

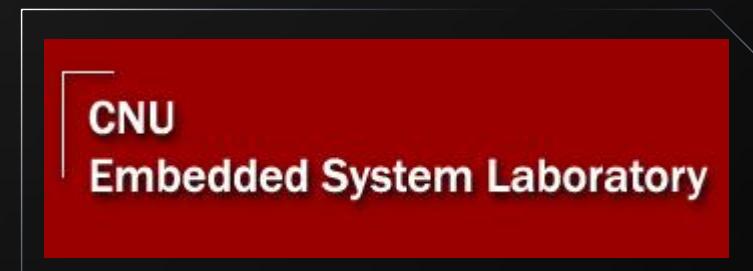
Smart Phone Power Model Generation using User Pattern Analysis

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Chungnam National University, Korea



2012 ICCE
2012.1.15 in Las Vegas



<http://eslab.cnu.ac.kr>

Motivation

Solution

Power Model

Environment

Experiment

Conclusion

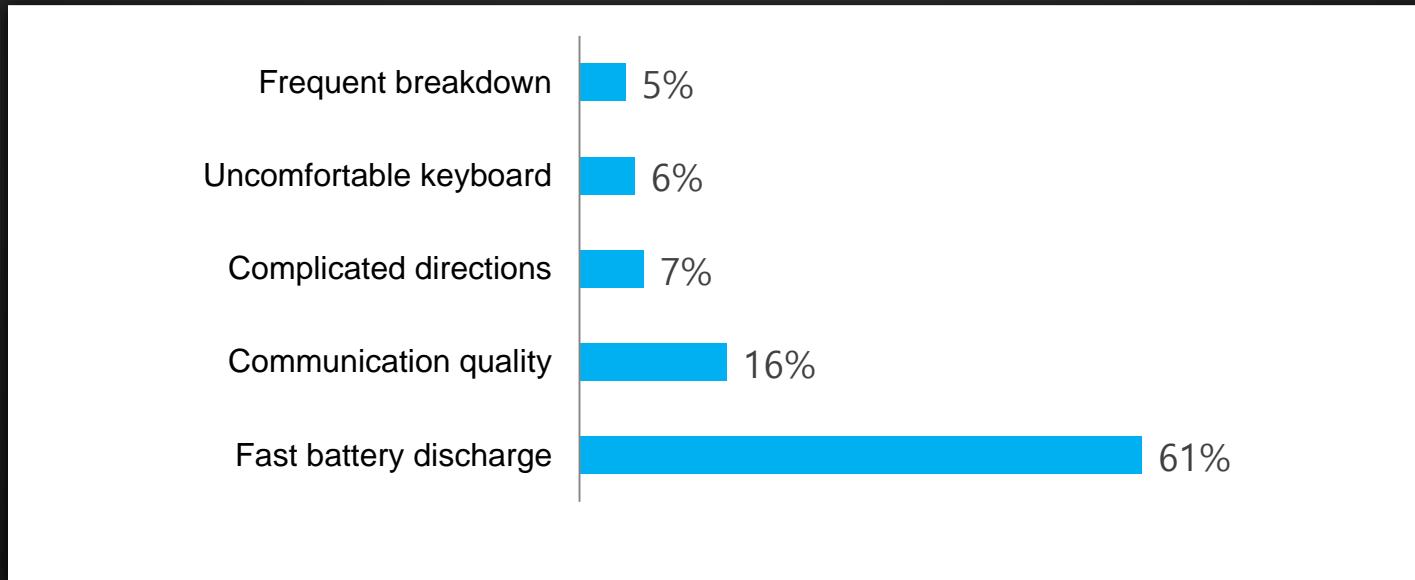
What is the most nerve-wracking concern in your **smart phone** ?



WebSite AppStore : a field study (2860 users)

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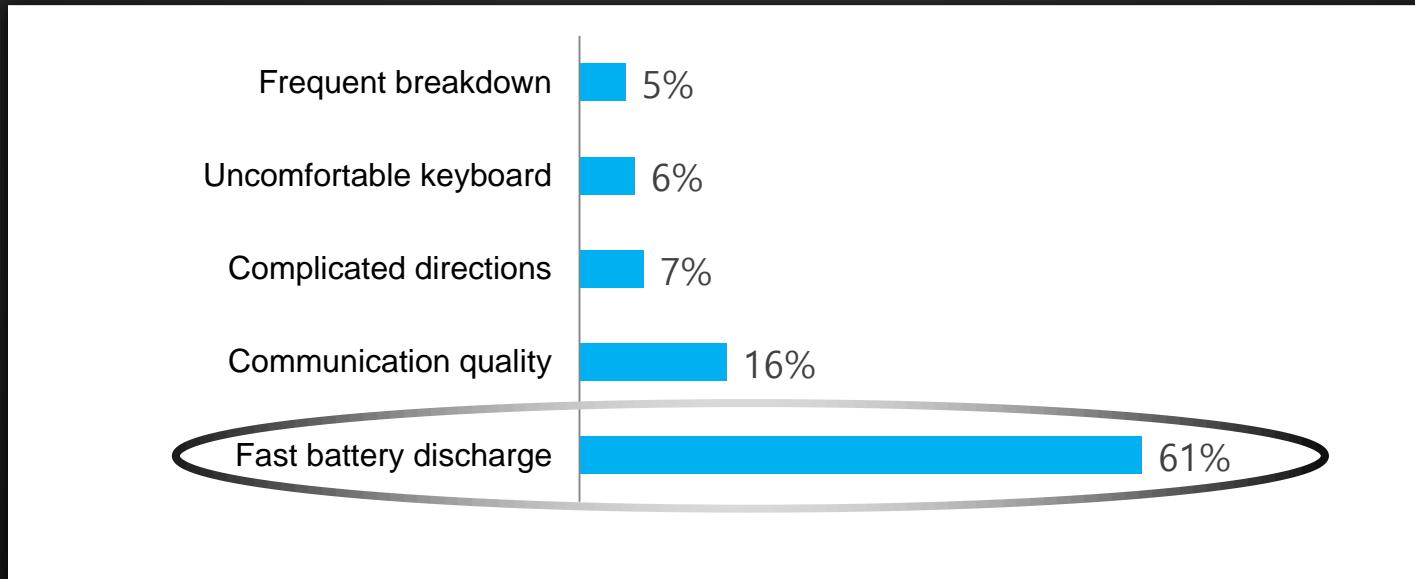
The Inconvenience in using Smart Phones



WebSite AppStore : a field study (2860 users)

What is the most nerve-wracking concern in your **smart phone** ?

The Inconvenience in using Smart Phones



WebSite AppStore : a field study (2860 users)

The biggest complaint is Fast battery discharge.

Solution for Fast Battery Discharge problem ?



Need for power consumption analysis

In order to solve fast battery discharge problem,
power consumption must be analyzed.

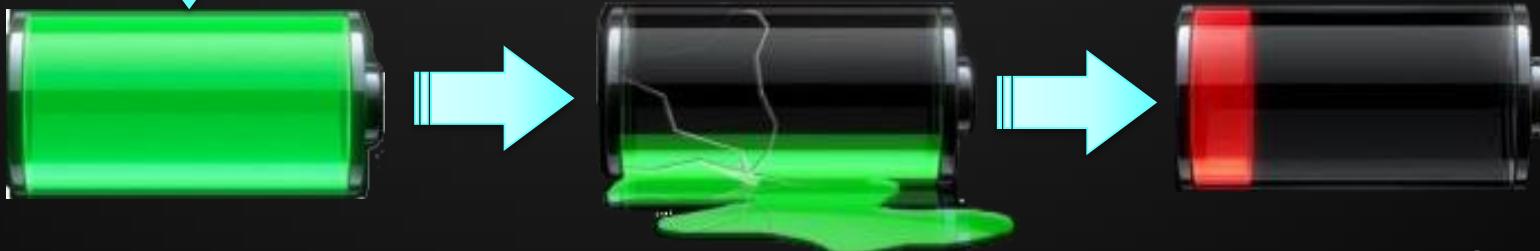
Solution for Fast Battery Discharge problem ?



Need for power consumption analysis

In order to solve fast battery discharge problem,
power consumption must be analyzed.

Requires visibility into where energy is being
consumed



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Two options for Power Consumption Measurement :

Two options for Power Consumption Measurement : First, direct measurement



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Manual measurements using external hardware equipment _

Very accurate measurement can be achieved.

The external equipment need to be installed.

Measurement setup is complicated and entangled.

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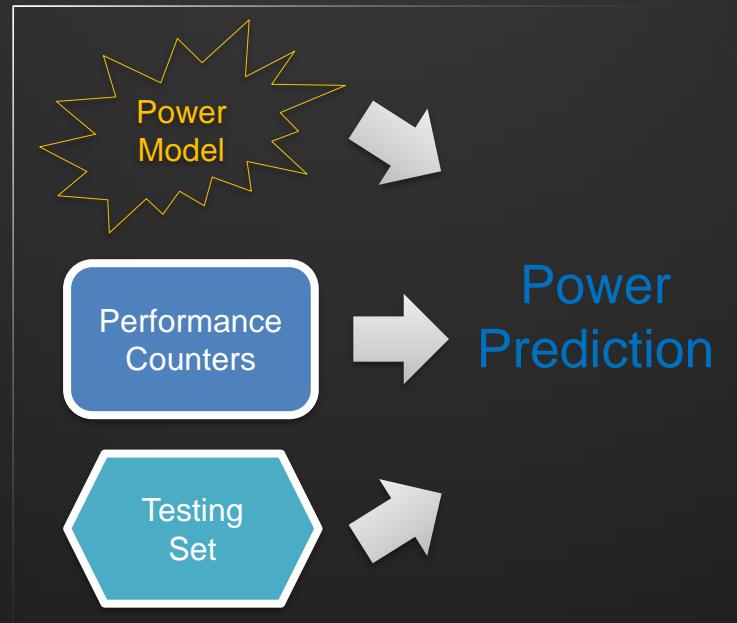
Two options for Power Consumption Measurement : Second. indirect measurement

High complexity

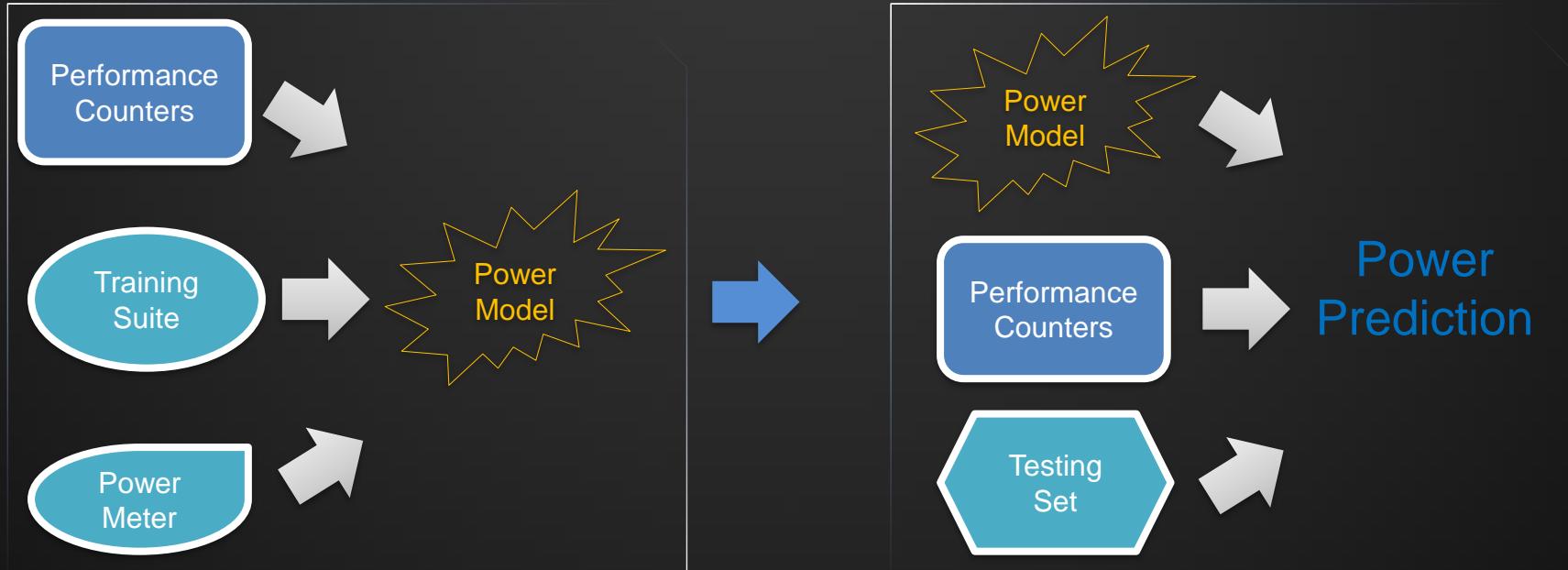


Two options for Power Consumption Measurement : Second, indirect measurement

Low complexity



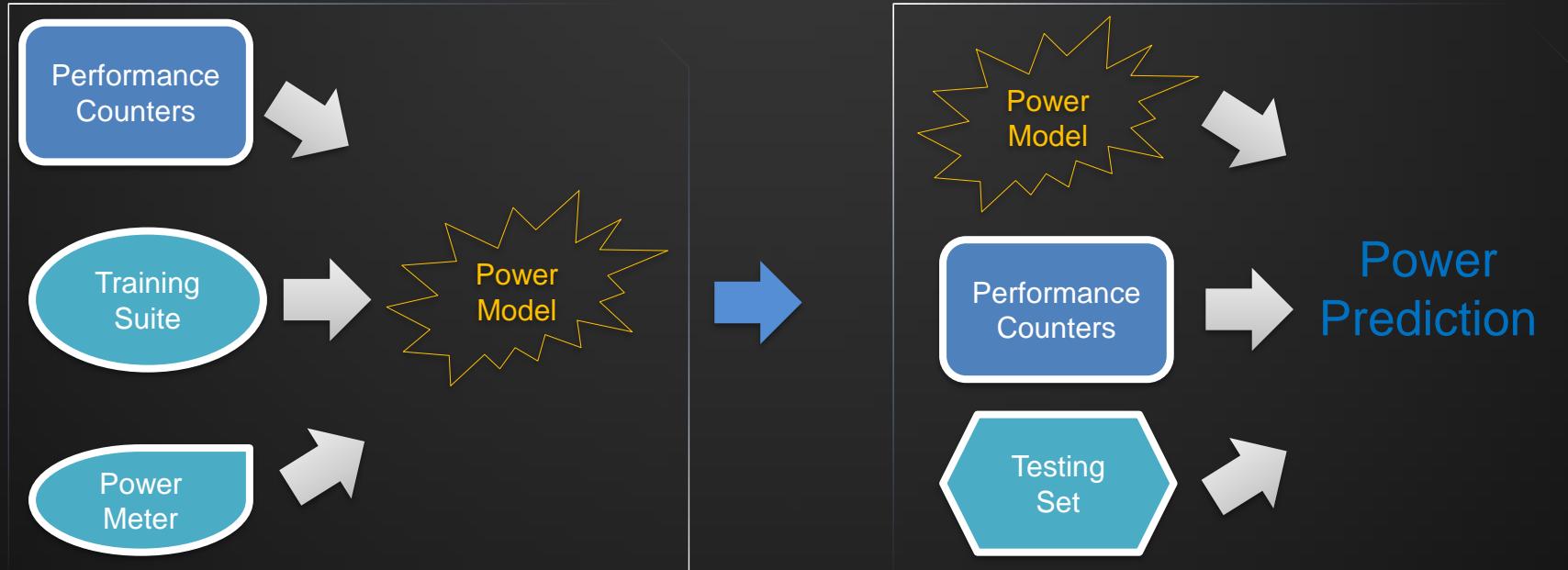
Two options for Power Consumption Measurement : Second, indirect measurement



Manually generate power model_

In order to generate a power model, the following three tools are necessary.

Two options for Power Consumption Measurement : Second, indirect measurement

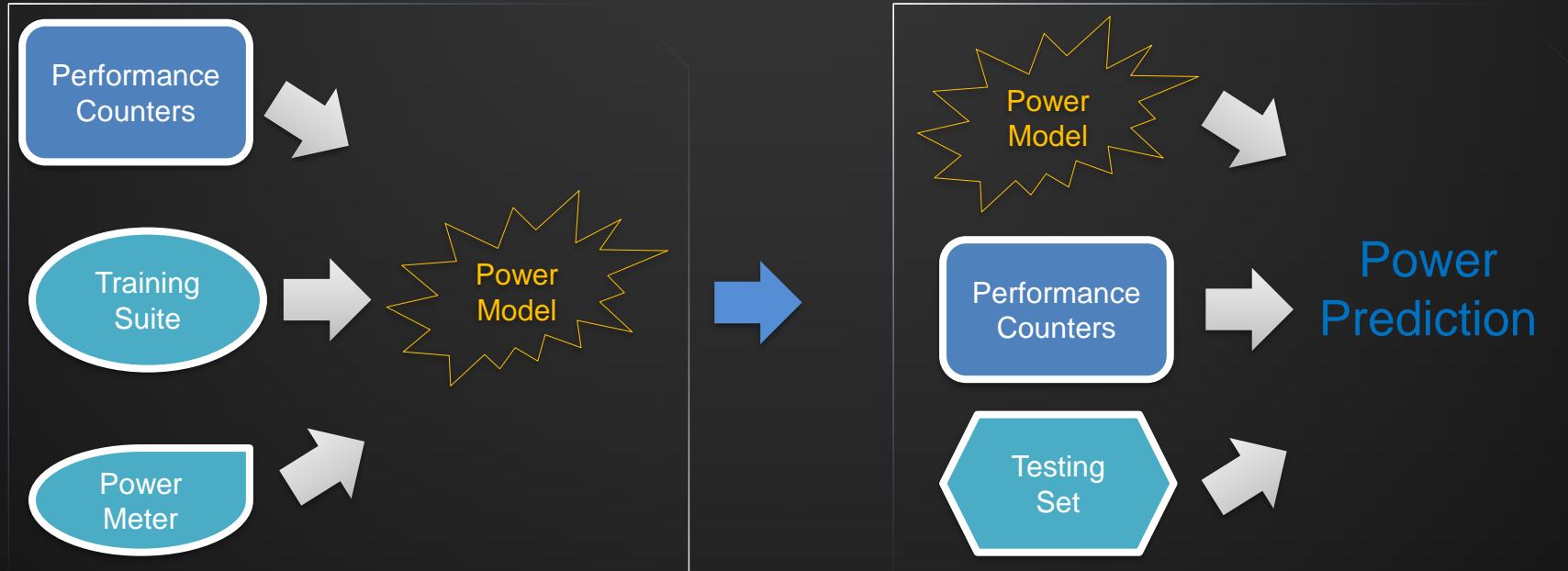


Manually generate power model_

In order to generate a power model, the following three tools are necessary.

- ✓ **Performance Counter** : to store the counts of hardware-related activities within computer systems

Two options for Power Consumption Measurement : Second, indirect measurement

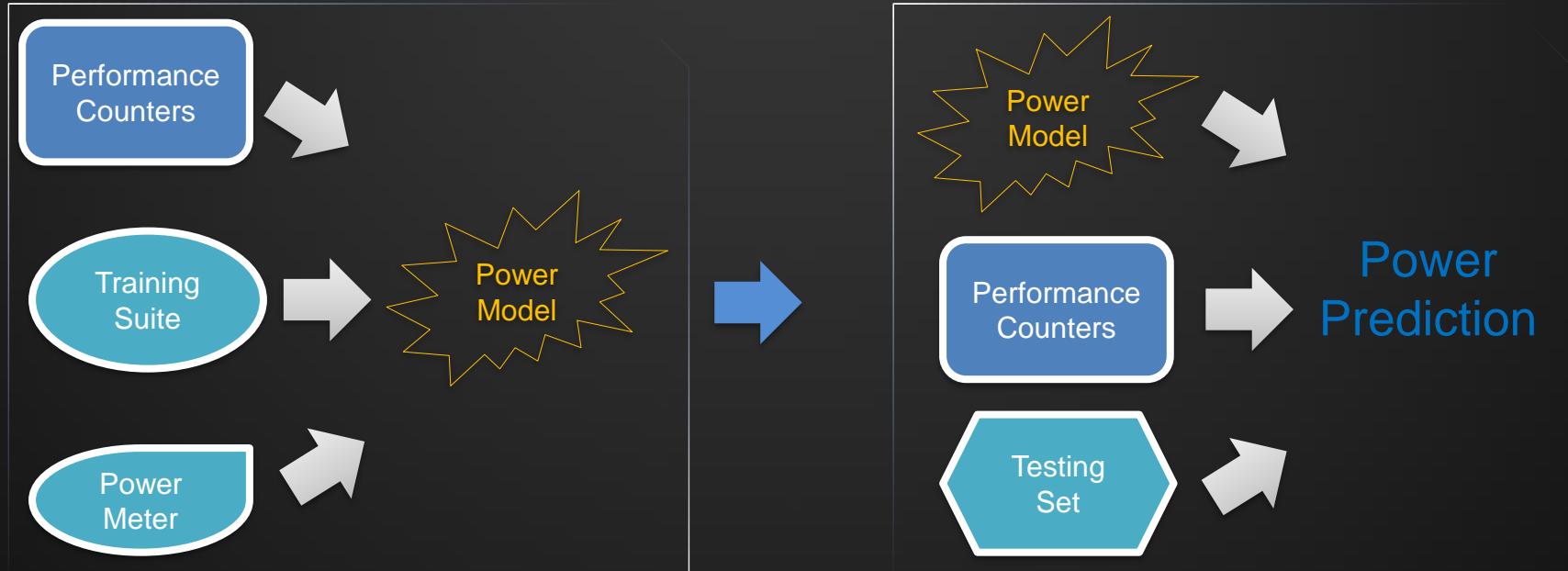


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In order to generate a power model, the following three tools are necessary.

- ✓ **Performance Counter** : to store the counts of hardware-related activities within computer systems
- ✓ **Training Suite** : program for keeping one power state

Two options for Power Consumption Measurement : Second, indirect measurement

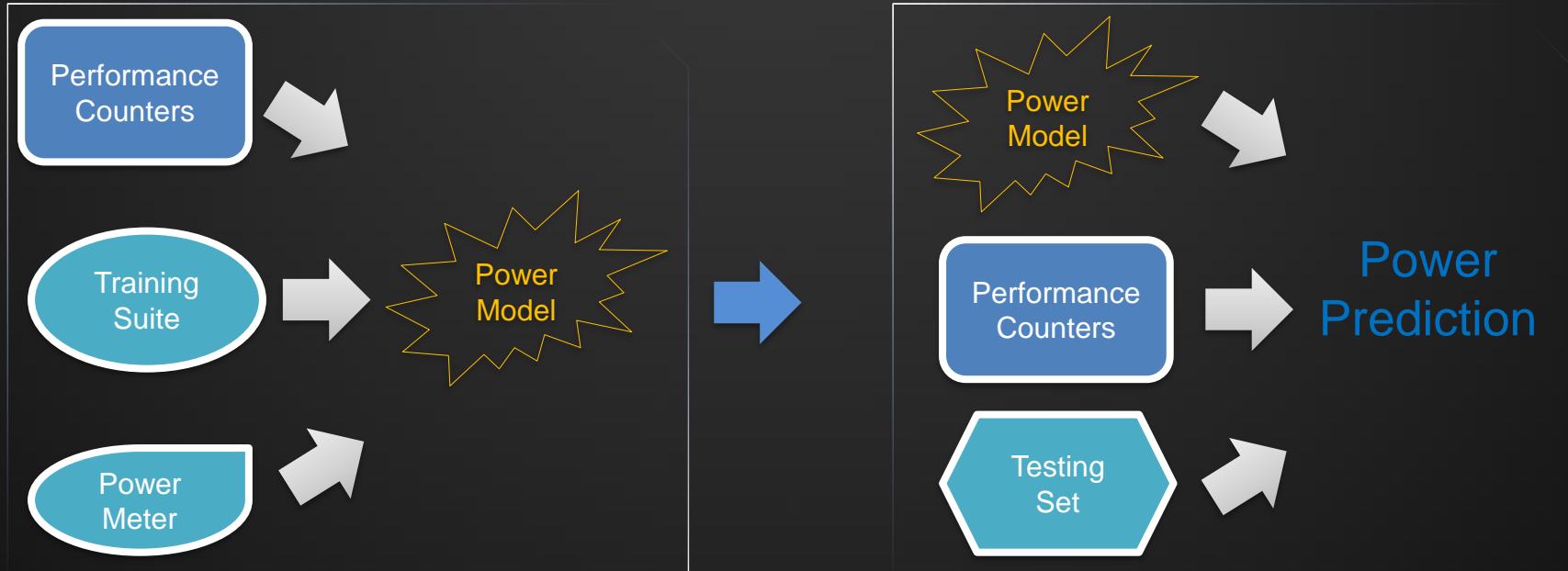


Manually generate power model_

In order to generate a power model, the following three tools are necessary.

- ✓ **Performance Counter** : to store the counts of hardware-related activities within computer systems
- ✓ **Training Suite** : program for keeping one power state
- ✓ **Power Meter** : external device for measuring power consumption

Two options for Power Consumption Measurement : Second, indirect measurement



This type of manually generated power model is accurate only for one type of smart phone.

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Why Do We Need an Automatic Power Model ?

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Smart Phone is very Diverse.

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Power Models are different in every Smart Phone.[L. Zhang, 2010]
Thus, we need to generate a new power model for every phone.

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Therefore, we need a way to automatically generate power models.

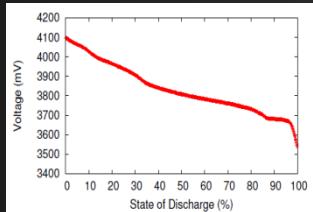
Automatic Power Model Generation : Current State-of-the-Art [L. Zhang, 2010 CODE/ISS]

This technique relies only on knowledge of the battery discharge curve and access to a battery voltage sensor

This technique requires training software to control phone component power and activity states.

But it has two limitations(1 and 2 in the figure)

Automatic Power Model Generation : Current State-of-the-Art [L. Zhang, 2010 CODE/ISS]



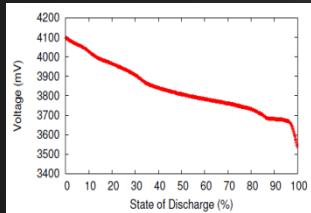
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Determined using
the built-in battery
voltage sensor

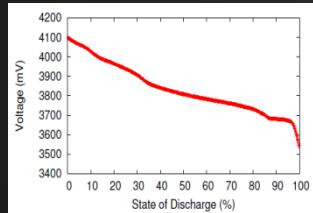
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battery
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Training
Software



Power
Model

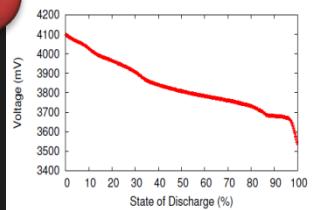
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battery
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Training
Software



Power
Model

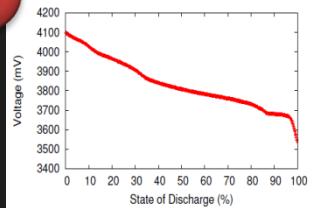
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Training
Software



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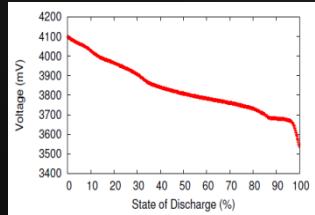
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Research Objectives

This research suggests more feasible automatic method from the use pattern than previous automatic methods.

Two advantages more than previous automatic methods.



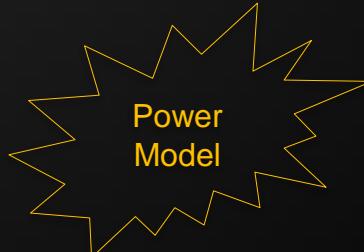
battery
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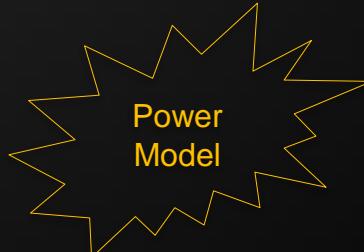
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Training
Software



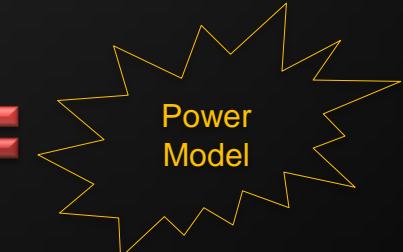
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Our automatic power model generation method

Our automatic power model generation method

I. Using Android system-provided data.

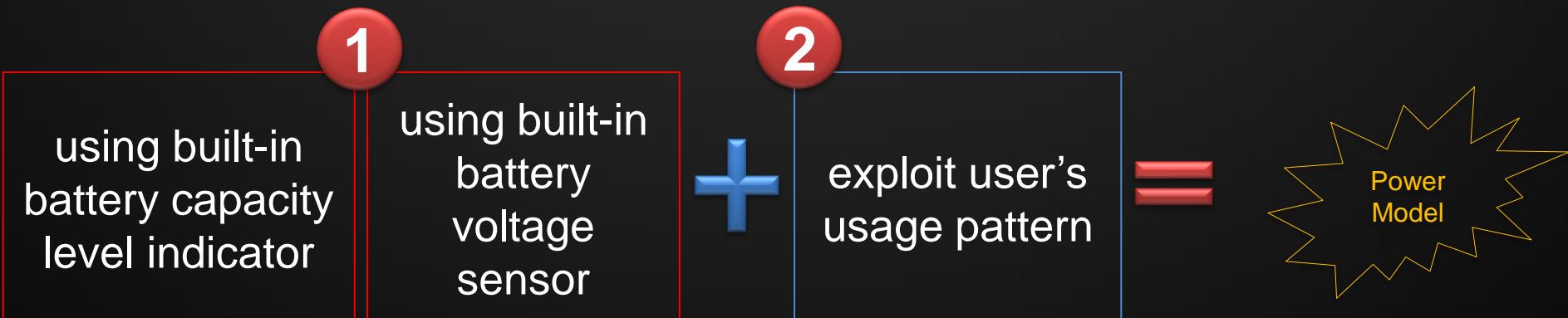
1

using built-in
battery capacity
level indicator

using built-in
battery
voltage
sensor

Our automatic power model generation method

- I. Using Android system-provided data.
- II. logged activity and power consumption data.



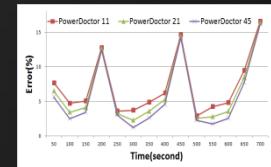
What we did

1. We propose new automatic power model generation method based on use pattern analysis



Power Doctor

2. We developed Android application named PowerDoctor.
Collect valid patterns and compute power model



3. Verify the accuracy of power models.
Compare with the power model from prior project.



VS



Power Doctor
Model

Power Tutor
Model

4. Verify the feasibility of this research.
Power Model generation of HTC Nexus one and HTC Desire

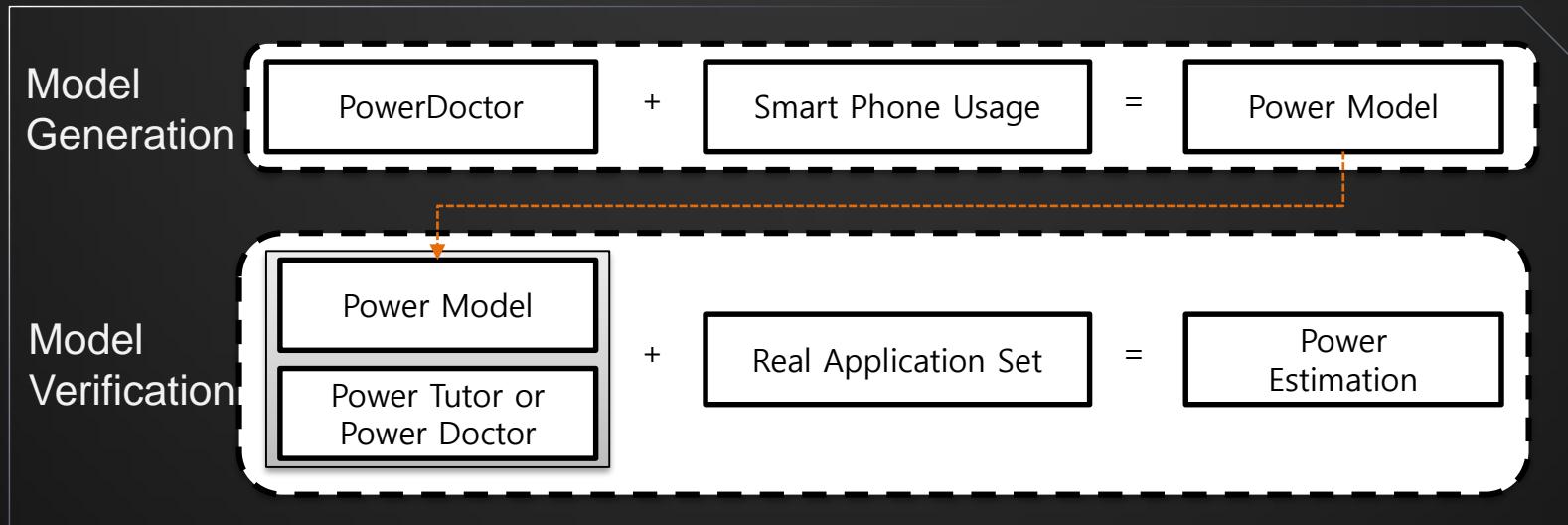


HTC Nexus one

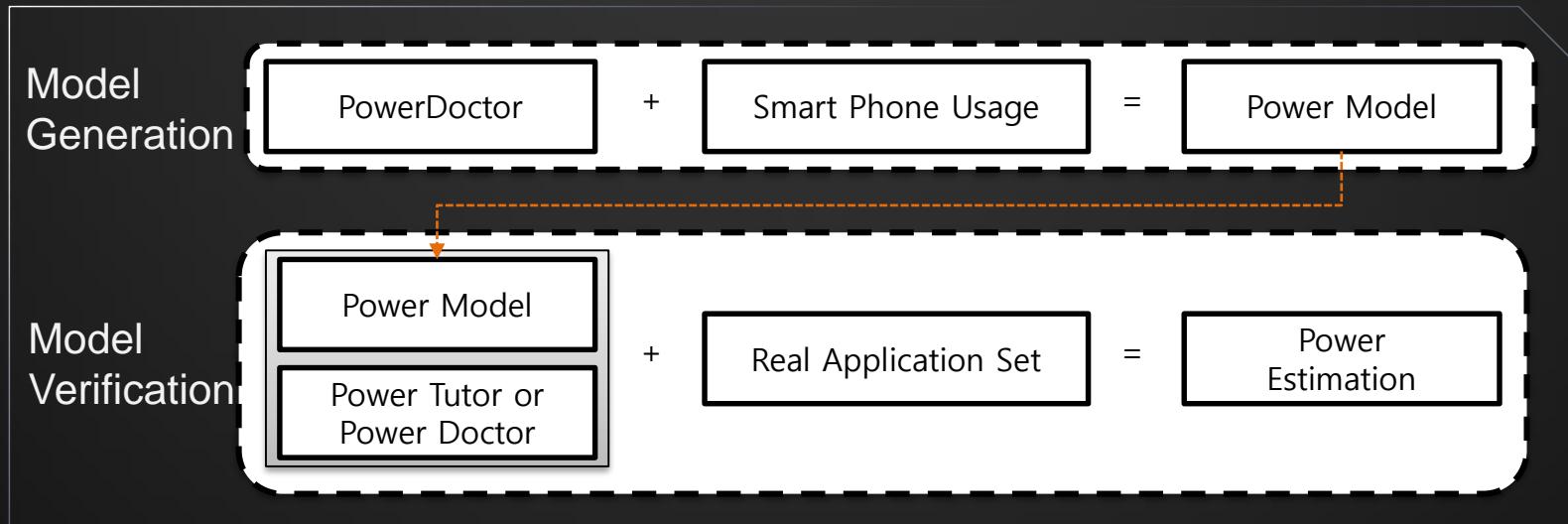


HTC Desire

Our Framework



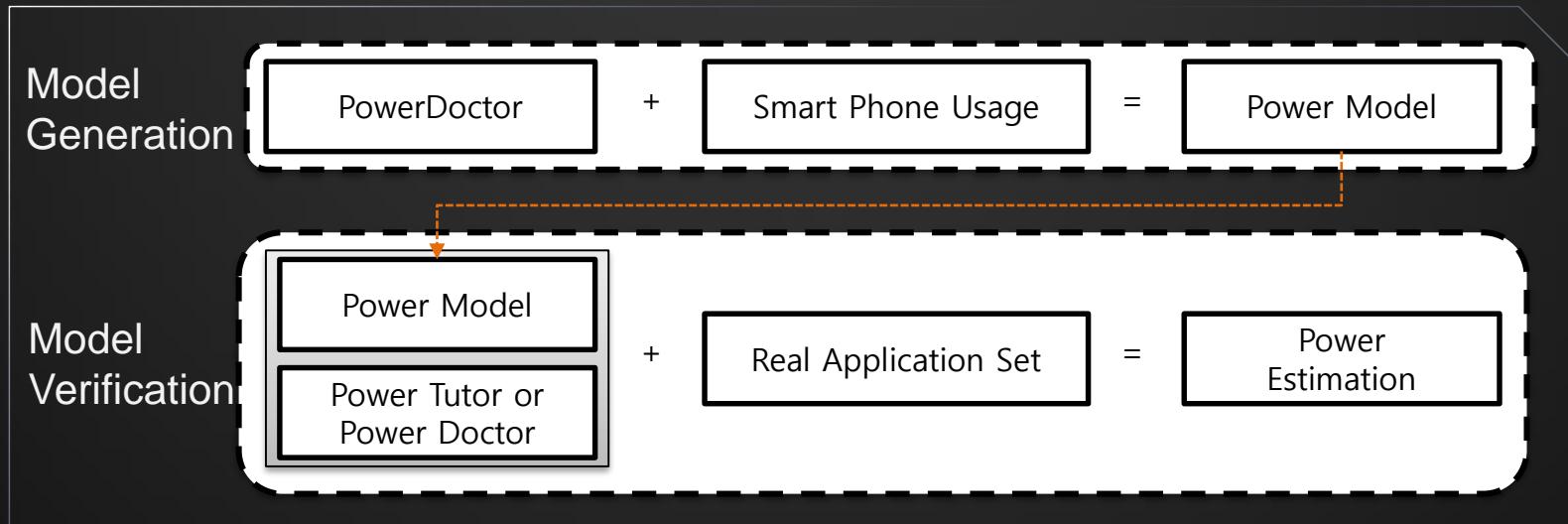
Our Framework



Model Generation

- Collect the phone's usage pattern and generate the power model.

Our Framework



Model Generation

- Collect the phone's usage pattern and generate the power model.

Model Verification

- Generated power model is verified with the proven PowerTutor
- Compare estimated power with the measured value

Motivation

Solution

Power Model

Environment

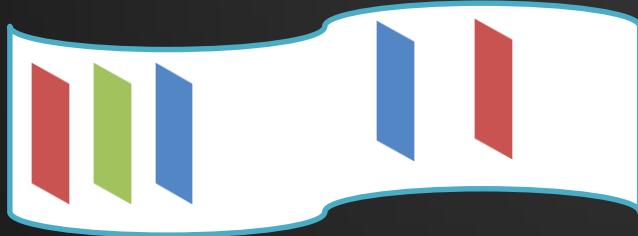
Experiment

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Power model generation procedure

Power model generation procedure

step 1

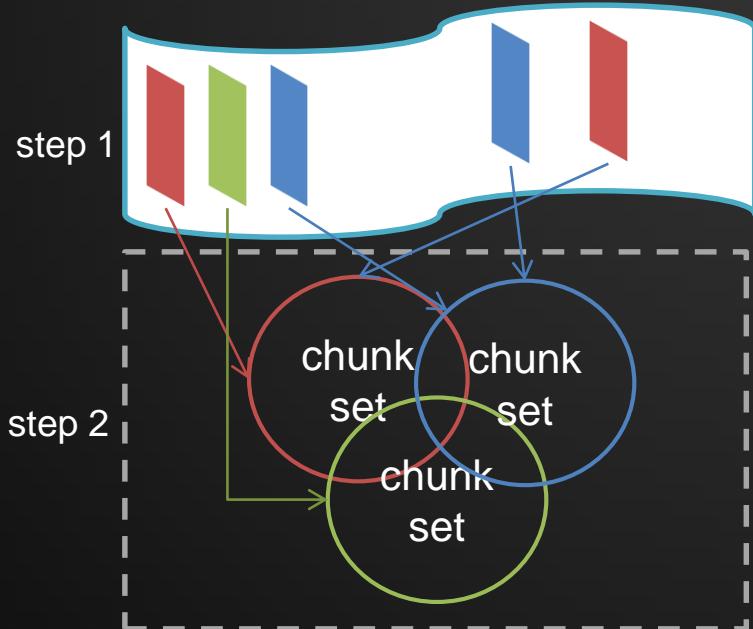


Step 1 : Collect Chunks

Collect use pattern and power consumption
with PowerDoctor

Build Chunks from them

Power model generation procedure



Step 1 : Collect Chunks

Collect use pattern and power consumption
with PowerDoctor

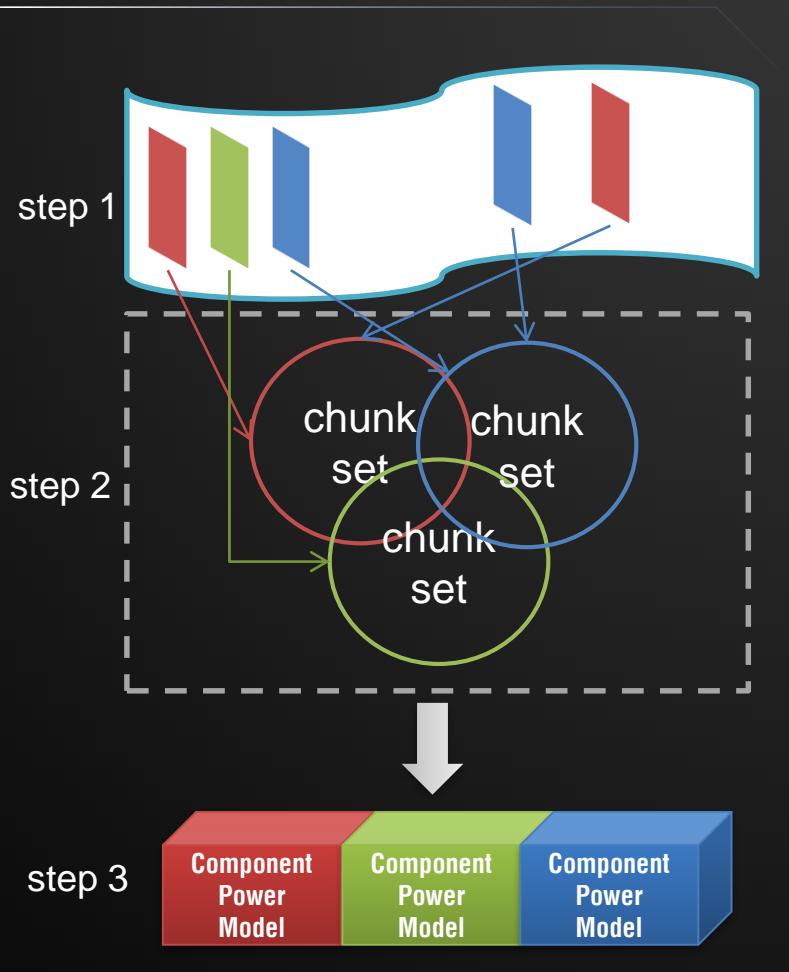
Build Chunks from them

Step 2 : Build reliable chunk group

Group chunks into each hardware
component.

Remove unreliable chunks.

Power model generation procedure



Step 1 : Collect Chunks

Collect use pattern and power consumption
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Build Chunks from them

Step 2 : Build reliable chunk group

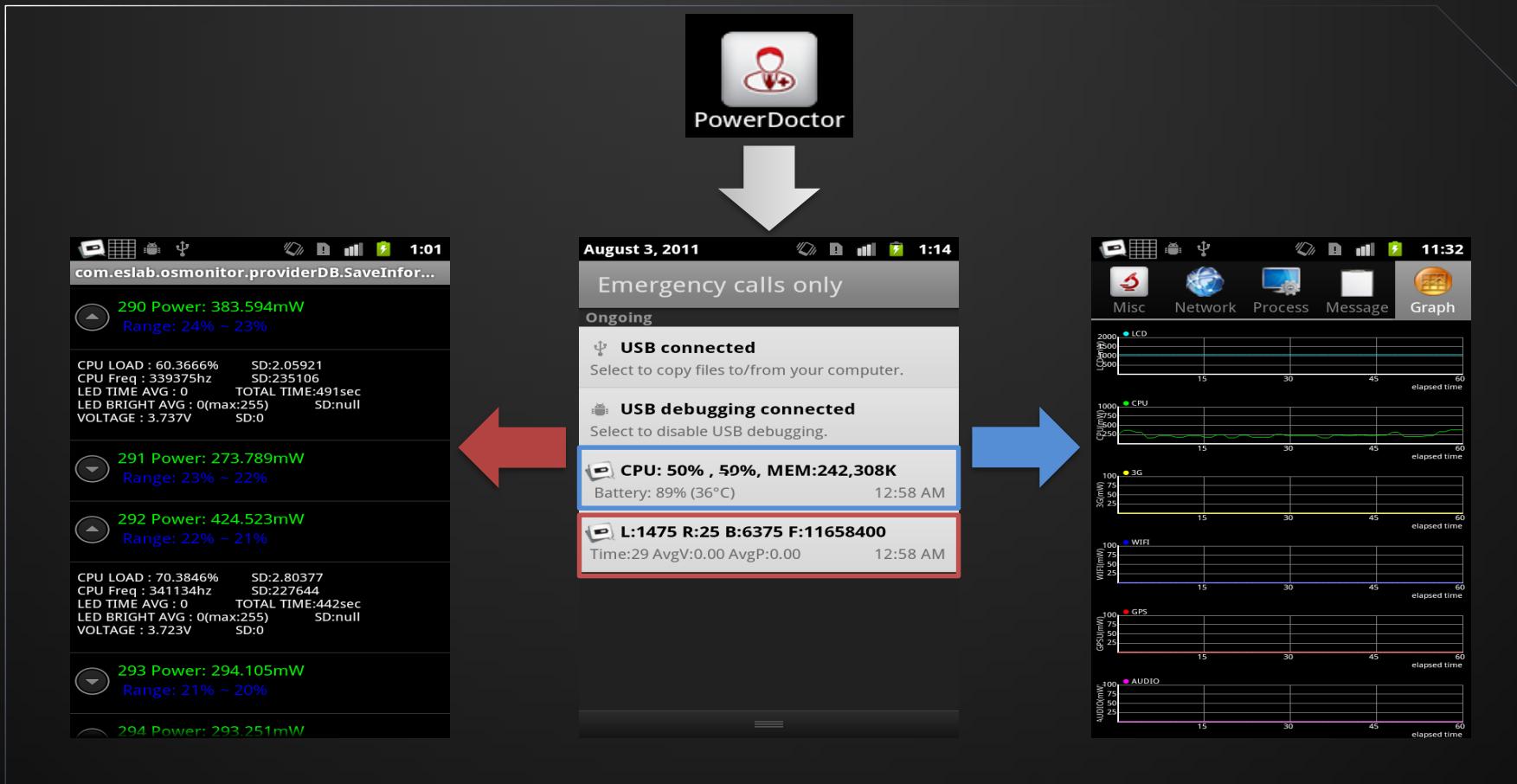
Group chunks into each hardware
component.

Remove unreliable chunks.

Step 3 : Compute power model.

Perform regression analysis on the reliable
chunks

PowerDoctor Structure



PowerDoctor's two components.

- ✓ Chunk pattern analyzer(left),
- ✓ Power analyzer(right).

UsedPhones



HTC Nexus One

CPU : 1Ghz Qualcomm

Snapdragon

GPU : Internal Graphics

OS : Android 2.3.3

Memory : 512MB RAM / 512MB

ROM

Display : 3.7 OLED

Wi-Fi 802.11 a/b/g

Battery : Standard battery, Li-Ion

1400 mAh

GPS : Y



HTC Desire

CPU : 1Ghz Qualcomm

Snapdragon

GPU : Adreno 200

OS : Android 2.2

Memory : 576 MB RAM/ 512 MB

ROM

Display : 3.7 OLED

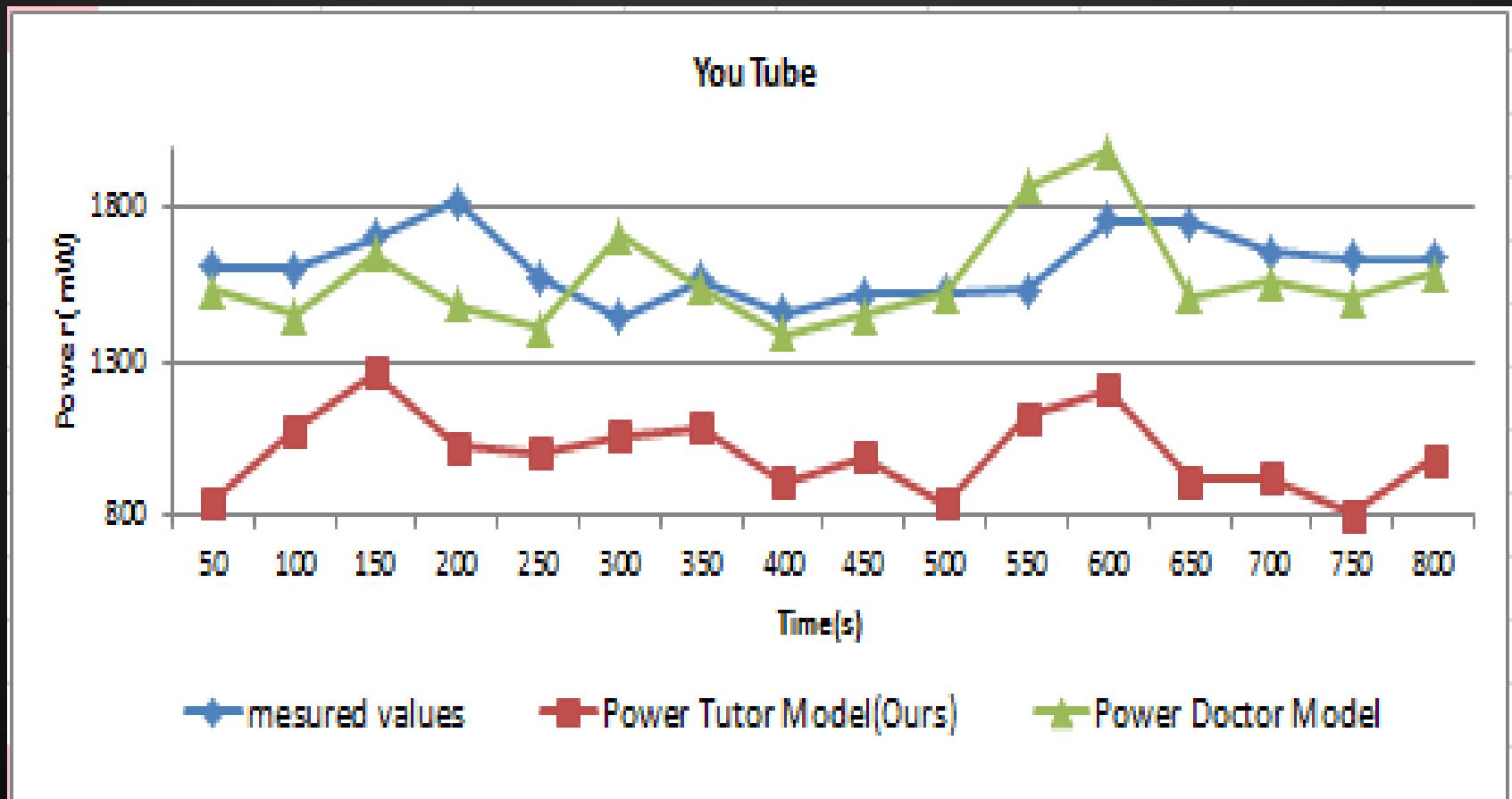
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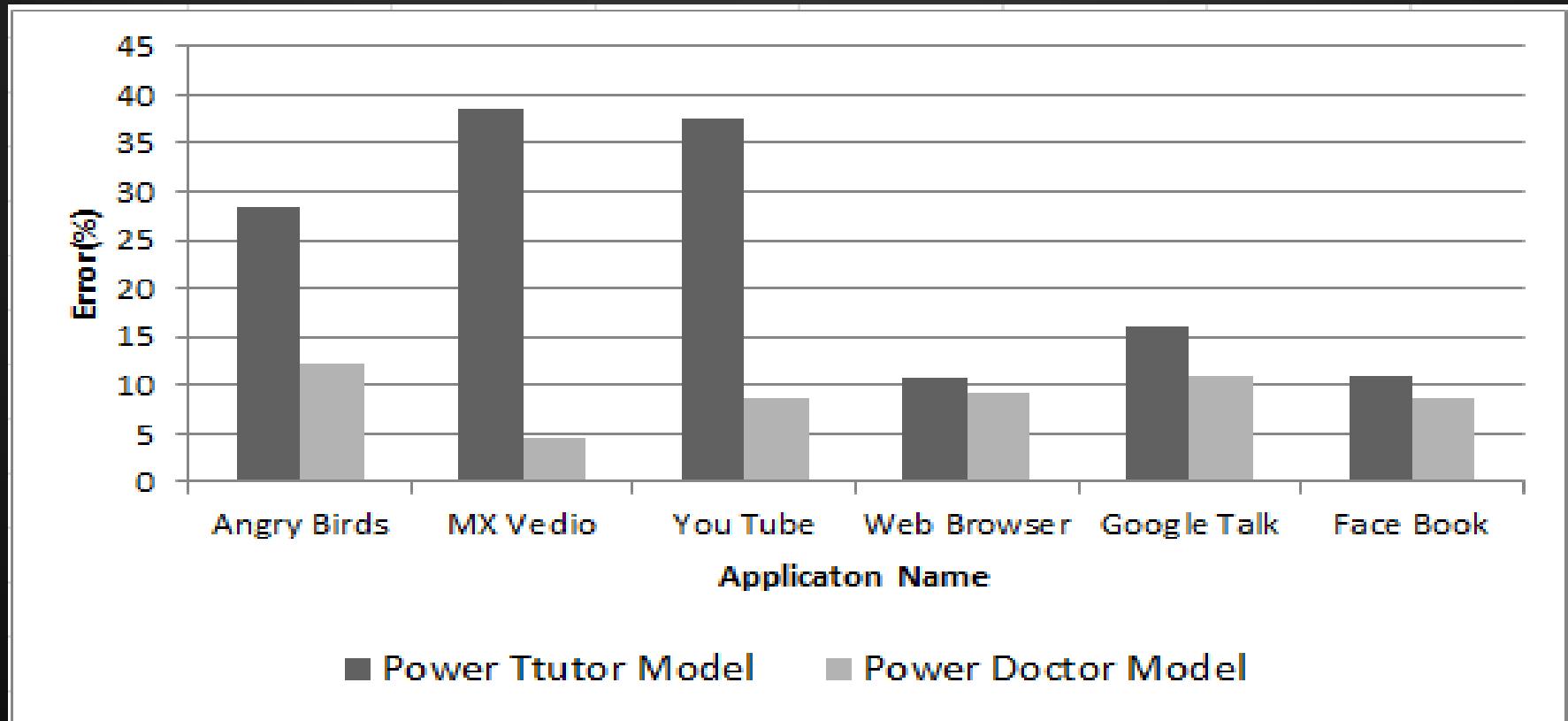
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YouTube

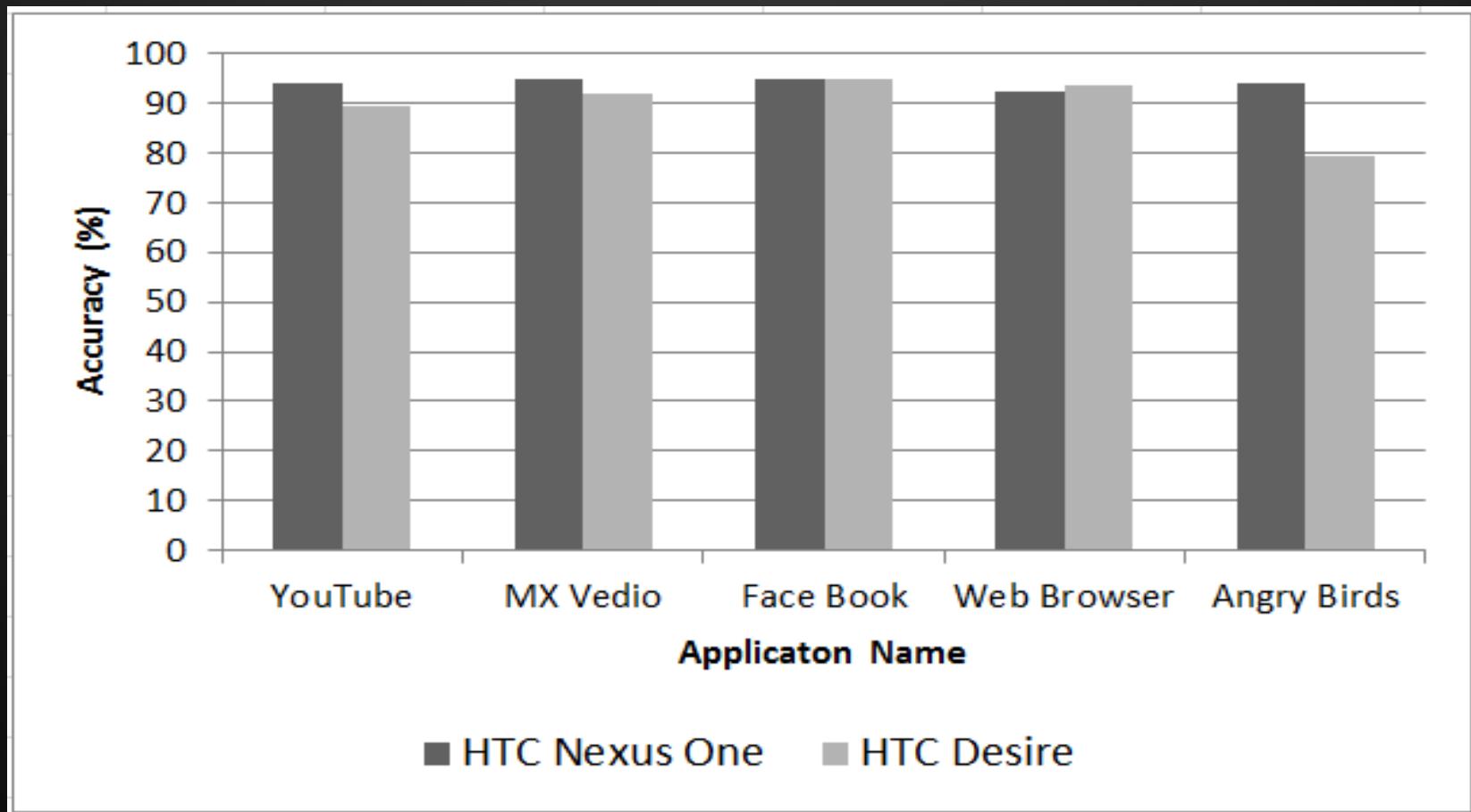


Accuracy of power model is compared to PowerTutor[L. Zhang, 2010]

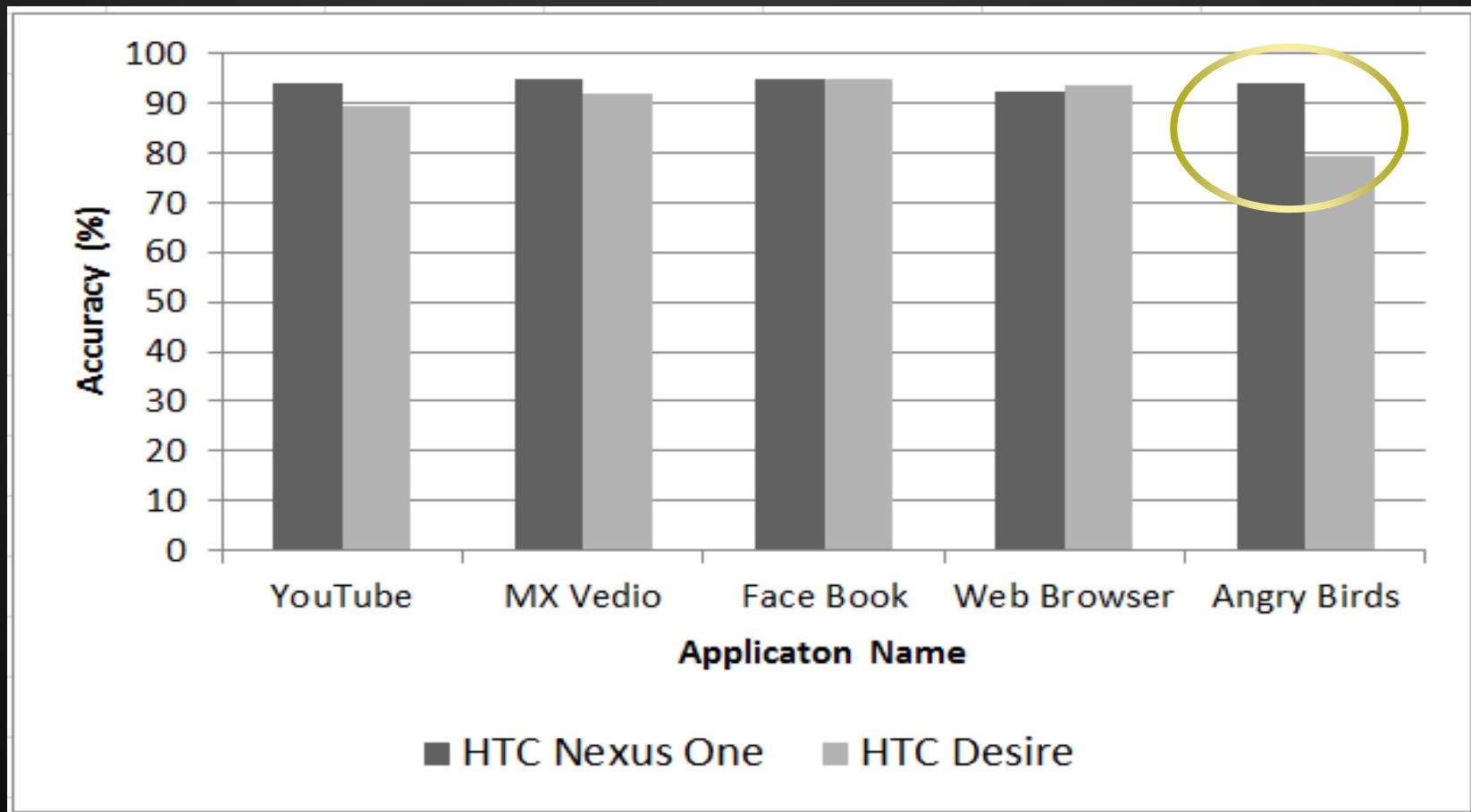


$$\text{Error} = \left| \frac{\text{measured} - \text{estimated}}{\text{measured}} \right| * 100\%$$

Feasibility of our method



Feasibility of our method



Conclusion

- We have Generated power model without external equipment or explicit training programs.
- We verified power model through comparing with the actual measurement values
- Our method has better applicability than the previous works.

A dark, abstract background featuring swirling, translucent wisps of light in shades of purple, blue, and pink, resembling smoke or energy fields.

THANK YOU!

What we did

1. **Collect user's usage patterns and power model generation.**

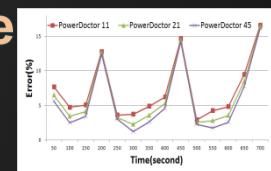
Development of Power Doctor



Power Doctor

2. **User verifies the accuracy of power models based on usage patterns.**

Development of Power Doctor



3. **Verify the accuracy of power models.**

Compare with generating power model from prior project.



VS



Power Doctor
Model

Power Tutor
Model

4. **Verify the portability of this research.**

Power Model generation of HTC Nexus one and HTC Desire

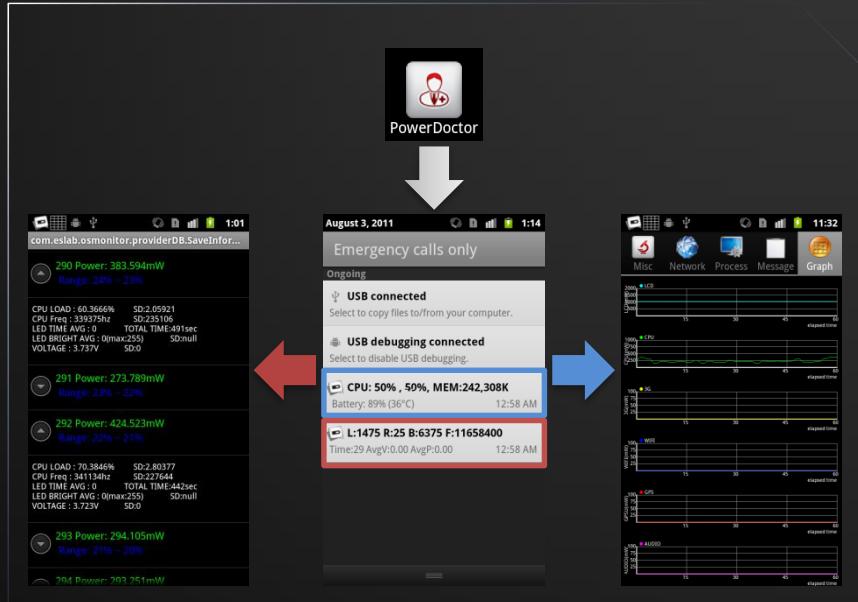


HTC Nexus one



HTC Desire

Power Doctor Structure



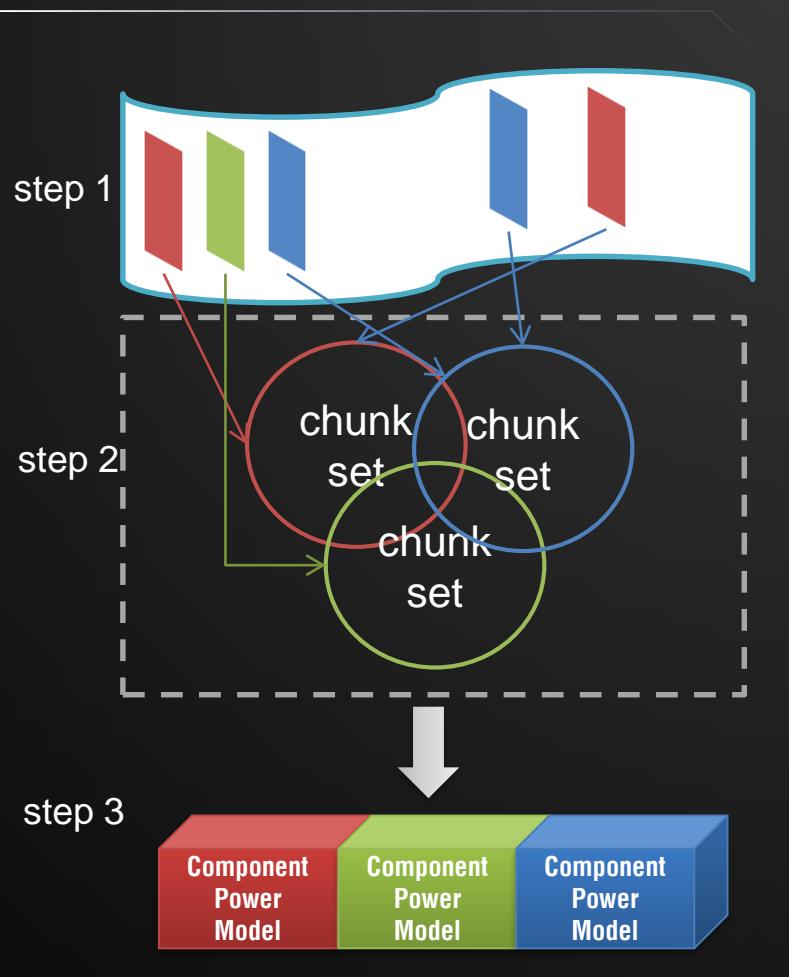
PowerDoctor's two components.

- ✓ Chunk pattern analyzer(left),
- ✓ Power analyzer(right).

Power Doctor consists of two parts

- ✓ User usage pattern analyzer that collects user activity log into multiple chunks.
- ✓ Power analyzer that computes power consumption of the chunks related to the interested hardware components.

Power Model is extracted as the following three steps are shown below.



Step 1 : Collecting pattern and Building Chunk

Collect user usage pattern by using our power doctor.

Step 2 : Set up high reliability chunk group.

Group chunks into each accessed hardware components.

Chunks with small standard deviation are selected for the next step.

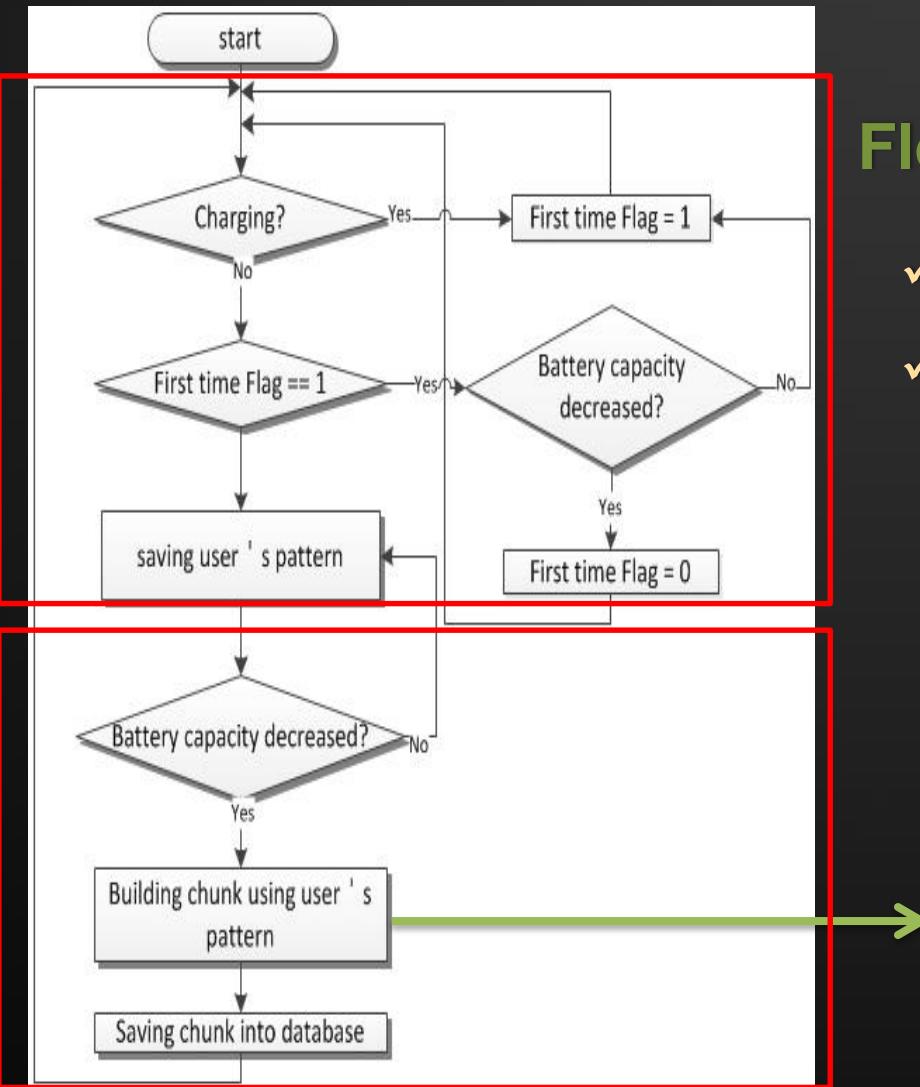
Others are discarded due to the unreliability of the sampled values.

Only the chunk groups containing more than 3 reliable chunks are combined for further processing.

Step 3 : Generate power model.

Perform regression analysis and moving average

Method of Collecting chunk and Defining chunk



Flow Chart consists of two parts

- ✓ Saving user's usage pattern
- ✓ Building chunk using user's usage pattern and then saving chunk into databases

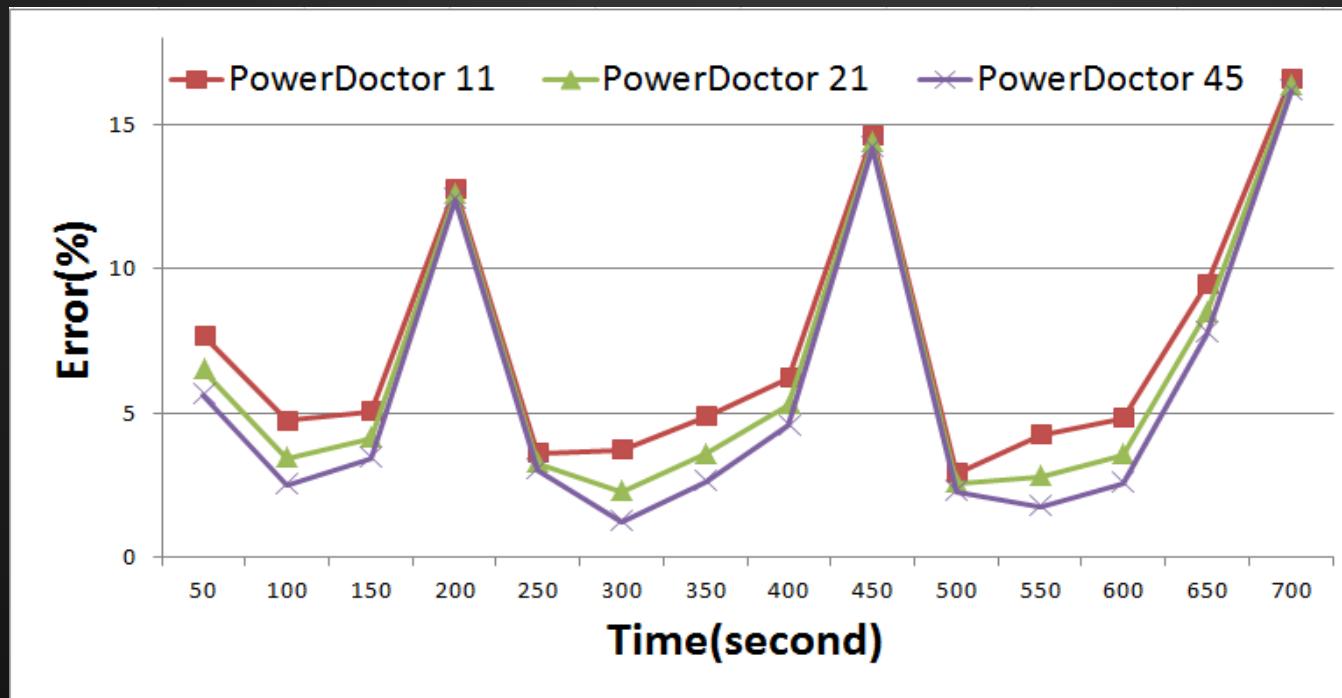
Chunk component

average power
average cpu utilization
cpu utilization standard deviation
..
average battery voltage
capacity range
chunk length

Experiments to evaluate power model generated method the following two.

- ✓ First: Evaluating impact on the power model accuracy of the model along the number of chunk.
- ✓ Second: Evaluate accuracy of power model through comparing with prior model.
- ✓ Third: Evaluate portability of power model generated method.

Evaluating impact on the power model accuracy of the model along the number of chunk



Power estimation error between current sensor
and three versions of Power Doctor.

Our models show 7.2%, 6.2%, 5.7% average errors respectively.

LIMITATIONS

- ✓ 내부 센서만을 이용 했기 때문에 정확성 부분에서 희생이 있다.
- ✓ 많은 사용자 패턴 정보를 필요로 한다.
- ✓ 우리의 전력 모델은 필수 요소를 고려 하지 않았다.