



# **Google Play Apps Energy Rating Model: Multi-Criteria Evaluation Model to Generate Tentative Energy Ratings for Google Play Store Apps**

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# Disclaimer

This research did not cover Apple smartphones for reasons related to lack of open source materials



# Procedural Model of Study

• Conducting a narrative-style Literature Review with a thematic analysis, which allows us to familiarize ourselves with the subject matter

• Establishing a hypothesis regarding the battery saving behaviour of Android Users

• Creating a concept of classification that is able to categorise existing power saving techniques and charting the data in a matrix framework

• Interpret the created classification in relation to user behaviour, highlighting the limitations of current practices through a survey

• Propose a solution, using existing information technologies on how to better match types with battery saving solutions.



# Motivation

- A common issue among android smartphones is the battery life.
- Smartphones are known to intake an unusual amount of energy budget of the world due to the repeated charging of battery (Ahmad et al., 2016).

# Motivation

- A report provided by Barry Flscher showed that the volume of energy it takes in charging a smartphones globally is equal to the accumulated power utilized by 54000 United States households for each year.
- Following this report, the power demanded by a smartphone each year is ranging from 3.5 to 4.9 kWh. (Fischer, n.d. 2012)
- The Need to Save Smartphones Battery-Life During COVID-19 Pandemic is more important to consider as many governments implemented location-tracking applications.

# The Problem



Nokia 3310

Popular Uses

- SMS
- Voice Dialing
- Calculator
- Snake
- Customize Ringtones

Battery Standby

**For up to a month**

[https://www.nokia.com/phones/en\\_int/nokia-3310](https://www.nokia.com/phones/en_int/nokia-3310)

# The Problem

## Smartphones



## Popular Uses

- Internet connectivity.
- A mobile browser.
- The ability to sync more than one email account to a device.
- Embedded memory.
- A hardware or software-based QWERTY keyboard.
- Wireless synchronization with other devices, such as laptop or desktop computers.
- The ability to download applications and run them independently.
- Support for third-party applications.
- The ability to run multiple applications simultaneously.
- Touchscreen.
- Wi-Fi.
- A digital camera, typically with video capability.
- Gaming.
- Unified messaging.
- GPS.

## Average Battery Standby

**6 hours**

# The Problem

Reverse Relationship between phone functionality and battery life

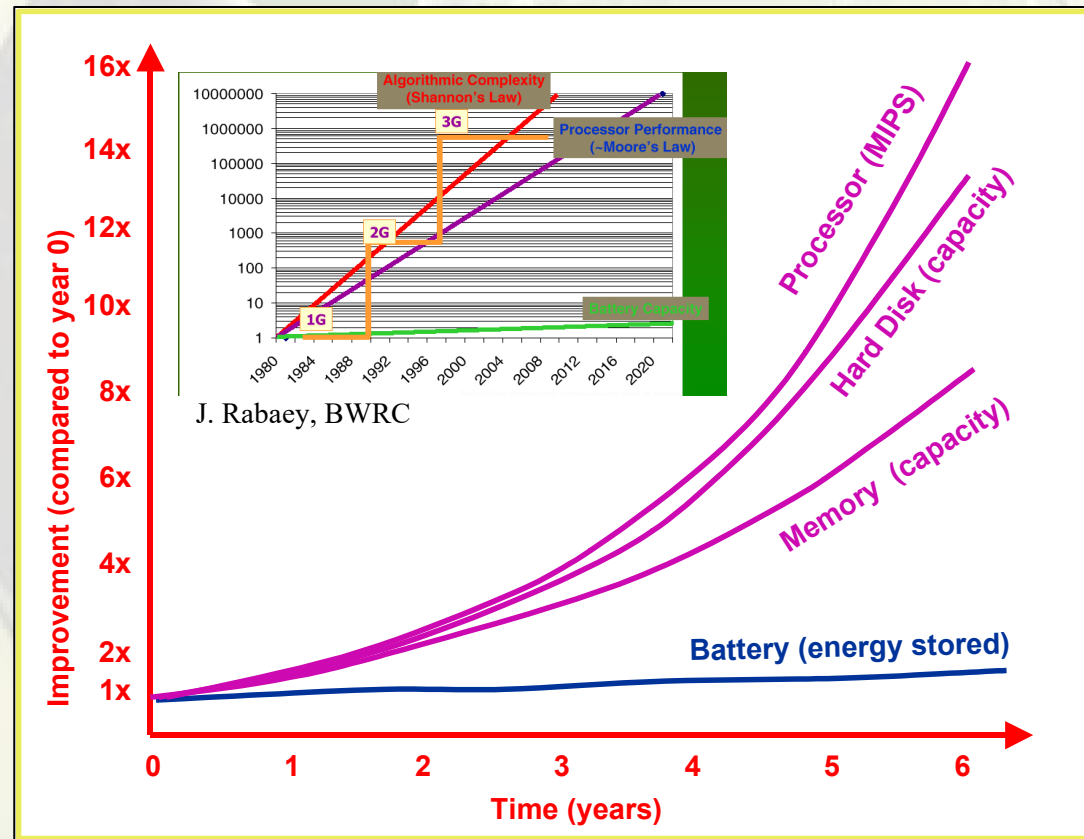


**Less** Technology More  
Battery Life



More Technology **Less**  
Battery Life

# The Problem

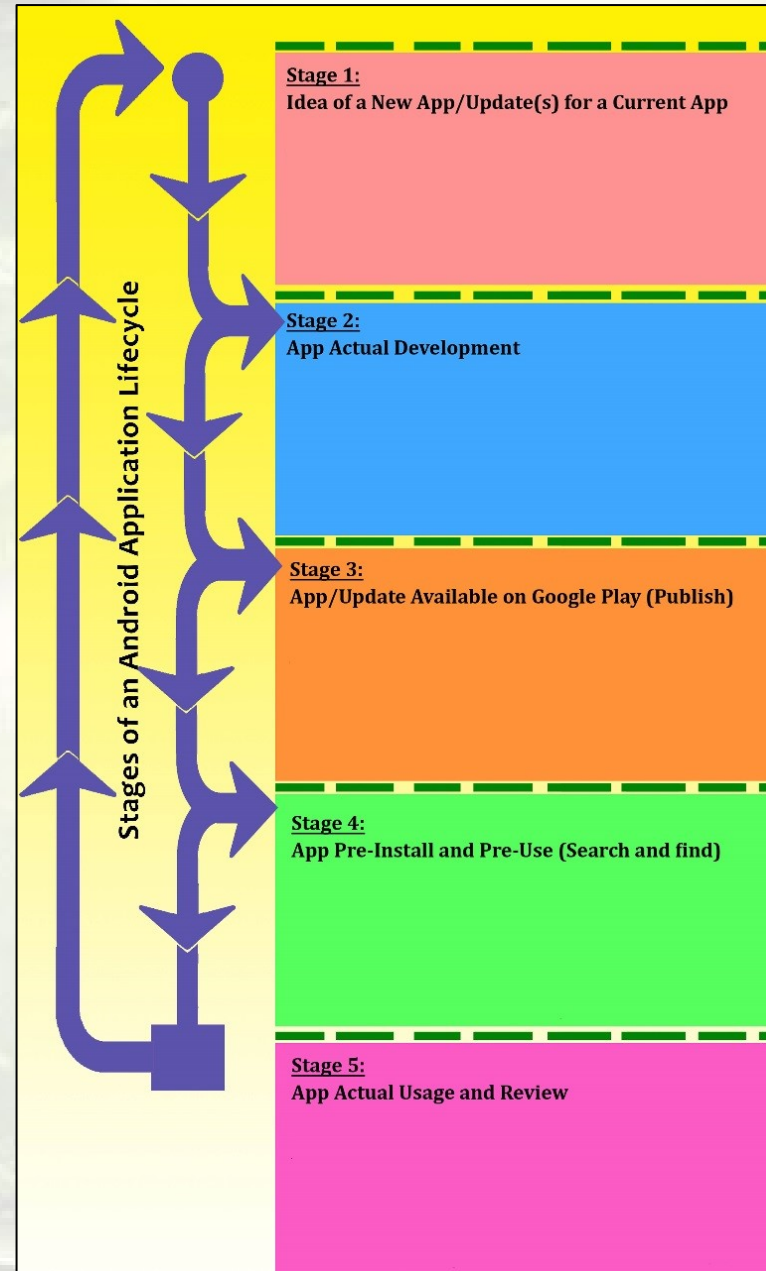


# Introduction

## Understanding Power-saving Basic Approaches

# Introduction

## Average Android-Application-Lifecycle





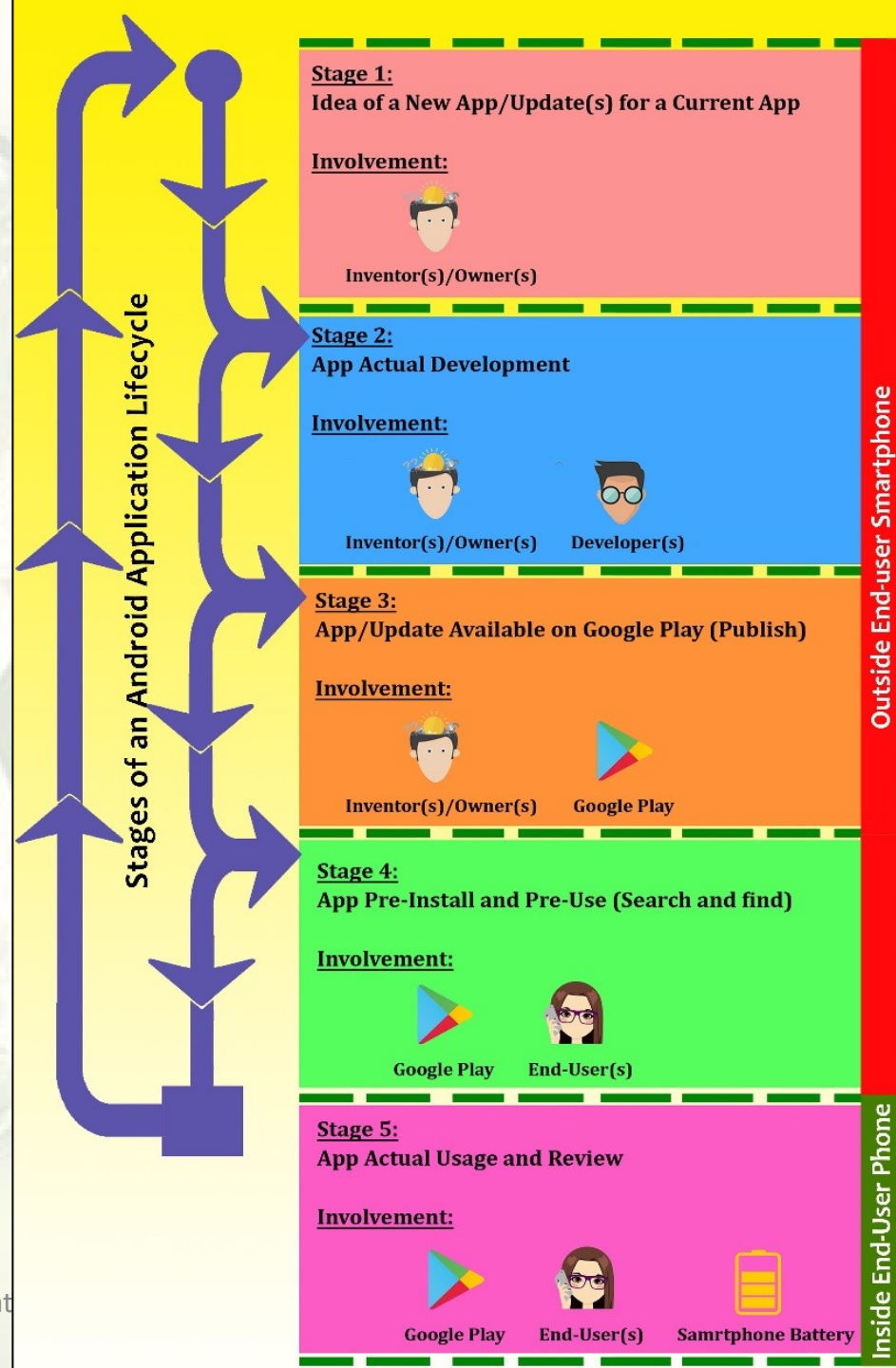
# Introduction

- List the Concerned Parties and Identify their Involvement



# Status of App Among Different Stages of an Application Lifecycle

1. Outside the End-User's Phone  
(Under development or Available on Google Play)
2. Inside the End-User's Phone  
(Installed & Running)

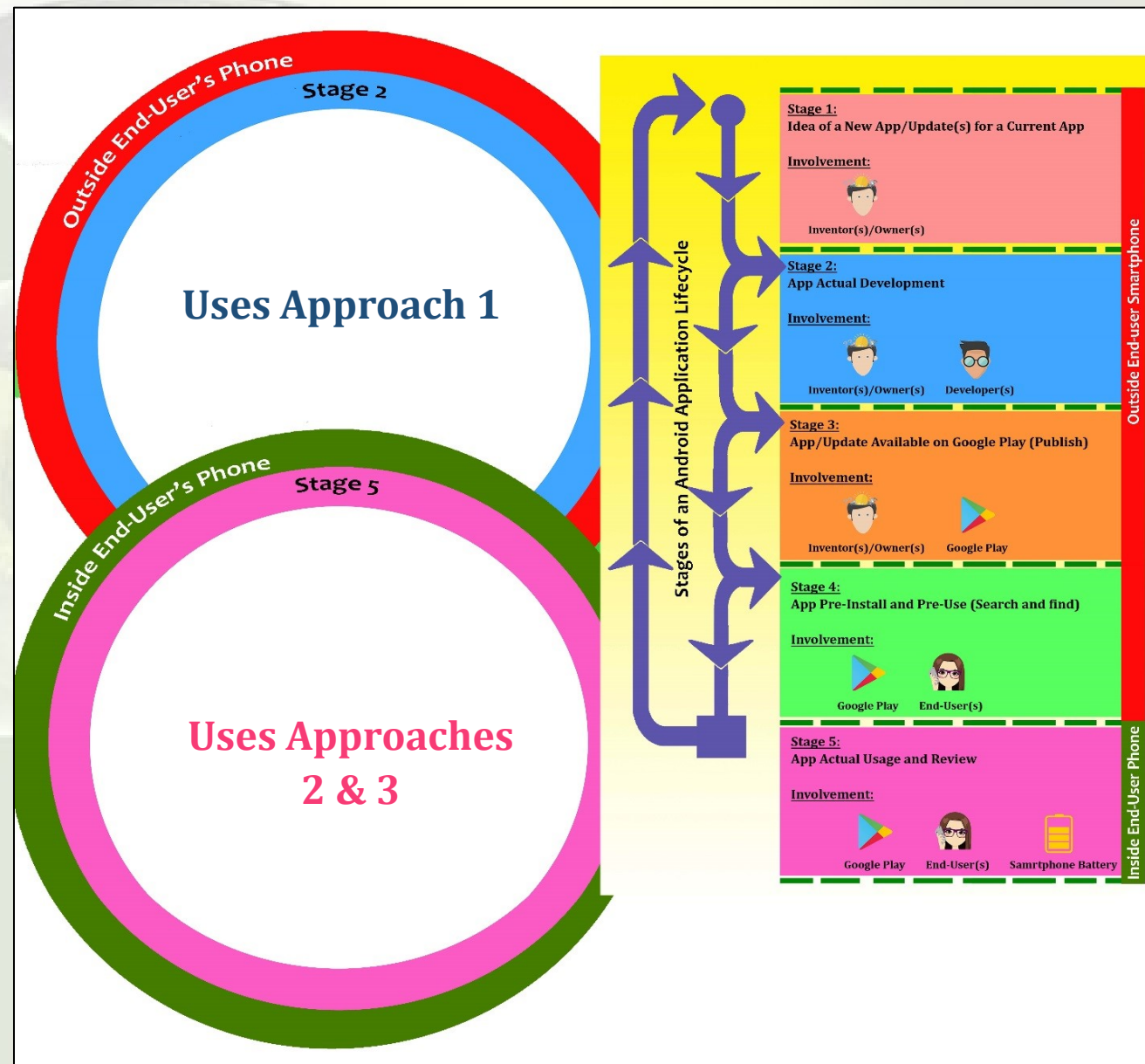


# Current power-saving approaches and its usage among the lifecycle

**Approach 1:**  
 To Simulate & Estimate  
or  
 To Apply Thin Client

**Approach 2:**  
 To Monitor, Detect and Control

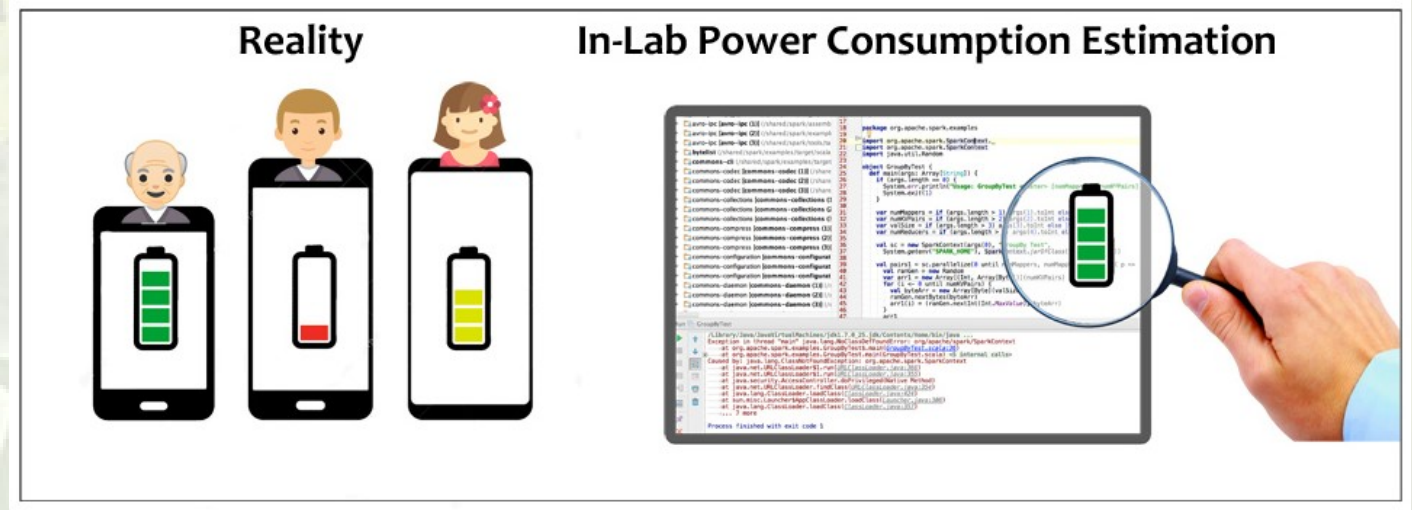
**Approach 3:**  
 To Sacrifice Technology



# Key Issues of Current Power-Saving Approaches

## Key Issue of the “Simulate & Estimate” Approach:

- Not all hardware is equal and not all apps works the same on all hardware.
- Methods of normalizing energy consumption still ignores the usage habits and the lifestyle of the end user.
- Testing a single build of the code might not be enough.

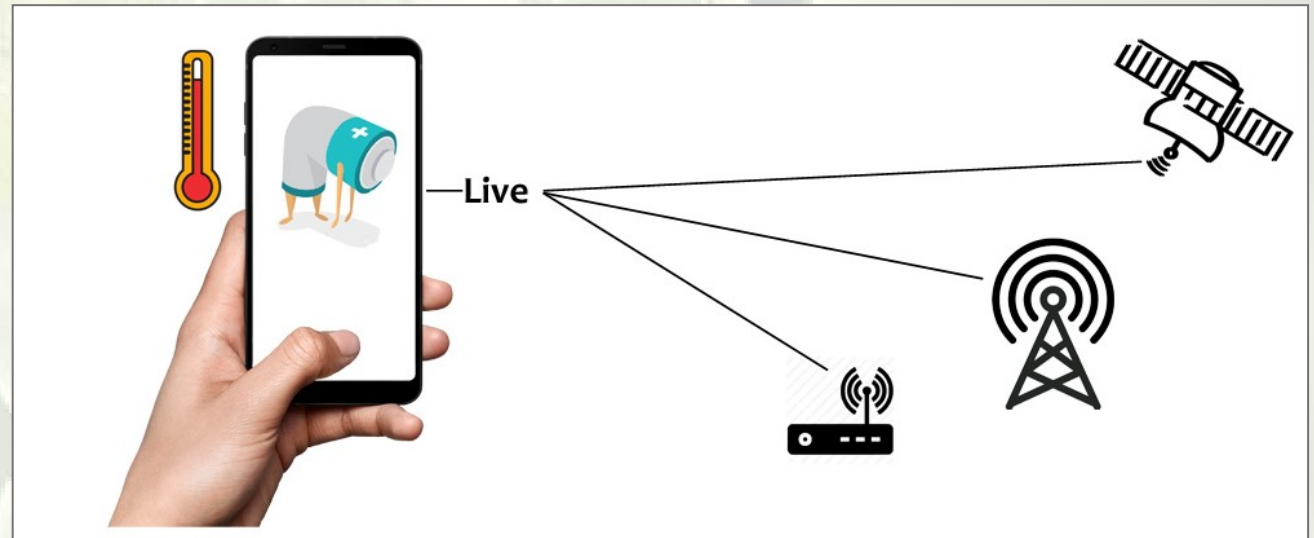




# Key Issues of Current Power-Saving Approaches

## Key Issue of the “Thin Client” Approach :

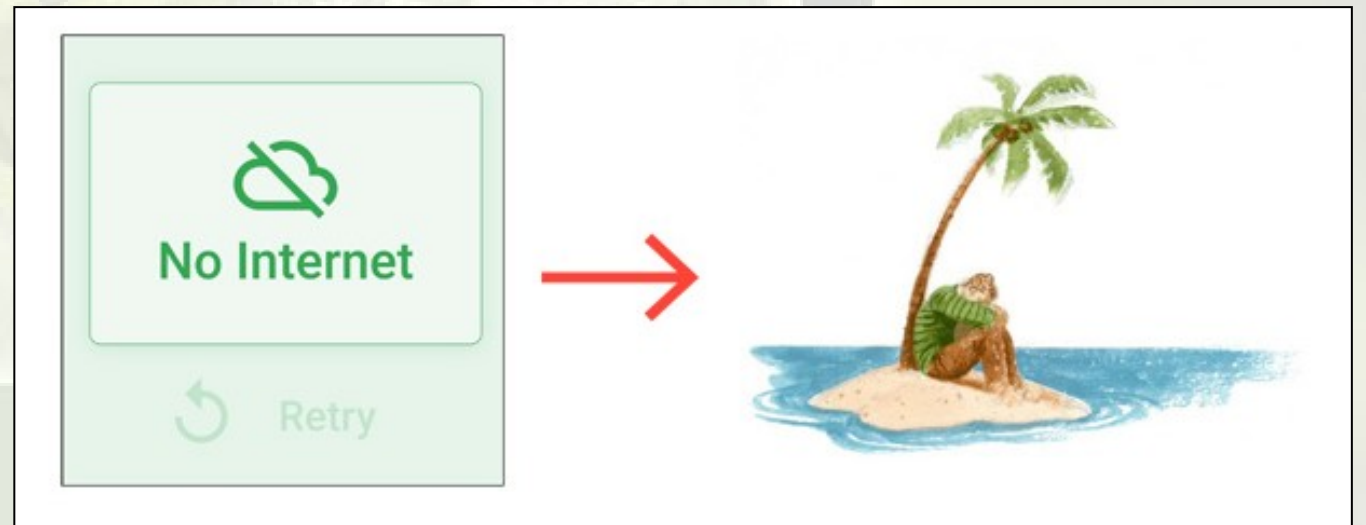
- Continuous need of internet connectivity uses local connection hardware resources that require complicated power aware connectivity algorithms on both the sender and receiver side (router, tower, satellite.. etc).



# Key Issues of Current Power-Saving Approaches

## Key Issue of the “Thin Client” Approach :

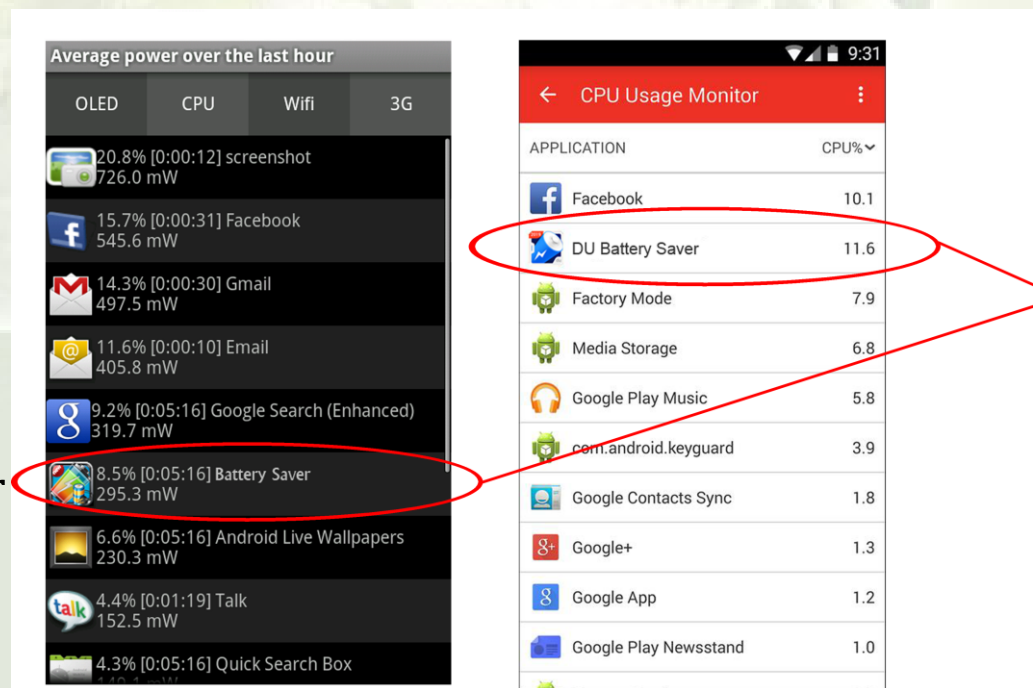
- Finally, downtime is often cited as one of the biggest disadvantages of cloud computing.



# Key Issues of Current Power-Saving Approaches

## Key Issue of “Monitor and control” Approach :

- It requires power which causes it to fail in delivering its main goal of saving energy.
- Simply, monitoring and announcing consumes power for the sake of saving power.
- Whatever runs on the application and/or the OS layers of the phone consumes power from the same phone battery.

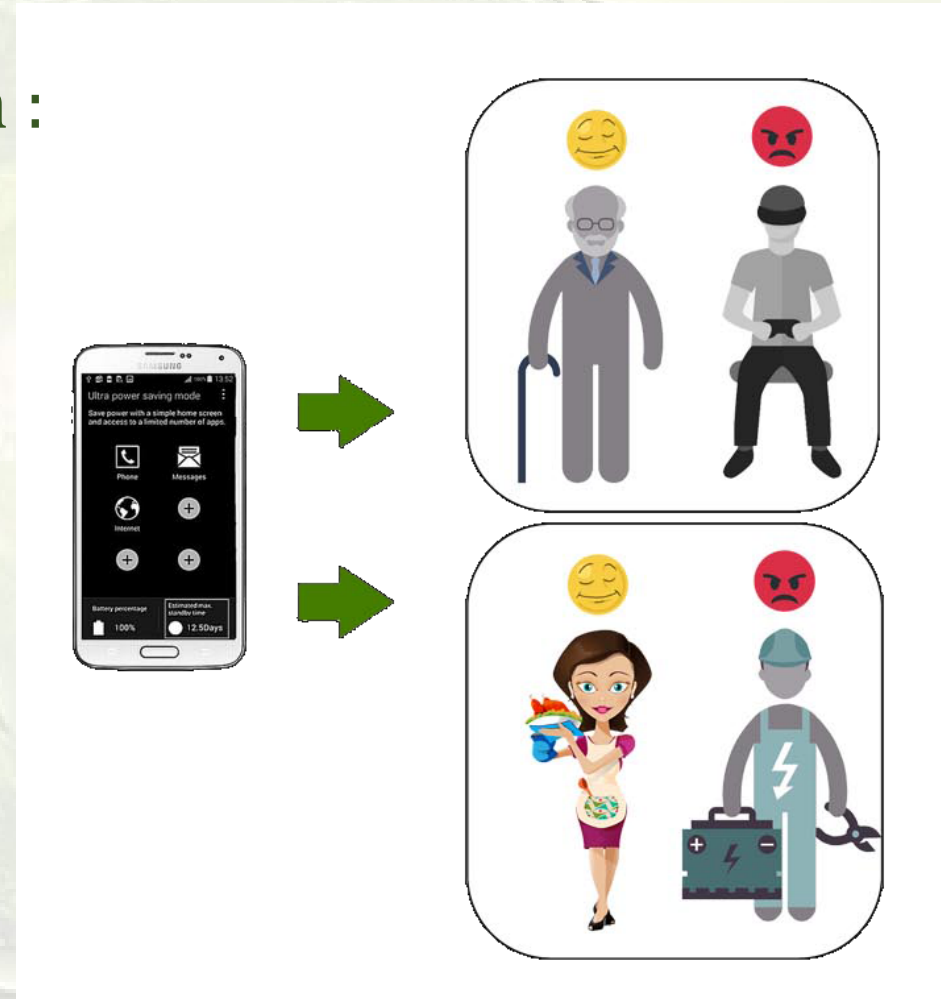


Using PowerTutor® and Trepn Profiler® to read the amount of energy consumed by two popular power-optimizing applications

# Key Issues of Current Power-Saving Approaches

## Key Issue of “Sacrifice” Approach :

- Predefined saving plans does not differentiate between users in terms of using habits.
- One-size-fits all solution to convert the colorful screen of the smartphone to a semi-black and white old screen for either a heavy gamer or a 70 years old user.





# Key Issues of Current Power-Saving Approaches

## Key Issue of “Sacrifice” Approach :








- Flexible Saving Plans relies on user’s personal estimations to control the phone components/technologies “on/off switches” which the user may never bother to go through.



# The Simplified Idea

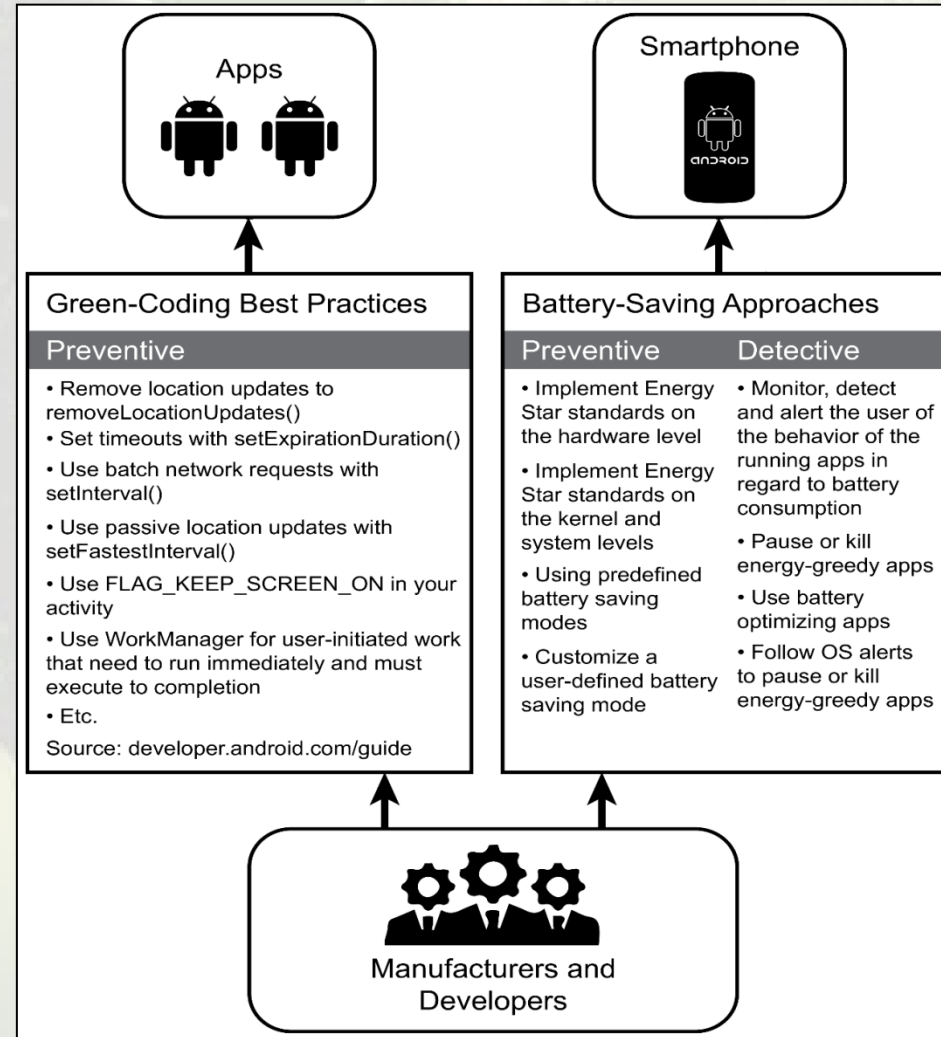


stylish photo fancy scanner ar

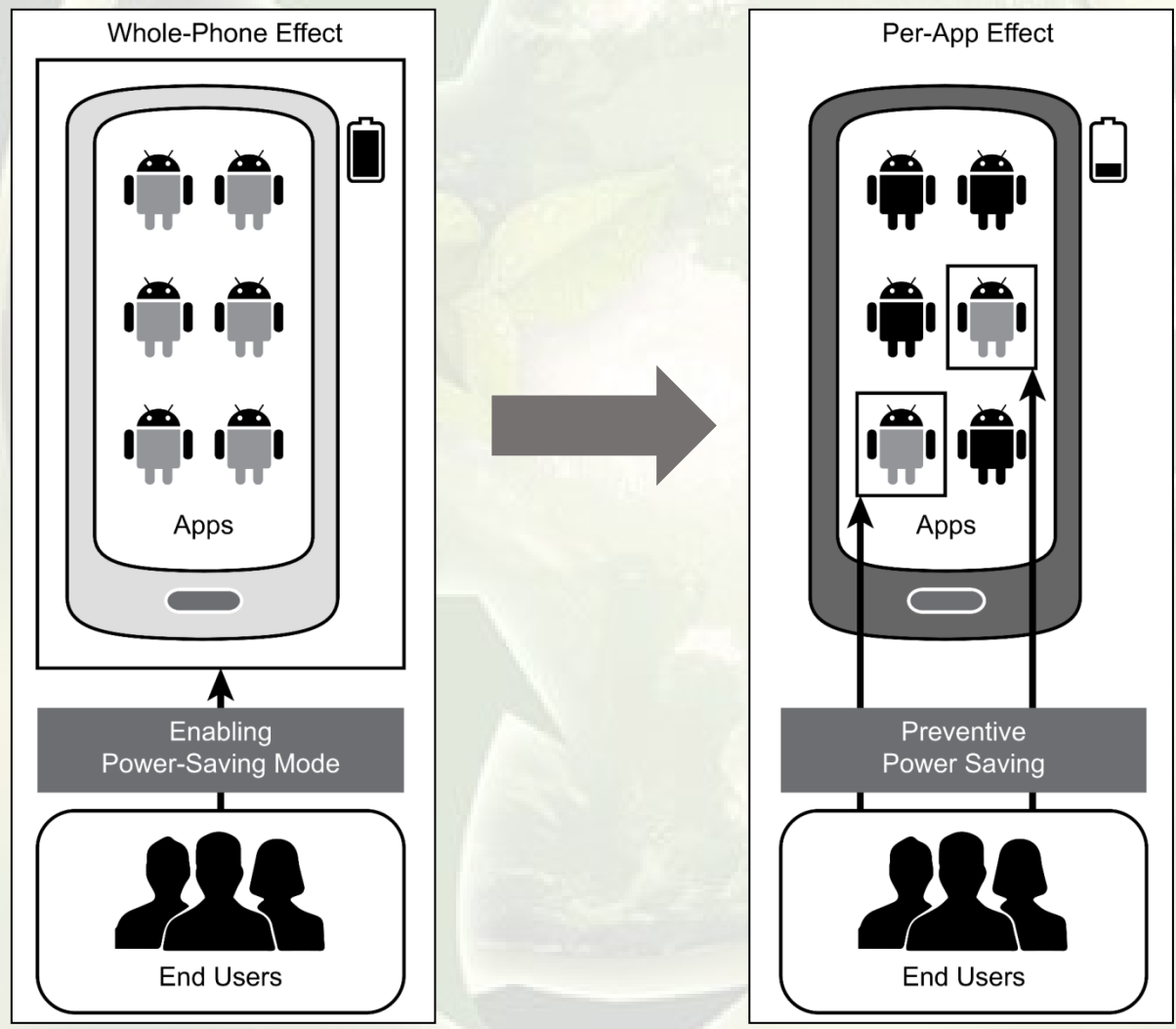
-  **TextNow: Free Texting & Calling App**  
TextNow, Inc. • Communication  
4.3★ 47 MB 50M+
-  **textPlus: Free Text & Calls**  
textPlus • Social  
3.8★ 32 MB 10M+
-  **Text Me: Text Free, Call Free, Second Pho...**  
TextMe, Inc. • Social  
4.2★ 28 MB 10M+
-  **Nextplus Free SMS Text + Calls**  
textPlus • Communication  
3.6★ 33 MB 5M+
-  **TextMe Up Free Calling & Texts**  
TextMe, Inc. • Communication  
4.1★ 28 MB 5M+
-  **Phonto - Text on Photos**  
youthr • Photography  
4.5★ 17 MB 10M+
-  **Free phone calls, free texting SMS on free...**  
Dintone, Inc. • Social



# The Current Whole Picture of Power-Saving

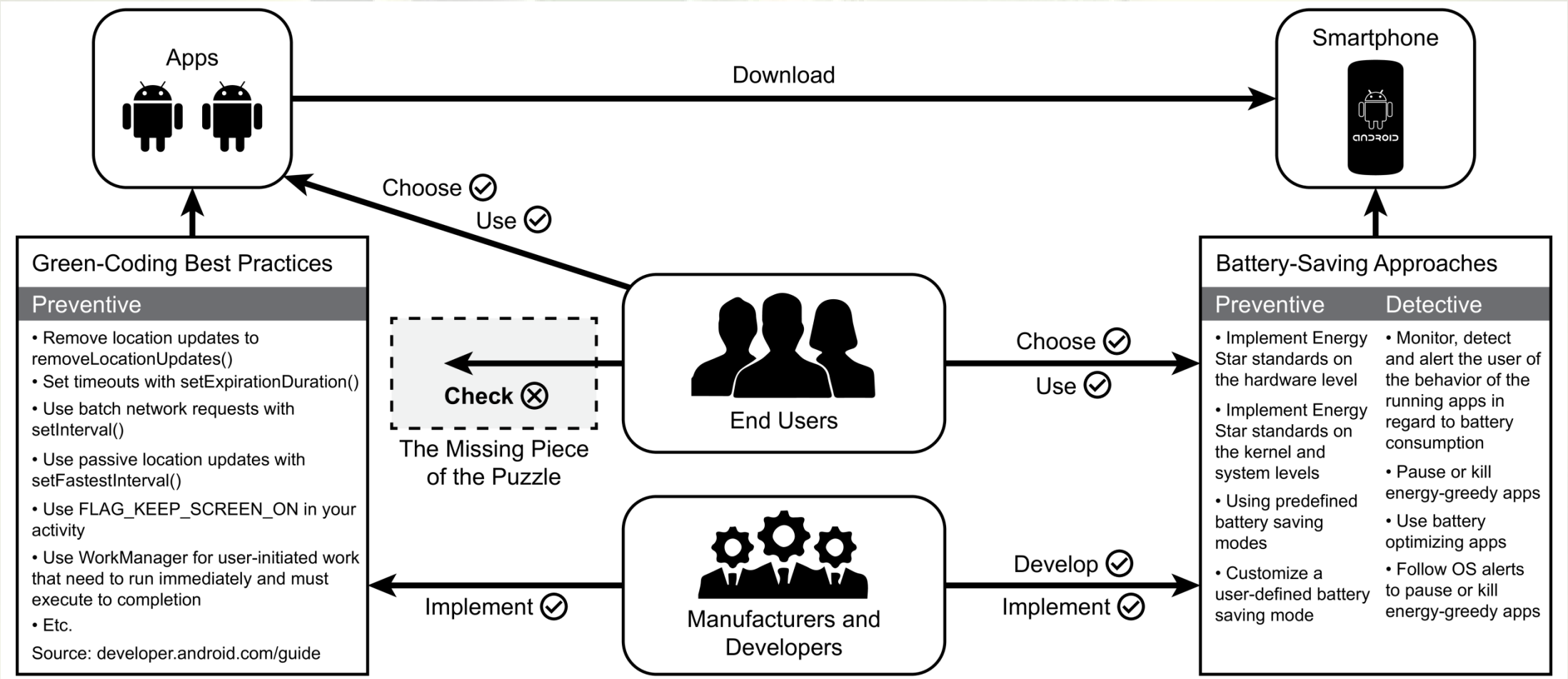


# From The “Whole Effect” to the “Per-App”



Star-rating evaluation model for rating the energy-efficiency level of android google play apps. Published In: International Journal of Electrical and Computer Engineering

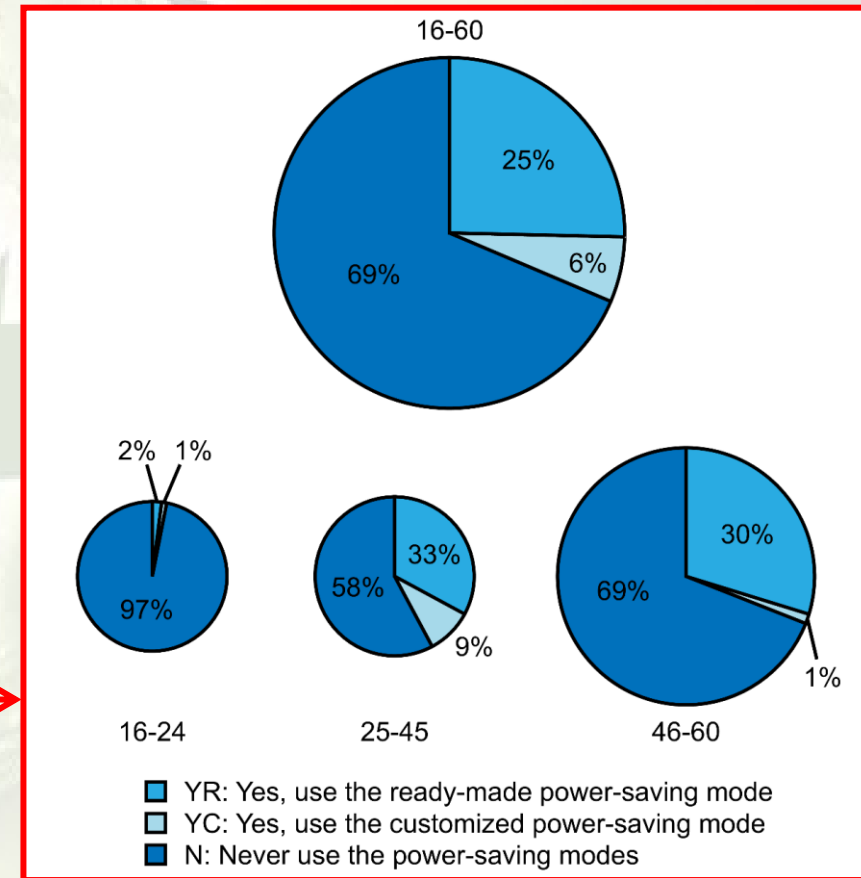
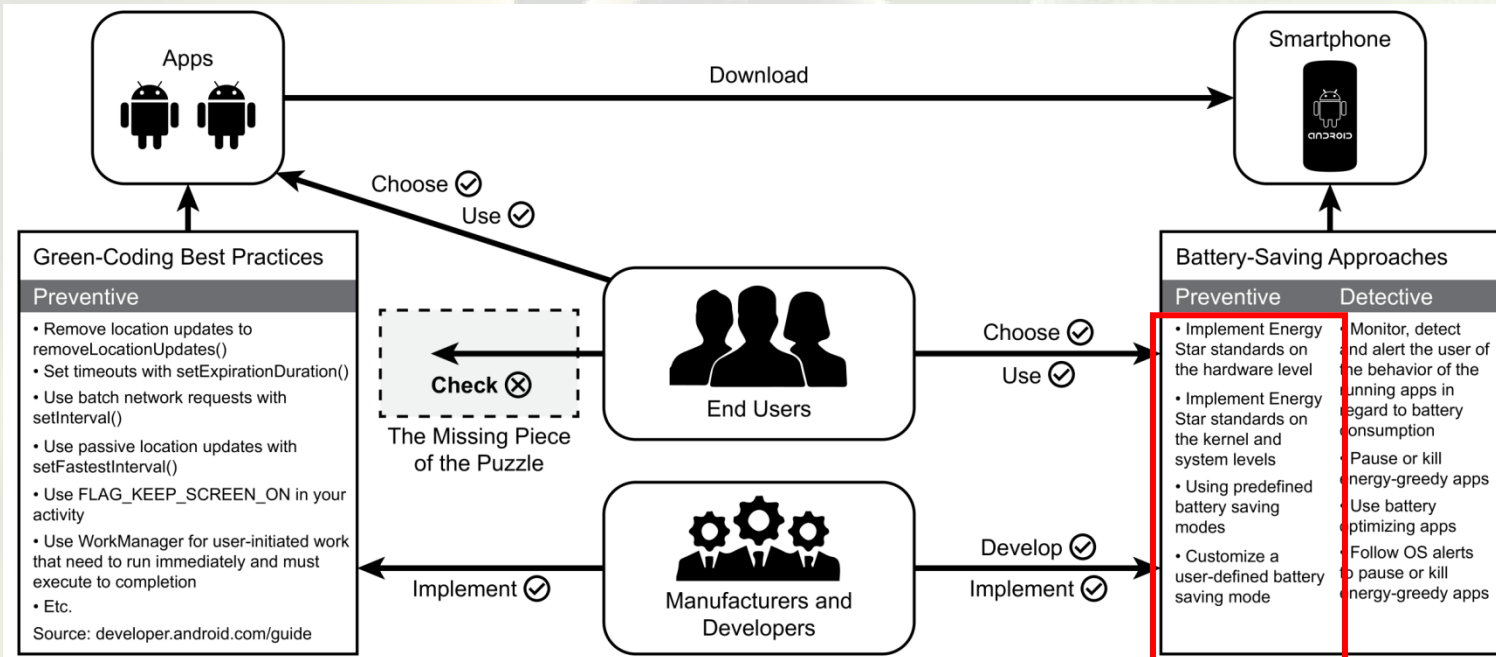
# The Missing Piece of the Puzzle



Star-rating evaluation model for rating the energy-efficiency level of android google play apps. Published In: International Journal of Electrical and Computer Engineering



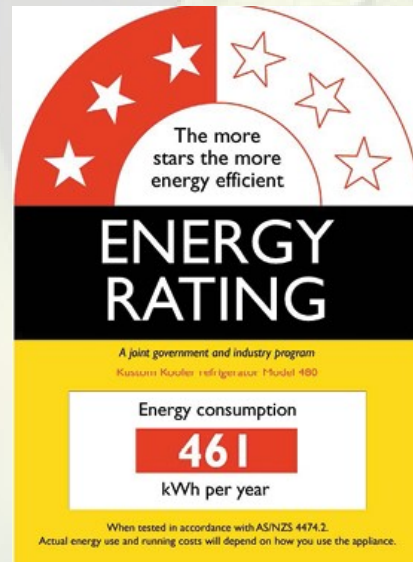
# Studying the User Acceptance Level of The Current Preventive Power-Saving Approaches



A survey implemented among a sample of more than 443 Android smartphone users got different results, which we first averaged and then classified by age groups from 16 to 60 years old.

# Proposed Solution

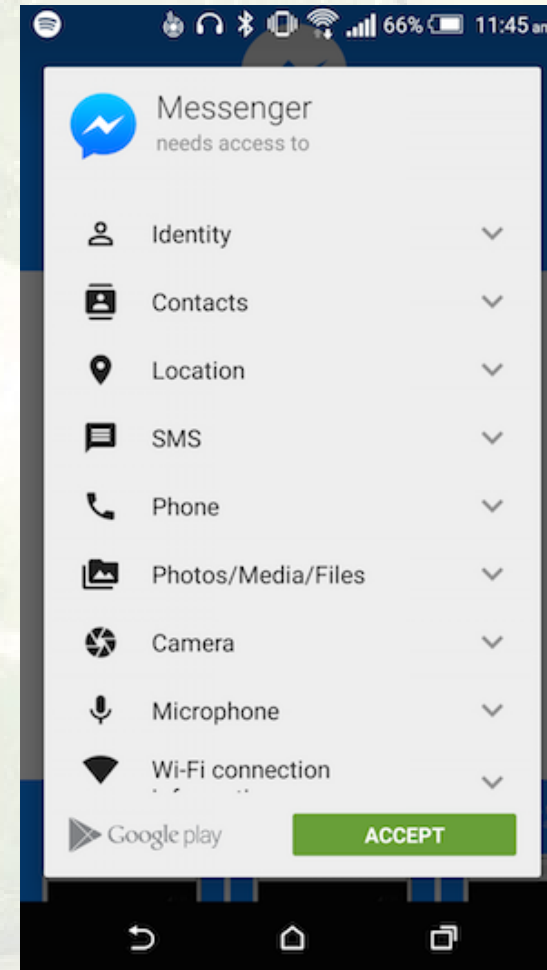
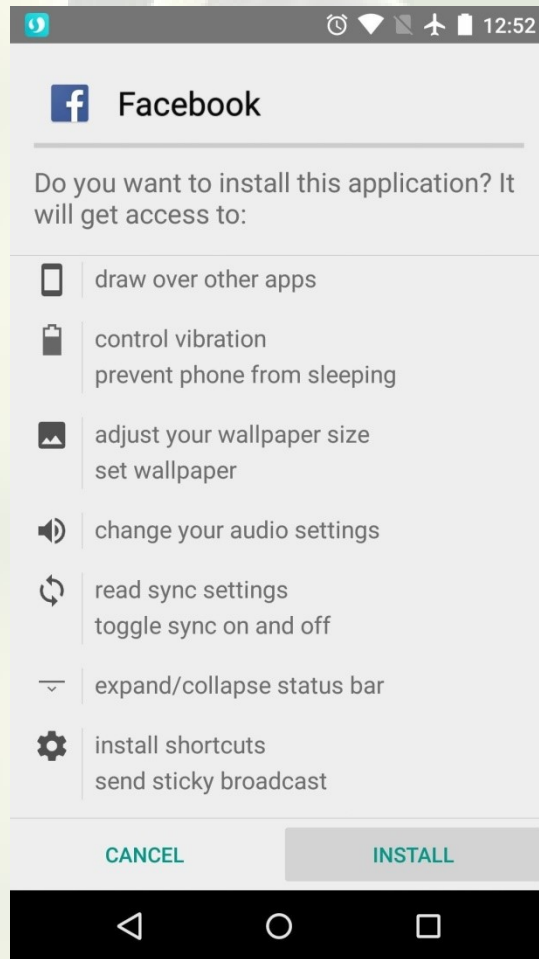
Rating Google-Play Apps' Energy Consumption on Android Smartphones



Permissions-Based Rating (Basic)

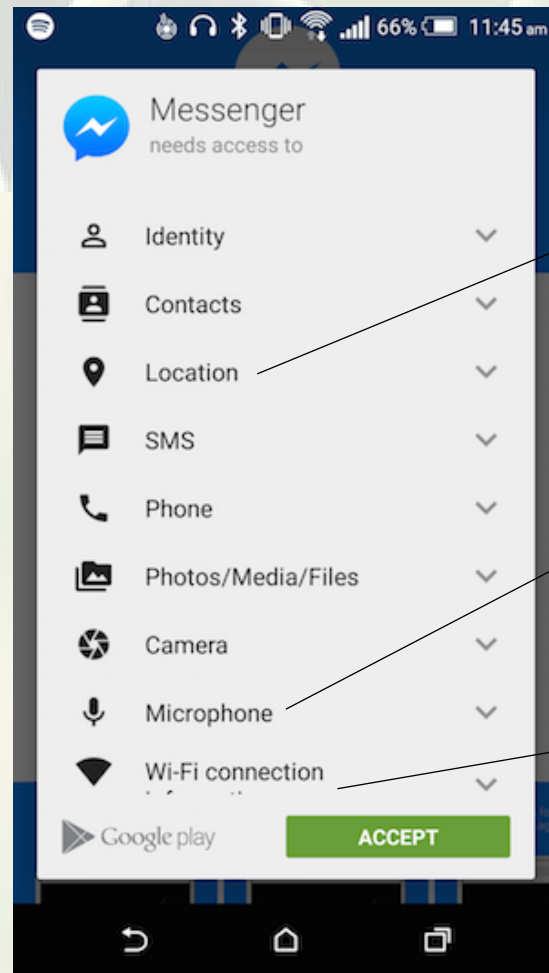
Technical Comparison Rating (Advanced)

# "Permissions" from Google Play Store (Basic)

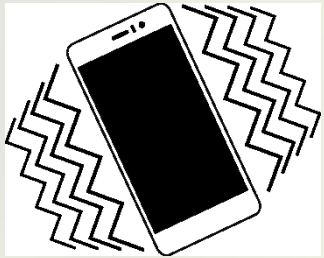




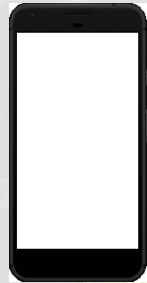
# "Permissions" in the area of power consumption (Basic)



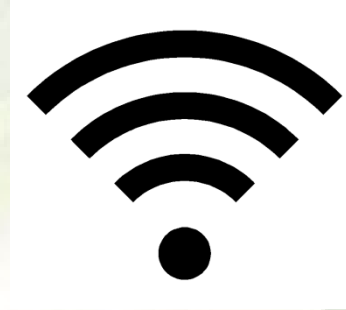
# Example of Average Smartphone Components (Basic)



Vibration Motor



Screen Light



Wi-Fi Radio



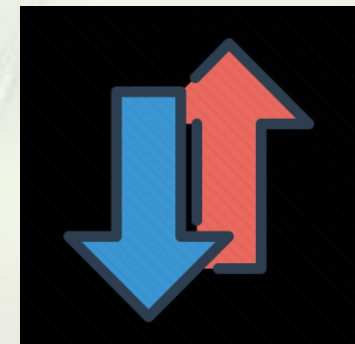
Flash Light



Speaker



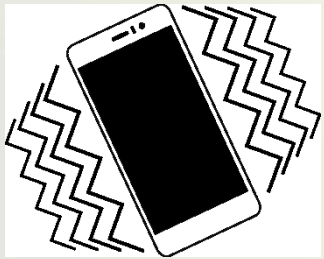
GPS Radio



Cell Data Radio

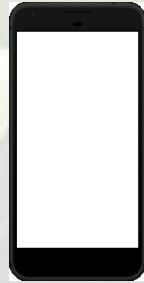
# Measuring the Amount of Energy Consumption for each Component per Minute

Smartphone Component	Capacity of the phone Battery before fully activating the component (mAh)	Capacity of the phone Battery after fully activating the component alone for a period of 60 seconds (mAh)	Average Amount of Energy Consumption measured (mAh/m)
GPS	2600	~ 2575	~ 25
Flash Light	2600	~ 2581	~ 19
Cellular Radio	2600 (Fully Charged)	~ 2583	~ 17
Cameras	2600	~ 2583	~ 17
Screen	2600	~ 2584	~ 16
Wi-Fi Radio	2600	~ 2588	~ 12
Bluetooth Radio	2600	~ 2590	~ 10



Vibration Motor

Average Amount of Energy  
Consumption (mAh/m) = ~15



Screen Light

Average Amount of Energy  
Consumption (mAh/m) = ~ 16



Wi-Fi Radio

Average Amount of Energy  
Consumption (mAh/m) = ~ 12



Flash Light

Average Amount of Energy  
Consumption (mAh/m) = ~ 19



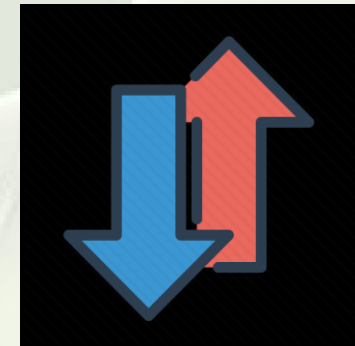
Speaker

Average Amount of Energy  
Consumption (mAh/m) = ~ 9



GPS Radio

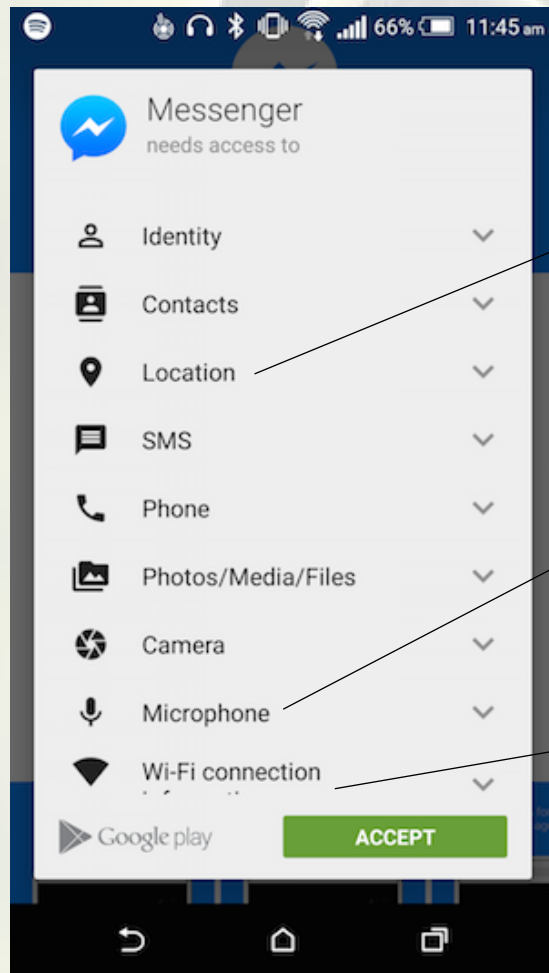
Average Amount of Energy  
Consumption (mAh/m) = ~ 25



Cell Data Radio

Average Amount of Energy  
Consumption (mAh/m) = ~ 17

# Matching App Permissions to Smartphones Components



Average Amount of Energy Consumption (mAh/m) =

~ 25

+



Average Amount of Energy Consumption (mAh/m) =

~ 9

+



Average Amount of Energy Consumption (mAh/m) =

~ 12



# Extracting Power Consuming Permissions

Smartphone Component	Capacity of the phone Battery before fully activating the component (mAh)	Capacity of the phone Battery after fully activating the component alone for a period of 60 seconds (mAh)	Average Amount of Energy Consumption measured (mAh/m)
GPS	2600	~ 2575	~ 25
Flash Light	2600	~ 2581	~ 19
Cellular Radio	2600 (Fully Charged)	~ 2583	~ 17
Cameras	2600	~ 2583	~ 17
Screen	2600	~ 2584	~ 16
Wi-Fi Radio	2600	~ 2588	~ 12
Bluetooth Radio	2600	~ 2590	~ 10

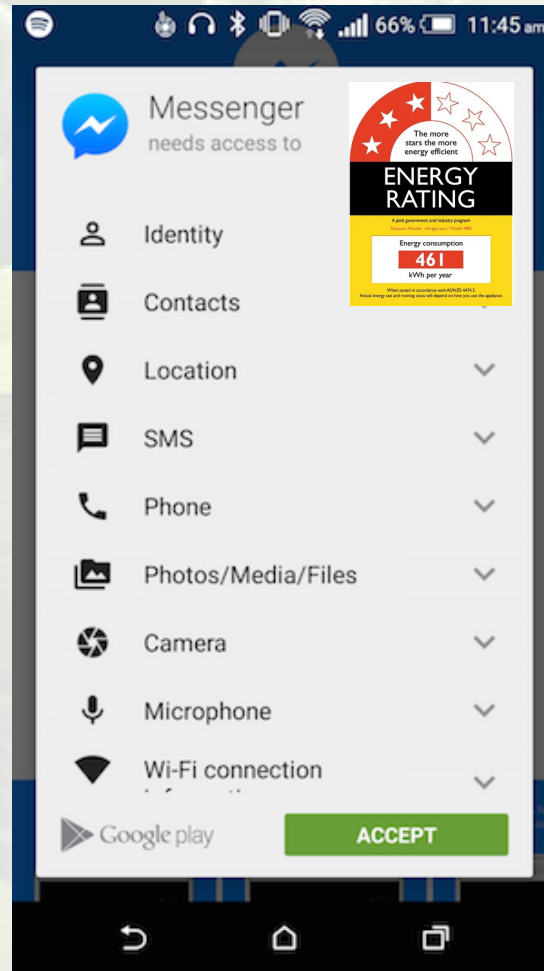
Google Play Power Consuming Applications Permissions	
<ul style="list-style-type: none"> <li>• access Bluetooth settings</li> <li>• allow Wi-Fi Multicast reception</li> <li>• Broadcast data messages to apps</li> <li>• change network connectivity</li> <li>• change system display settings</li> <li>• change your audio settings</li> <li>• change/intercept network settings and traffic</li> <li>• connect and disconnect from Wi-Fi</li> <li>• control flashlight</li> <li>• control vibration</li> <li>• directly call phone numbers</li> <li>• download files without notification</li> <li>• full network access</li> <li>• make app always run</li> </ul>	<ul style="list-style-type: none"> <li>• modify phone state</li> <li>• modify secure system settings</li> <li>• modify system settings</li> <li>• pair with Bluetooth devices</li> <li>• precise (GPS) location</li> <li>• prevent phone from sleeping</li> <li>• read your social stream</li> <li>• record audio</li> <li>• run at startup</li> <li>• send sticky broadcast</li> <li>• take pictures and videos</li> <li>• toggle sync on and off</li> <li>• view Wi-Fi connections</li> <li>• write to your social stream</li> </ul>

# Measuring the Amount of Energy Consumption for an App

Power Consuming Applications Permissions	Amount of Energy Consumption of each Used Component	Permission Average Energy Consumption Amount per minute	Permission Star Rating out of Six Stars (~ 1 to ~ 30 mAh)
access Bluetooth settings	Bluetooth Radio (~ 10 mAh)	~ 10 mAh	★★
Broadcast data messages to apps	Wi-Fi Radio (~ 12 mAh) Cellular Radio (~ 17 mAh)	~ 15 mAh	★★★
connect and disconnect from Wi-Fi	Wi-Fi Radio (~ 12 mAh)	~ 12 mAh	★★
precise (GPS) location	GPS (~ 25 mAh)	~ 25 mAh	★★★★★

Category	App	Needed Power Consuming Permissions for the App	Permissions consumption rate	Average Energy Consumption Amount per minute	Application Star Rating out of Six Stars (~ 1 to ~ 30 mAh)
Entertainment	4shared	full network access	~ 16 mAh	~ 18 mAh	★★★★★
		send sticky broadcast	~ 16 mAh		
		prevent phone from sleeping	~ 18 mAh		
		run at startup	~ 20 mAh		

# Permissions-Based App Energy-friendly Rating (Basic)





# Energy-Aware Refactoring For Apps (Advanced)

```
package imrankst1221.website.`in`.webview

import ...

class MainActivity : Activity() {
    private lateinit var mContext: Context
    internal var mLoaded = false

    // set your custom url here
    internal var URL = "https://www.infixsoft.com/"

    //for attach files
    private var mCameraPhotoPath: String? = null
    private var mFilePathCallback: ValueCallback<Array<Uri>>? = null
    internal var doubleBackToExitPressedOnce = false

    //AdView adView;
    private lateinit var btnTryAgain: Button
    private lateinit var mWebView: WebView
    private lateinit var prgs: ProgressBar
    private var viewSplash: View? = null
    private lateinit var layoutSplash: RelativeLayout
    private lateinit var layoutWebView: RelativeLayout
    private lateinit var layoutNoInternet: RelativeLayout

    @SuppressWarnings("value")
    override fun onCreate(savedInstanceState: Bundle?) {
        super.onCreate(savedInstanceState)
        setContentView(R.layout.activity_main)

        AppCompatDelegate.setCompatVectorFromResourcesEnabled(true)

        mContext = this
        mWebView = findViewById<View>(R.id.webview) as WebView
    }
}
```

Before

Energy-Aware Code Refactoring

```
package imrankst1221.website.`in`.webview

import ...

class MainActivity : Activity() {
    private lateinit var mContext: Context
    internal var mLoaded = false

    // set your custom url here
    internal var URL = "https://www.infixsoft.com/"

    //for attach files
    private var mCameraPhotoPath: String? = null
    private var mFilePathCallback: ValueCallback<Array<Uri>>? = null
    internal var doubleBackToExitPressedOnce = false

    AppCompatDelegate.setCompatVectorFromResourcesEnabled(true)

    mContext = this
    mWebView = findViewById<View>(R.id.webview) as WebView
}
```

After

# Energy-Aware Refactoring For Apps (Advanced)

Average Amount  
of Energy  
Consumption for  
running the code  
is =  $\sim 895$  mW

```
package imrankst1221.website.`in`.webview

import ...

class MainActivity : Activity() {
    private lateinit var mContext: Context
    internal var mLoaded = false

    // set your custom url here
    internal var URL = "https://www.infixsoft.com/"

    //for attach files
    private var mCameraPhotoPath: String? = null
    private var mFilePathCallback: ValueCallback<Array<Uri>>? = null
    internal var doubleBackToExitPressedOnce = false

    //AdView adView;
    private lateinit var btnTryAgain: Button
    private lateinit var mWebView: WebView
    private lateinit var prgs: ProgressBar
    private var viewSplash: View? = null
    private lateinit var layoutSplash: RelativeLayout
    private lateinit var layoutWebView: RelativeLayout
    private lateinit var layoutNoInternet: RelativeLayout

    @SuppressWarnings("unused")
    override fun onCreate(savedInstanceState: Bundle?) {
        super.onCreate(savedInstanceState)
        setContentView(R.layout.activity_main)

        AppCompatDelegate.setCompatVectorFromResourcesEnabled(true)

        mContext = this
        mWebView = findViewById<View>(R.id.webview) as WebView
    }
}
```

**Before**

Energy-Aware  
Code  
Refactoring

```
package imrankst1221.website.`in`.webview

import ...

class MainActivity : Activity() {
    private lateinit var mContext: Context
    internal var mLoaded = false

    // set your custom url here
    internal var URL = "https://www.infixsoft.com/"

    //for attach files
    private var mCameraPhotoPath: String? = null
    private var mFilePathCallback: ValueCallback<Array<Uri>>? = null
    internal var doubleBackToExitPressedOnce = false

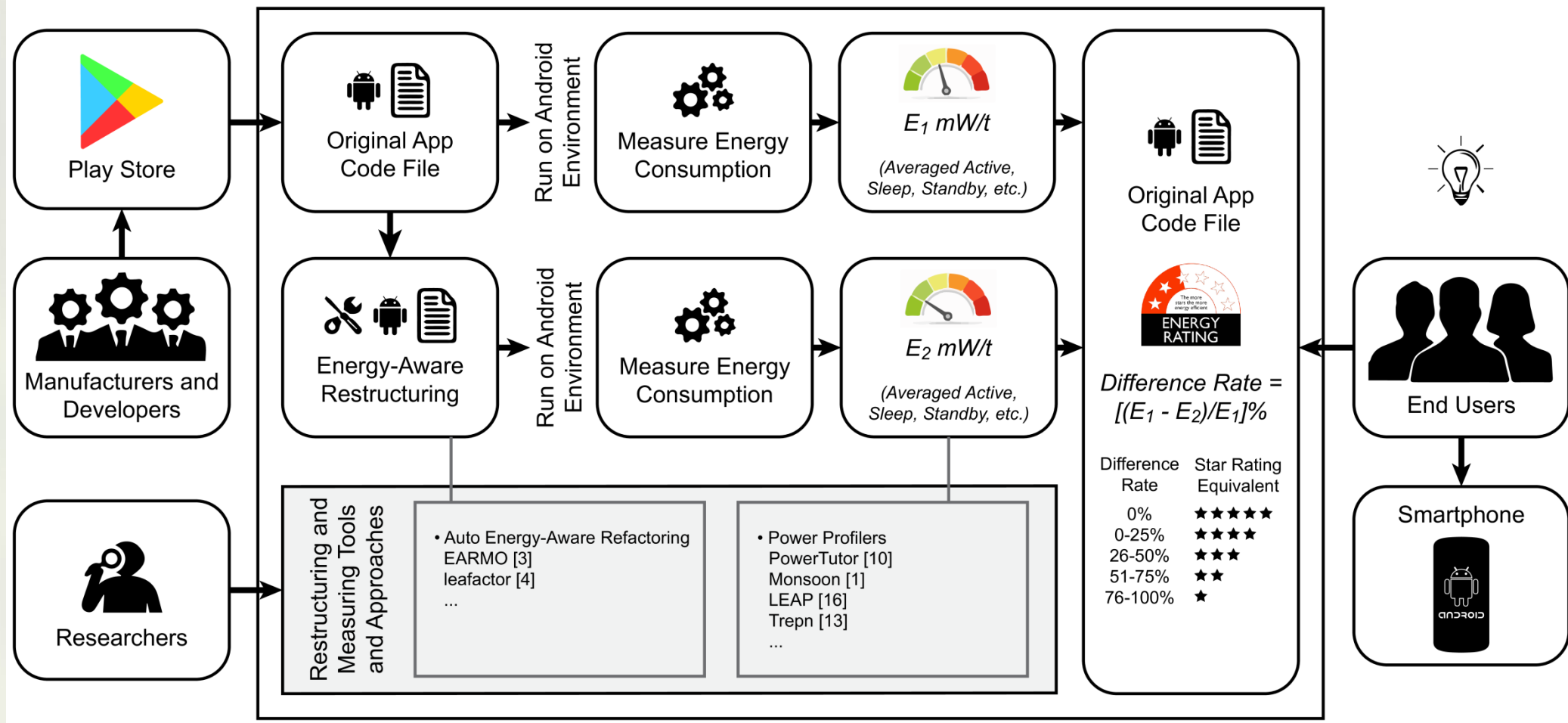
    AppCompatDelegate.setCompatVectorFromResourcesEnabled(true)

    mContext = this
    mWebView = findViewById<View>(R.id.webview) as WebView
}
}
```

**After**

Average Amount  
of Energy  
Consumption for  
running the code  
is =  $\sim 795$  mW

# Energy-Aware Refactoring For Apps (Advanced)



58% 2:12 AM

**Candy Crush Saga**  
King  
Casual #1 Top Grossing

TRY NOW INSTALL

In-app purchases

4.4 ★ 24M reviews  
500M+ Downloads

**ENERGY RATING**  
The more stars the more energy efficient.

**Candy Crush Saga**

The sweetest match 3 puzzle game! Switch and smash candies to solve the puzzles!

[Read more](#)

3:30

**Top Charts**

TOP FREE TOP PAID TOP GROSSING TOP NEW PAID

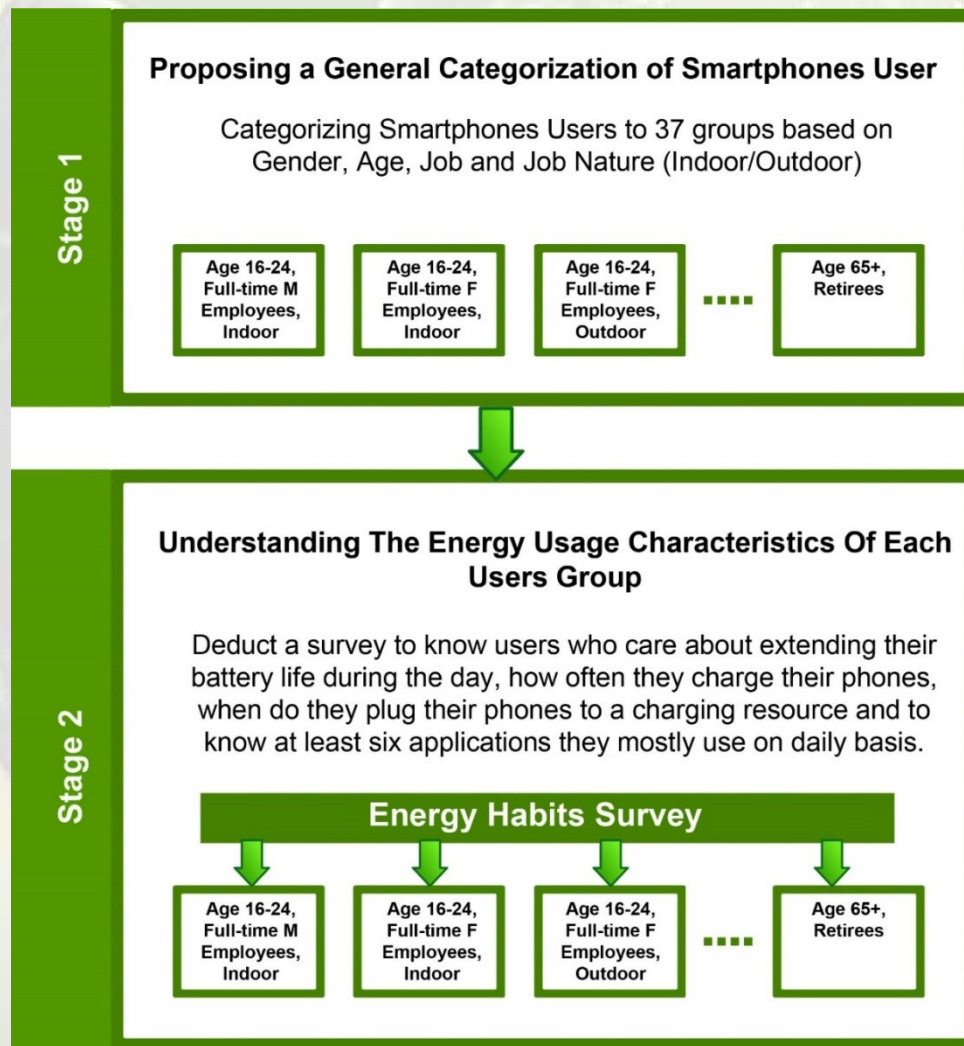
Rank	App Name	Developer	Rating	Energy Rating	Status
1.	Google Duo	Google Inc.	4.5 ★	ENERGY RATING	INSTALLED
2.	Messenger	Facebook	3.9 ★	ENERGY RATING	FREE
3.	Pokémon GO	Niantic, Inc.	4.1 ★	ENERGY RATING	INSTALLED
4.	Facebook	Facebook	4.0 ★	ENERGY RATING	INSTALLED
5.	Snapchat	Snapchat Inc.	3.9 ★	ENERGY RATING	FREE
6.	YouTube Mus	Google Inc.	4.4 ★	ENERGY RATING	

Google Play Apps Energy Rating Model: Multi-Criteria Evaluation Model to Generate Tentative Energy Ratings for Google Play Store Apps



# Simulation of Usage

Simulation Prerequisites



# Simulation of Usage

Application Category	Popularity Among Installed Apps	App Category Energy Consumption Rate /min (Averaged)	Weighted Number for each Category
Social	0.07	~ 28 mAh	1.80
Tools	0.03	~ 26 mAh	0.87
Communication	0.10	~ 27 mAh	2.60
Personalization	0.00	~ 21 mAh	0.00
Lifestyle	0.00	~ 21 mAh	0.00
Productivity	0.00	~ 21 mAh	0.00
Travel & Local	0.00	~ 20 mAh	0.0
Health & Fitness	0.07	~ 17 mAh	1.13
Business	0.00	~ 17 mAh	0.00
Music & Audio	0.10	~ 17 mAh	1.60
Photography	0.07	~ 16 mAh	1.07
Entertainment	0.17	~ 17 mAh	2.67
Media & Video	0.17	~ 17 mAh	2.67
Shopping	0.00	~ 17 mAh	0.00
Transportation	0.00	~ 15 mAh	0.0
Medical	0.00	~ 14 mAh	0.00
Books & Reference	0.07	~ 12 mAh	0.80
Weather	0.00	~ 13 mAh	0.00
News & Magazines	0.00	~ 10 mAh	0.00
Education	0.10	~ 10 mAh	1.00
Libraries & Demo	0.07	~ 4 mAh	0.27
Average Energy Consumption Amount Per Minute			~ 17 mAh

Figure 7.11: An Example of a Calculated Average Consumption Rate for “Male, Age 8-16, Full-time Students” User Group

# Simulation of Usage

Users Age Range	Smartphone User Category	User Group	Average Energy Consumption Amount /min	User Group Rank
8 to 16	Full-time Students		~ 17.27 mAh	6
16 to 24	Full-time Students		~ 17.27 mAh	6
	Part-time employees	Indoor	~ 16.64 mAh	8
		Outdoor	~ 18.19 mAh	5
	Full-time Employees	Indoor	~ 17.19 mAh	7
Outdoor		~ 19.22 mAh	2	
25 to 34	Part-time students		~ 15.98 mAh	12
	Full-time employees	Indoor	~ 15.63 mAh	14
		Outdoor	~ 18.28 mAh	4
	Businessmen		~ 16.57 mAh	10
35 to 64	Part-time students		~ 14.59 mAh	16
	Full-time employees	Indoor	~ 16.33 mAh	11
		Outdoor	~ 19.37 mAh	1
	Businessmen		~ 16.60 mAh	9
	Part-time employees	Indoor	~ 15.96 mAh	13
Outdoor		~ 18.45 mAh	3	
65+	Retirees		~ 14.66 mAh	15
Male Users Average Consumption Amount per minute			~ 16.89 mAh	

Figure 7.12: Amount of energy consumption for each group from the proposed male users groups and the ranking of each group.

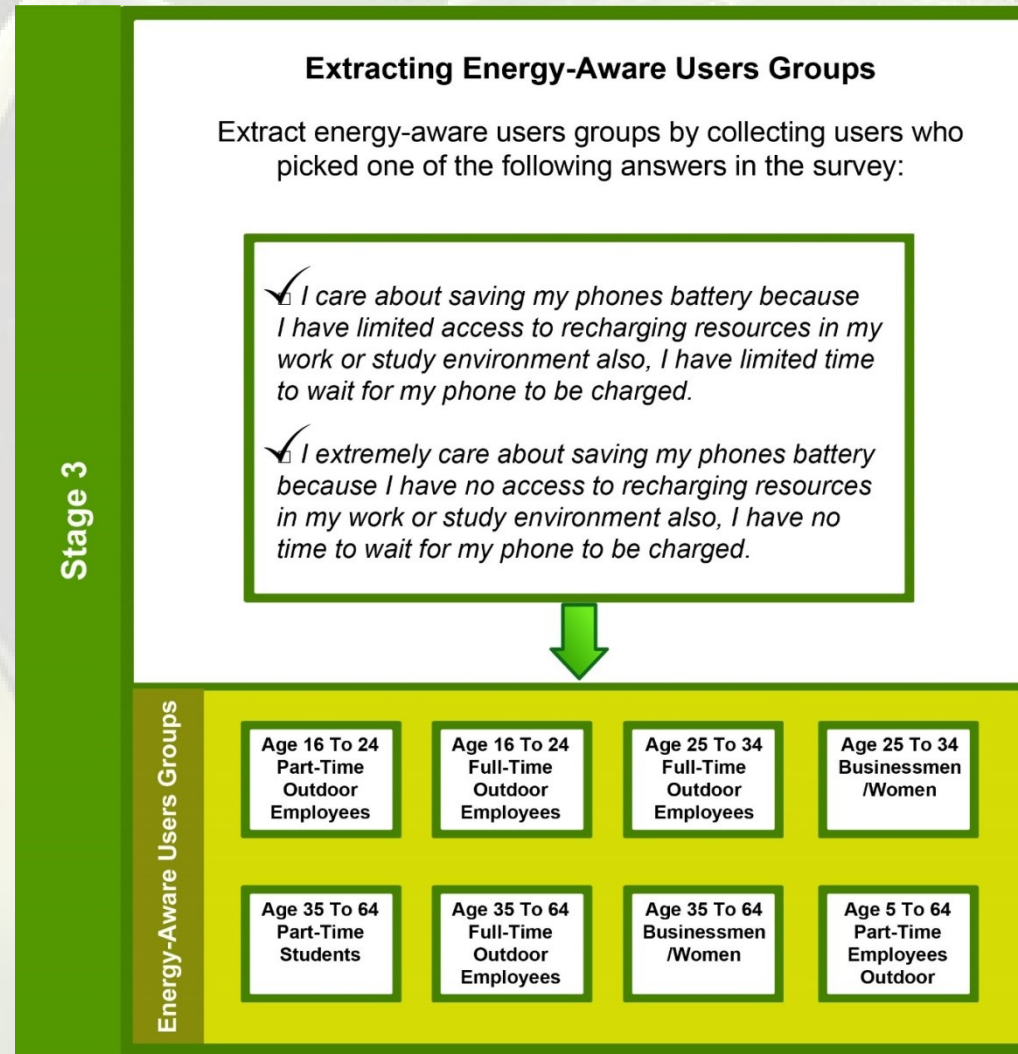
# Simulation of Usage

Users Age Range	Smartphone User Category		User Group Average Energy Consumption Amount /min	User Group Rank
8 to 16	Full-time Students		~ 17.50 mAh	10
16 to 24	Full-time Students		~ 17.60 mAh	9
	Part-time employees	Indoor	~ 16.88 mAh	14
		Outdoor	~ 18.28 mAh	4
	Full-time Employees	Indoor	~ 16.56 mAh	15
Outdoor		~ 18.85 mAh	1	
25 to 34	Part-time students		~ 16.28 mAh	16
	Full-time employees	Indoor	~ 17.29 mAh	11
		Outdoor	~ 18.19 mAh	5
	Business women		~ 16.94 mAh	13
	Housewives		~ 17.89 mAh	7
35 to 64	Part-time students		~ 17.89 mAh	7
	Full-time employees	Indoor	~ 14.73 mAh	19
		Outdoor	~ 18.78 mAh	2
	Business women		~ 18.30 mAh	3
	Housewives		~ 17.14 mAh	12
	Part-time employees	Indoor	~ 16.00 mAh	17
Outdoor		~ 18.08 mAh	6	
65+	Housewives		~ 14.98 mAh	18
	Retirees		~ 17.88 mAh	8
Female Users Average Consumption Amount per minute			~ 17.30 mAh	

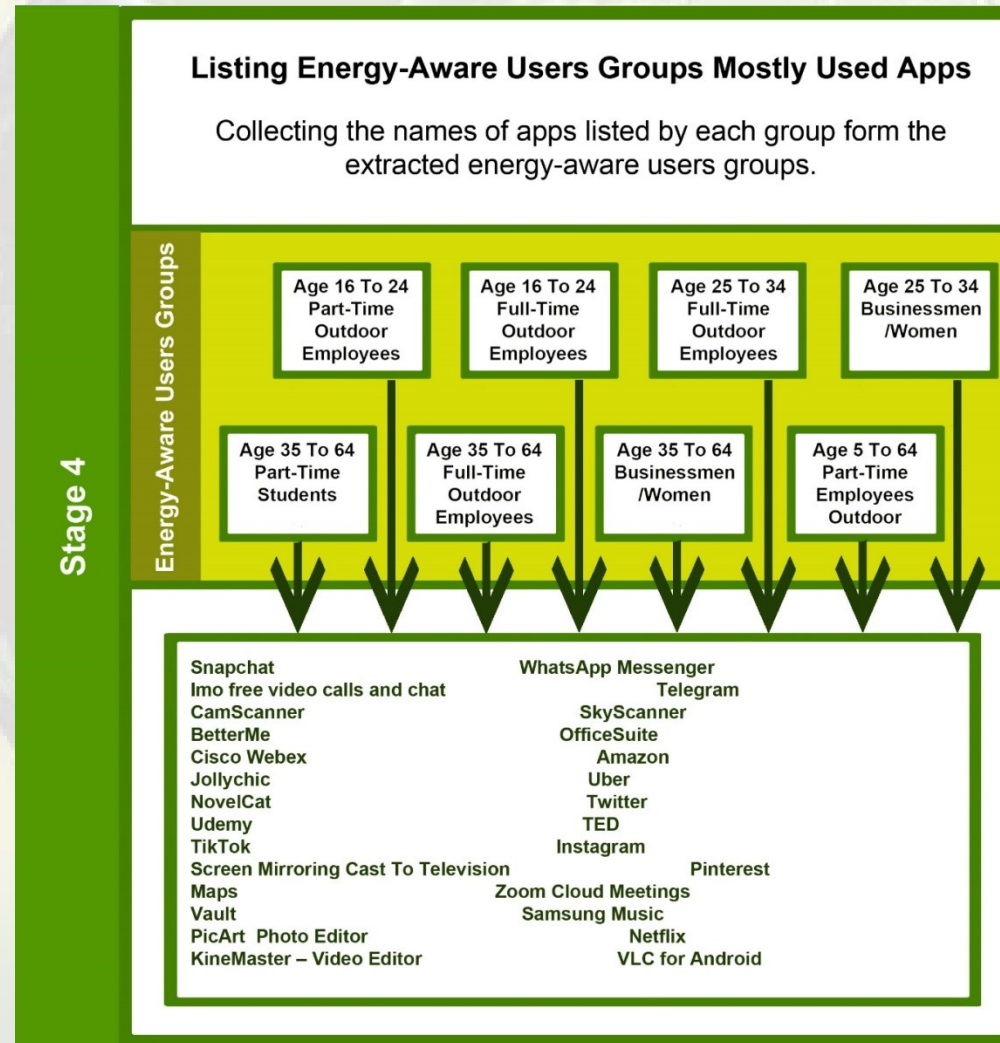
Figure 7.13: Amount of energy consumption for each category from the proposed groups of female users and the ranking of each group



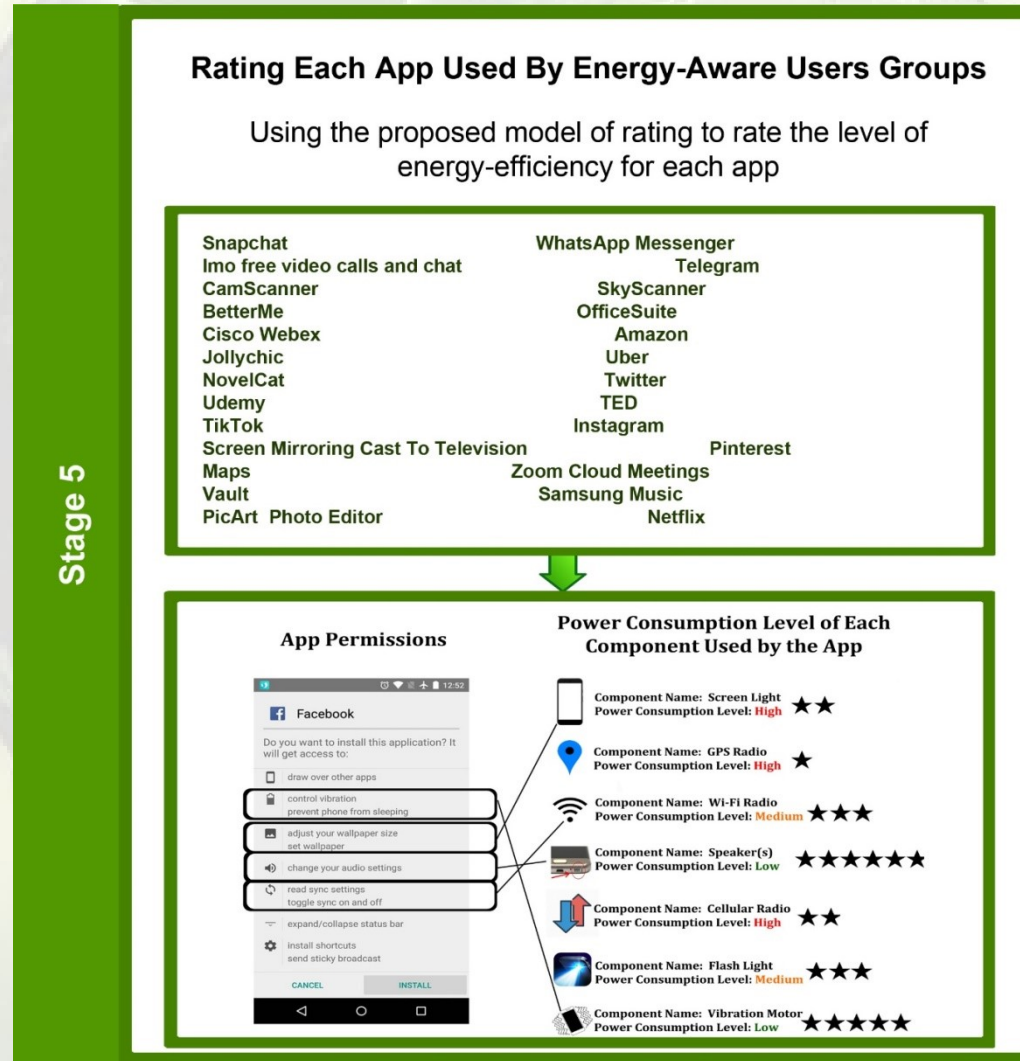
# Simulation of Usage



# Simulation of Usage



# Simulation of Usage



# Simulation of Usage

## Proposing alternative apps for power-hungry apps used by Energy-Aware Users Groups

Proposing alternative applications based on the shared features and less required power-hungry permissions of each app.

Stage 6

### Example of Used Energy-Hungry App

The screenshot shows the app page for 'BetterMe: Home Workouts & Diet'. The app has a 4.2 star rating, 78k reviews, and is 13 MB in size. It is categorized under Health & Fitness. The 'About this app' section lists features like 'Weight Loss Workout: Abs, Butt, Legs and Whole 30 Diet: Keto, Vegetarian Fasting'. The 'Ratings and reviews' section shows a 4.2 star rating.

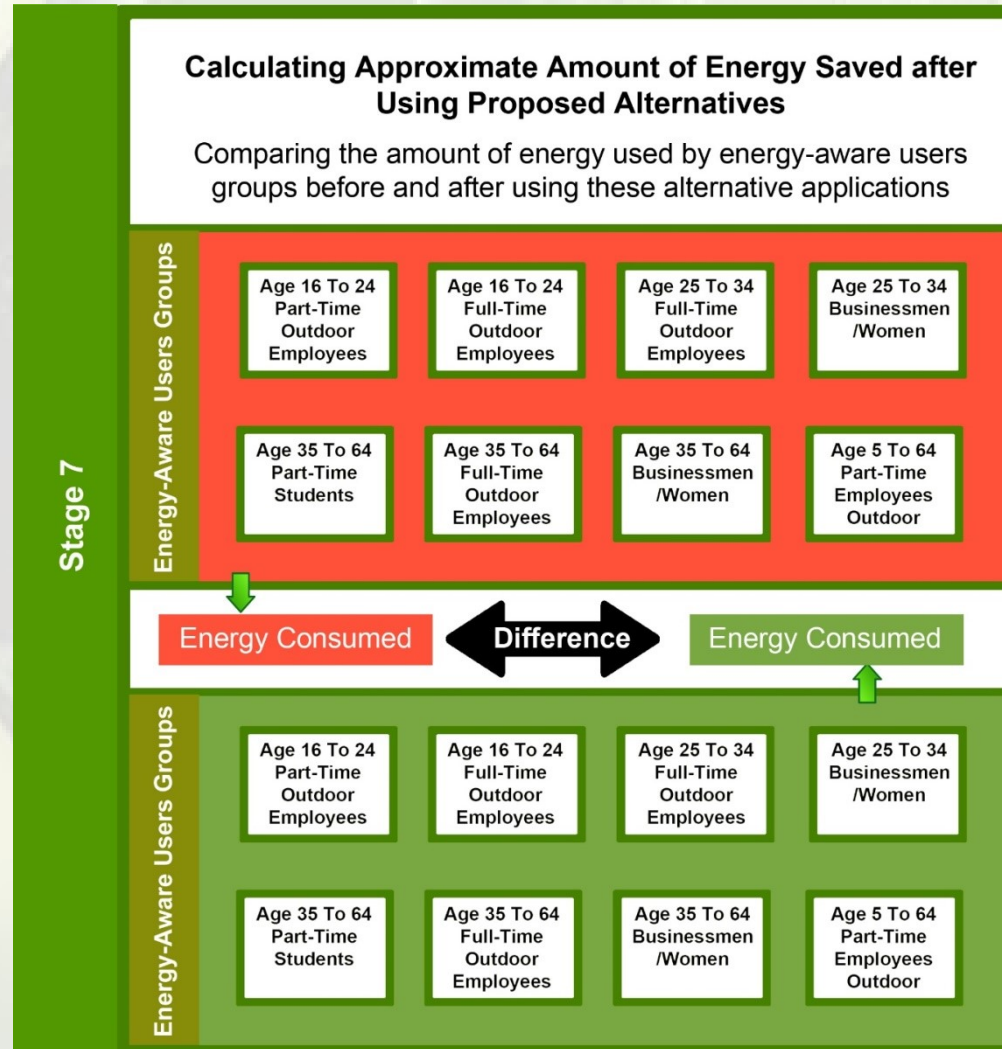
The screenshot shows the 'App permissions' page for 'BetterMe: Home Workouts & Diet'. It lists permissions under 'Camera' (take pictures and videos) and 'Other'. The 'Other' permissions include: run foreground service, control vibration, Google Play billing service, run at startup, have full network access, view network connections, prevent phone from sleeping, Play install Referrer API, view Wi-Fi connections, recognize physical activity, receive data from Internet, and activity recognition.

### Example of Alternative Energy-Efficient App

The screenshot shows the app page for 'BodBot Personal Trainer: Workout & Fitness Coach'. The app has a 4.6 star rating, 24k reviews, and is 36 MB in size. It is categorized under Health & Fitness. The 'About this app' section describes it as 'The most advanced fitness platform ever: intelligent, adaptive workout planning'. The 'Ratings and reviews' section shows a 4.6 star rating.

The screenshot shows the 'App permissions' page for 'BodBot Personal Trainer: Workout & Fitness Coach'. It lists permissions under 'Other'. The 'Other' permissions include: have full network access, view network connections, control vibration, prevent phone from sleeping, Play install Referrer API, Google Play billing service, run at startup, and receive data from Internet.

# Simulation of Usage



# Findings

Users Age Range	Smartphone User Category		User Group Average Energy Consumption Amount per minute	User Group Average Energy Consumption Amount Per Minute After Using the Alternative Apps	Percentage of Saved Energy
16 to 24	Part-time employees	Outdoor	~ 18.19 mAh	~ 16.10 mAh	<b>11%</b>
	Full-time Employees	Outdoor	~ 19.22 mAh	~ 16.15 mAh	<b>16%</b>
25 to 34	Full-time employees	Outdoor	~ 18.28 mAh	~ 17.19 mAh	<b>6%</b>
	Businessmen / women		~ 16.57 mAh	~ 15.19 mAh	<b>8%</b>
35 to 64	Part-time students		~ 14.59 mAh	~ 11.19 mAh	<b>23%</b>
	Full-time employees	Outdoor	~ 19.37 mAh	~ 17.11 mAh	<b>12%</b>
	Businessmen / women		~ 16.60 mAh	~ 15.19 mAh	<b>8%</b>
	Part-time employees	Outdoor	~ 18.45 mAh	~ 14.19 mAh	<b>23%</b>

Percentage of Saved Energy among Users Groups That Pays High Level of Attention towards Their Phone Battery Level





Thank You

Obrigado

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