho) = \begin{cases} \rho * c & if\ b \leq 0.2 \\ 0 & otherwise \end{cases}$$

Savings – an Example

- VLC Direct: video stream player
- One recurrent request – every 30 sec
- Introduced 100% delay – to 60 sec
- Run for 30 mins
- 5.8% reduction in energy consumption (16% upper bound)

Providing Incentives

- Problem: applications are "greedy"
  - Do not consider other apps
  - Do not consider battery status
- In plan: game-theoretical approach for mobile energy marketplace
  - price energy and bill applications for the energy they use

Summary

Mobile Application Developers

Lack knowledge, tools, and incentives to deal with:

- Security
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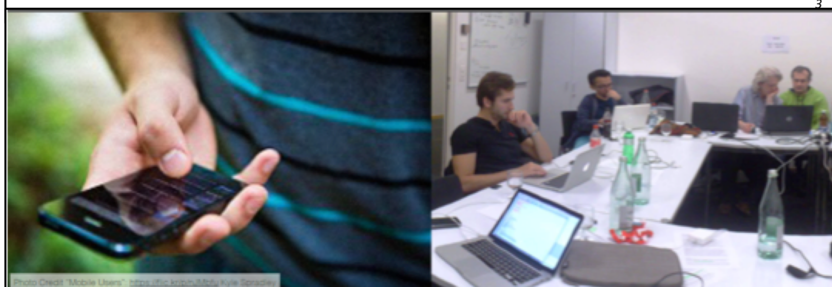

Mobile Users	Mobile Developers
Goal Maximize Battery Life Minimize Energy Consumption	**Goal** Maximize Revenue (Ads) Maximize App Insight (Analytics)

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