

Selection and Execution of User Level Test Cases for Energy Cost Evaluation of Smartphones

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Motivation



BlackBerry



iPhone



NOKIA

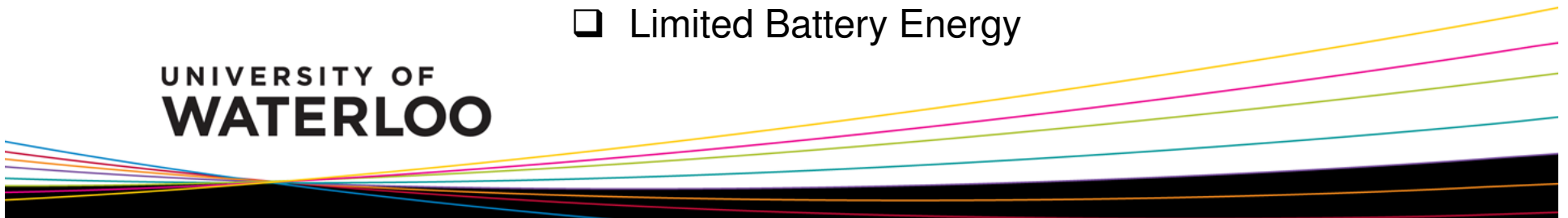


HTC

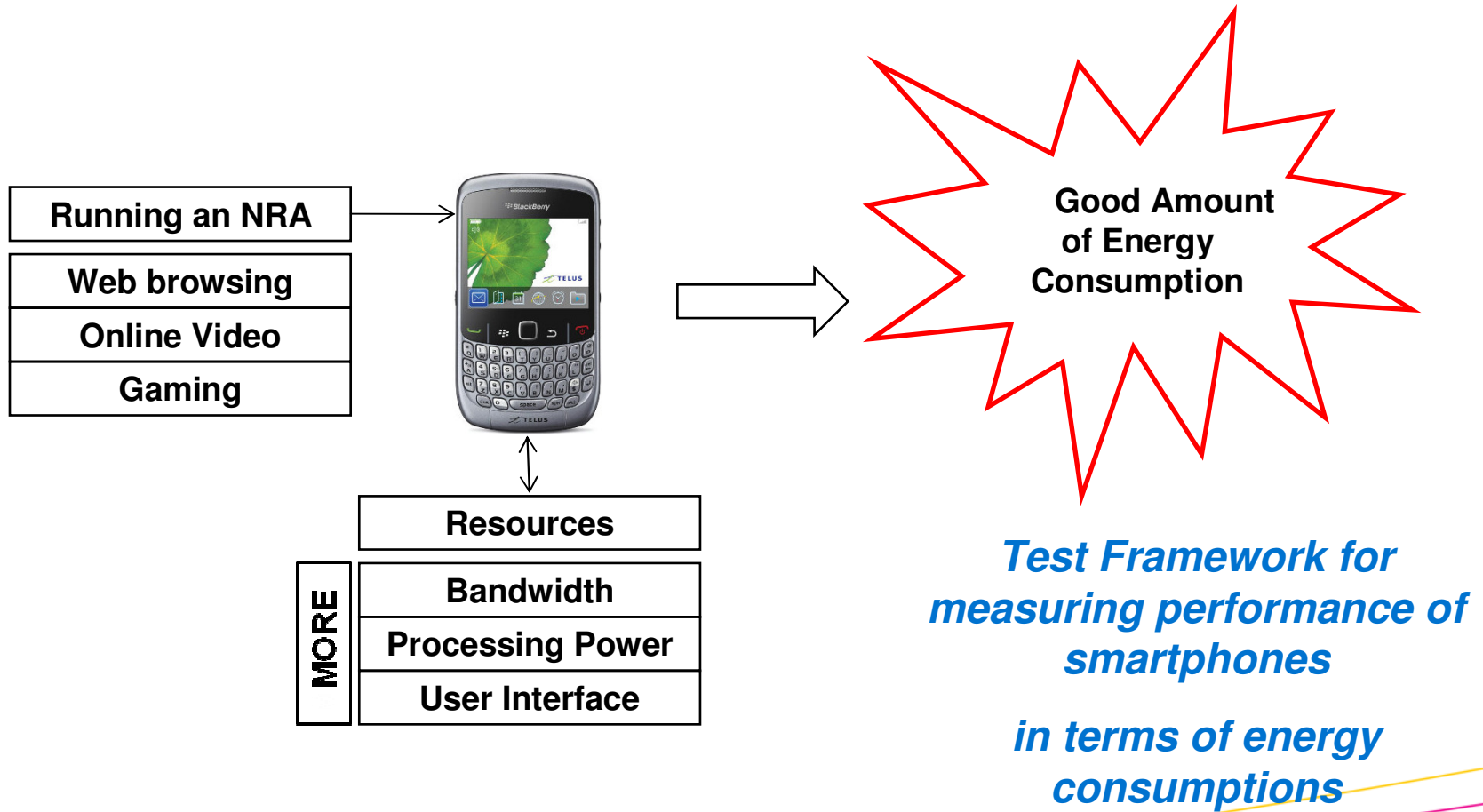
Latest Smartphones

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- ❑ Rapid development of smartphones equipped with latest features and applications.
- ❑ Availability of Internet via Wi-Fi and 3G networks. They have become popular. Network related applications (NRAs) such as online audio/video streaming, uploading/ downloading, web browsing etc.
- ❑ In North America and Western Europe, more than **50%** current mobile users are expected to switch to smartphones by **2014**.
- ❑ Limited Battery Energy



What is the Catch?



Performance Metric: Energy Consumptions

- A Methodology / Procedure
 - To measure the energy cost in smartphones
 - Energy cost of an NRA (Video/Web Browsing)
 - Energy cost of a parameter (Volume, Brightness)
 - Energy cost across smartphones (iPhone, BB)
 - Energy cost across networks (3G, WiFi, Bluetooth)

- Support researchers, manufacturers, developers to develop techniques for producing energy efficient smartphones

List of Basic Parameters (G0)

B_i	Parameters	Description	BB 9700	HTC Nexus One	Nokia E71	HTC HD2	iPhone 3GS
01	Display	Size of display	480 x 360 pixels, 2.44"	480 x 800 pixels, 3.7"	320 x 240 pixels, 2.36"	480 x 800 pixels, 4.3"	320 x 480 pixels, 3.5"
02	Operating System (OS)	Name of the OS	BlackBerry OS	Android	Symbian	Windows CE	iPhone OS 3
03	Battery Capacity	Battery type and capacity	Li-Ion 1500 mAh	Li-Ion 1400 mAh	Li-Po 1500 mAh	Li-Ion 1230 mAh	Li-Ion 1250 mAh

List of Passive Parameters (G1)

B _i	Parameters	Description	BB 9700	HTC Nexus One	Nokia E71	HTC HD2	iPhone 3GS
61	Network Selection Mode	This option lets the mobile device to select the network manually or automatically	Yes (Auto/Manual)	Yes (Search automatically)	Yes (Manual/Auto)	Yes (Auto - Select/Deselect)	Alternative (Auto - Select / Deselect)
62	WiFi Settings - Network Notification	This option prompts the user whenever any WiFi network is available	Alternative Prompt when manual connection or login is required	Yes (ON/OFF)	Yes Option 1: Show WiFi availability (Yes/No) Option 2: Scan for Networks (every 1 to 10 min)	No	Yes (ON/OFF)
63	Portable WiFi Hotspot	This option leads the mobile to act as a WiFi hotspot	No	Yes Portable WiFi Hotspot (Select/Deselect)	No	Alternative Internet sharing (Select/Deselect)	Alternative (Setup Internet Tethering)
64	Screen Timeout	This option allows the user to set the display timeout for the screen	Yes (10 sec to 2 Min)	Yes (15 sec to 30 min)	Yes (5 to 90 sec)	Yes (1 to 10 min on battery power) and (1 to 30 min on external power)	Yes (1 to 5 min or Never)

List of Active Parameters (G2)

B_i	Parameters	Description	BB 9700	HTC Nexus One	Nokia E71	HTC HD2	iPhone 3GS
31	Volume	This option allows the user to change the volume level of the device	Yes (0,1,...,10)	Yes Option 1: Sounds (Silent) Option 2: Volume levels: (0,1,...,15)	Yes volume levels (0,1,...,10)	Yes Option 1: Sounds (Silent) Option 2: Volume levels (0,1,...,15)	Yes volume levels (0,1,...,16)
32	Brightness	This option allows the user to change the brightness level of the device	Yes (0, 10,...,100)	Yes Continuous (0 to 100%)	Yes (0, 25,...,100)	Yes Continuous (0 to 100%)	Yes Continuous (0 to 100%)
33	Bluetooth	This option allows the user to turn on/off their Bluetooth connection	Yes (ON/OFF)	Yes (ON/OFF)	Yes (ON/OFF)	Yes (ON/OFF)	Yes (ON/OFF)
34	Data Access Mode	This option allows the user to select from WiFi/EDGE/3G connections	Yes	Yes	Yes	Yes	Yes

Challenge I: Large number of configurations

$$N_c = S_d \times \sum_{i=1}^M X_d(A_i) \times \eta(C_i)$$

of configurations for running an NRA

of identified NRAs

of contents for A_k

= 1 if NRA (A_k) is executable, else 0

A straightforward method to calculate S_d

$$S_d = \prod_{B_j \in U_d} \eta(B_j)$$

of available options for the j^{th} parameter

Set of available user settable parameters for a device 'd'

- ❑ For HTC HD2, $S_d \approx 800 \times 10^6$
- ❑ Considering # of NRAs and contents will lead to a large value of N_c

Challenge II: Choosing applications, contents and duration

- Large number of applications are available
 - Multiple contents for each application which includes multiple files, multiple formats
 - Duration which can capture the energy cost over time
-
- ❖ Identify a reduced set of configurations, popular applications, impact of content and duration of an application
 - ❖ Obtain a feasible set of experiments

Target

- To have a consistent test configuration across smartphones so that we can compare the results
- To capture the energy consumption behaviours of an application with reduced number of experiments

Proposed Methodology

- ❑ Examined the parameters which involve in energy consumption for five latest smartphones;
- ❑ Categorized these parameters into three groups;
- ❑ We conduct two type of experiments
 - **Main Experiments** : Keep B_{31} to B_{36} and vary just the network access modes (B_{37}) all the applications. The corresponding configurations are called as primary configurations
 - **Stand-alone Experiments**: Select a single/multiple application and vary just one of the standalone parameter (B_{31} to B_{36}) . The corresponding configurations are called as stand-alone configurations

Feasible Set of Experiments, N'_c

$$N'_c = (S_d^p + S_d^s) \times \sum_{i=1}^M X(A_i) \times \eta(C_i)$$

of primary configurations (4)
of stand-alone configurations

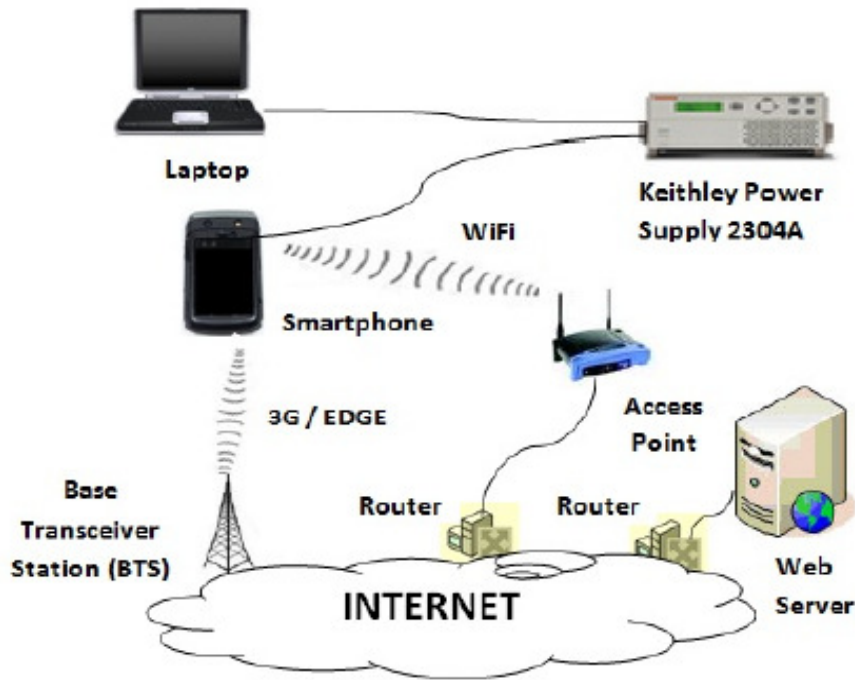
$$S_d^s = \sum_{B_j \in G1 \wedge j \neq i} Q_j$$

Standalone configuration corresponding to B_j

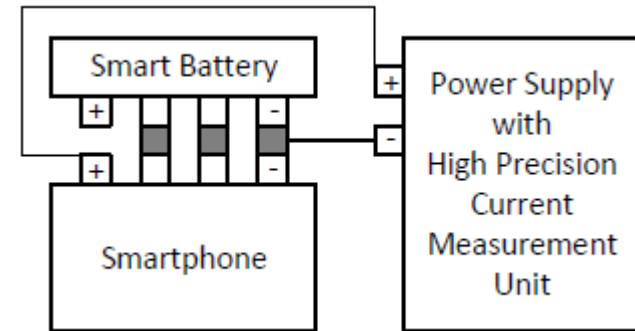
$$Q_j = \begin{cases} \eta(B_j) - 1 & B_i, B_j \text{ are independent;} \\ (\eta(B_j) - 1) \times S_d^p & B_i, B_j \text{ are dependent.} \end{cases}$$

For HTC HD2, $S^p + S^s = 35$

Test Bench



Experimental Setup



Connection details for the device

Energy Cost Metric

ξ	I_0	I_a	I_x	I_y	θ_x	θ_y
(mAh)	(mA)	(mA)	(mA)	(mA)	(h)	(h)
1500	7.5	50	350	80	4.3	18.7
1230	7	43	188	97	6.5	12.7
1400	9	175	196	375	7.1	3.7

- ξ : Battery rating for a smartphone
- I_0 : Standby current for a smartphone
- I_a : Average current when no application was run
- I_x : Average current when application 'x' was run
- I_y : Average current when application 'y' was run

- $\theta_x = \xi / I_x$: Energy metric when application 'x' was run
- $\theta_y = \xi / I_y$: Energy metric when application 'y' was run

Higher Energy metric implies better performance

Experiments

- *Experiment 1:* Run three most popular NRAs over Wi-Fi and Cellular networks for four smartphones
 - Online video via YouTube
 - Web Browsing
 - Email Composition
- *Experiment 2:* Run an online video over different network access modes (Wi-Fi, EDGE, 3G) for a smartphone
- *Experiment 3:* Run an online video at different levels of brightness using Wi-Fi and cellular network

Results: Experiment 1

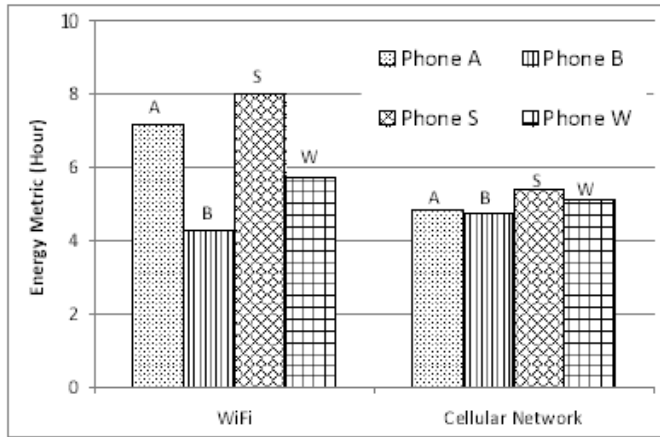


Figure 4: Comparison of energy metrics for playing YouTube video.

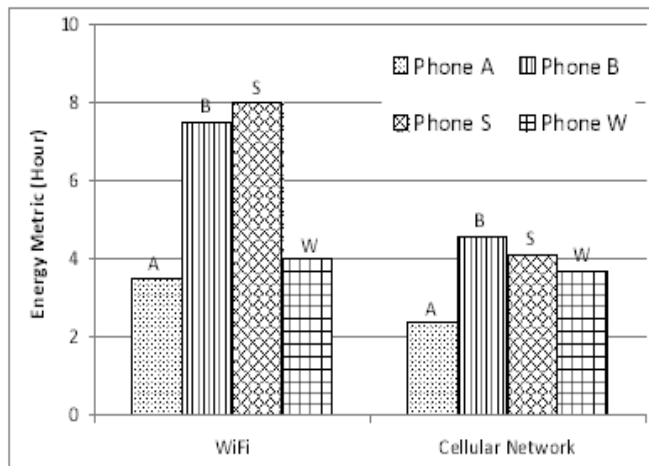


Figure 5: Comparison of energy metrics for Internet browsing.

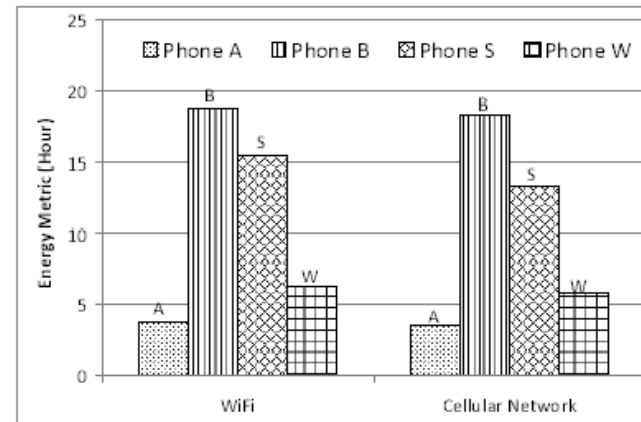


Figure 6: Comparison of energy metrics for composing email.

- Performance is almost equal for Cellular network for YouTube and Browsing
- Performance of Wi-Fi is better than Cellular networks
- For email composing performance is equal for Wi-Fi and Cellular Networks
- Use Wi-Fi connection whenever available

Experiment 2 :

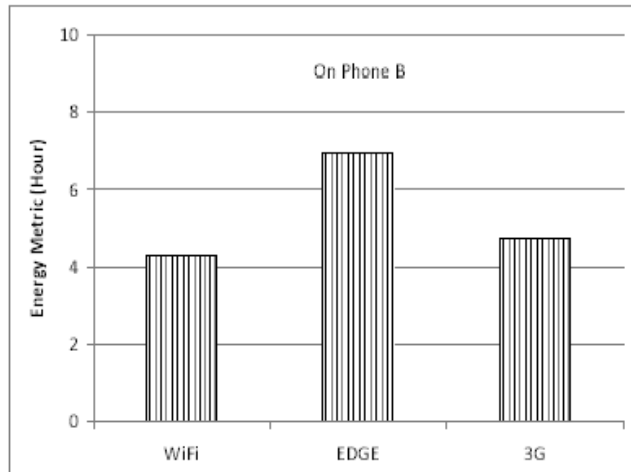


Figure 8: Comparison of energy cost metrics for different network connections on Phone B.

Experiment 3 :

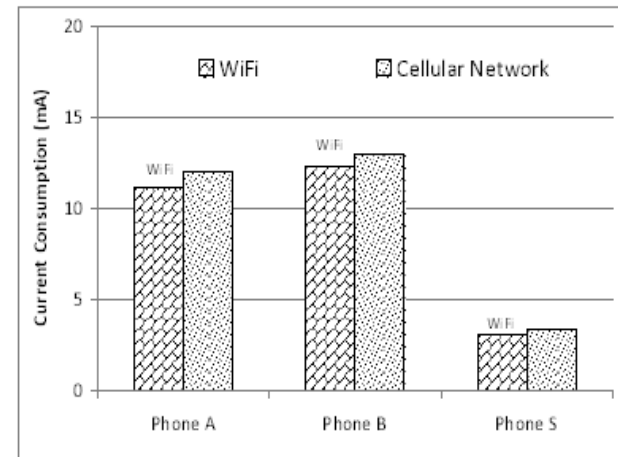


Figure 9: Comparison of current consumption for different brightness levels.

- ✓ EDGE performs better compare to Wi-Fi and 3G for some smartphone while running video application. This might vary across Smartphones
- ✓ Brightness is independent of network access mode

Limitations

- Trade-off between user perception and energy cost
- Network fluctuations is inevitable
- Actual lifetime of a battery might be different from our experimental value
- Similar settings on all the smartphones is not possible

**Thank you.
Questions??**