Indonesian Journal of Electrical Engineering and Computer Science
Vol. 8, No. 3, December 2017, pp. 597 ~ 609
DOI: 10.11591/ijeecs.v8.i3.pp597-609

Quality of Experience (QOE) Aware Video Attributes Determination for Mobile Streaming Using Hybrid Profiling

Muhamad Hanif Jofri*[1], Mohd Farhan Md Fudzee[2], Mohd Norasri Ismail[3], Shahreen Kasim[4], Jemal Abawajy[5]
[1,2,3] Multimedia and Mobile Group, Software & Multimedia Center, Faculty of Computer Science and Information Technology, Universiti Tun Hussein Onn Malaysia
[4] Soft Computing and Data Mining Centre, Faculty of Computer Science and Information Technology, Universiti Tun Hussein Onn, Johor, Malaysia
[5] School of Information Technology, Deakin University, Burwood, Australia
*Corresponding author: mhanif@uthm.edu.my

Abstract

Today, consumers use a smartphone device to display the media contents for work and entertainment purposes, as well as watching online video. Online video streaming is the main cause that consume smartphone's energy quickly. To overcome this problem, smartphone's energy management is crucial. Thus, a hybrid energy-aware profiler is proposed. Basically, a profiler will monitor and manage the energy consumption in the smartphone devices. The hybrid energy-aware profiler will set up a protocol preference of both the user and the device. Then, it will estimates the energy consumption in smartphone. However, saving energy alone can contribute to the Quality of Experience (QoE) neglection, thus the proposed solution takes into account the client QoE. Even though there are several existing energy-aware profilers that have been developed to manage energy use in smartphones however, most energy-aware profilers does not consider QoE at the same time. The proposed solution consider both, the performance of the hybrid energy-aware profiler is compared with the baseline energy models against a variation of content adaptation according to the pre-defined variables. Three types of variables were determined; resolution, frame rate and energy consumption in smartphone devices. In this area, QoE subjective methods based on MOS (Mean Opinion Score) are the most commonly used approaches for defining and quantifying real video quality. Nevertheless, although these approaches have been established to consistently quantify users' amounts of approval, they do not adequately realize which the criteria of video attribute that important are. In this paper, we conducted an experiment with a certain devices to measures user's QoE and energy usage of video attribute in smartphone devices. Our results demonstrate that the list of possible solution is a relevant and useful video attribute that satify the users.

***Keywords**: Content Adaptation, QoE, Energy Consumption*

1. Introduction

Dominant smartphone devices and more new features implemented in the smartphones have led to a growth of demand for online media streaming. The use of smartphone devices for streaming video content is very widespread nowadays. Hence the energy consumption is very high to play streaming video [8]. Moreover, most of the users overlook that they are using high energy in a smartphone devices without them realizing it [6]. This certain constraint is a huge challenge for media streaming development and service providers: on the one hand, they need to address this demand growth by constructing a suitable solution that satify users' and energy in the smartphone devices [4]. Nevertheless, in video content adaptation it is difficult to produce a good video attribute that satisfy energy and QoE at the same time. To overcome this problem we propose a list of possible solution for video content adaptation attribute can be determined through experimentation of user QoE subjective survey and energy usage as Quality of Services (QoS) in smartphone devices.

The concept of Quality-of-Experience (QoE) has extended solid concern from an academic researcher as well as industry viewpoint. Basically, QoE states to an accommodating of the quality of communication systems and applications that transcends traditional technology-

Received August 30, 2017; Revised October 29, 2017; Accepted November 20, 2017

focused Quality-of-Service (QoS) parameters. Instead, the concept is linked as closely as possible to the subjective perception of the end user. This user-centric focus is also replicated in the most widespread definition originating from the ITU-T SG 12 [11] which describes QoE as ”overall acceptability of an application or service, as perceived subjectively by the end user.”, which ”may be influenced by user expectations and context.”

2. Related Works

Although QoE is often used to measure user satisfaction at the same time QoS must also be taken into account in terms of energy use in smartphones. In addition, at one level where to obtain media content corresponding to energy consumption and it can satisfy the user is quite difficult [1]. There are some of the techniques that have been used by previous research to reduce energy consumption by lowering the profile of descriptive user and it will cause the user's QoE too low [15]. Then, the possible question to be answered is what is the acceptable level streaming of video that can be received by users of smartphones and it will saves energy consumption in the smartphone devices. Other essential part within this paper is energy profiling. Typically, energy profiler is the module that manage, cater and define the mobile energy usage on smartphone devices [4], [14]. In general, a profiler has a certain functionality to indicate and to collect data from the user, operating system, policy and application [16]. In addition, energy profiler also is the combination of the module that helps system to determine the policy of energy awareness [4]. Moreover, energy profiling was defined as the process of assigning, collecting and to characterize power consumption to its functionality [1], [2], [3], [16]. One of the challenging issues of smartphones is energy consumption management [3], [4], [7].

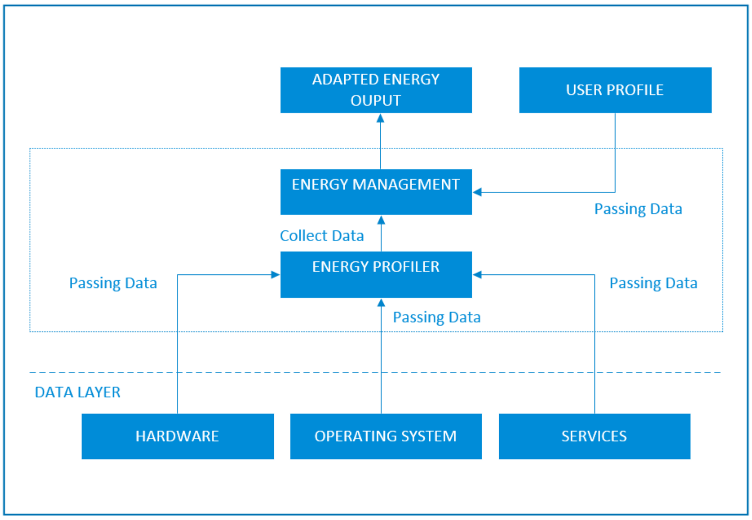

Figure 1. A Generic Energy-Aware Profiler

Figure-1 shows a generic energy-aware profiler to profiling energy data. Previously, energy profiler has been discovered by many researchers and most of them just focusing on analyzing the data via network analysis and software collection [2], [7]. Research by [2] defining a power consumption model are based on the energy model that enables them to empirical predict energy consumption by the different application. Understand the design and how the implementation of energy profiling on smartphone devices is a good start to develop a well-ordered set of hybrid energy-aware profiler.

One of the most important elements in the energy-aware profiler is the algorithm that running specific software or engine to reduce an energy consumption in the smartphone devices. Generic algorithm available in the Android SDK and running using *video_view* function attributes.

Algorithm 1: Shot Detection Algorithm

```
procedure Shot Detection Algorithm
Retrieve video service
FOR
Retrieve_service= True;// connection establish for video stream
        Access = content _vid
Stream_update
        IF (Retrieve_service = null AND (Access = empty))
THEN
Terminate Streaming; // if content not available, video is not
                      streamed
Else
Stream content _vid;    // play video streaming
END FOR(end_stream);  // stop video streaming if finish
RETURN
END
```

Algorithm 1 shows the generic energy-aware profiler for video application without any modification or alteration. Basically, generic algorithm gets input video from the server, then retrieve video services using Android Broadcast Services that enables video stream within the algorithm. After that, streaming will continue to play until finish without having QoS and energy consideration.

2. Research Method

2.1. Objectives

This section provides detail of the research methodology and explains the step by step processes from the component of profiler, notation, and outcome of the experiments. The components of the profiler portray the flow of the hybrid energy-aware profiler that runs on modified video streaming application within Android platform. This flow shows how the module in the profiler communicates with other components. Furthermore, this chapter presents: subjective QoE survey experiment setup, the algorithm of hybrid energy-aware profiler and the proposition to produce the list of possible solutions as the final result.

2.2 Initial Data Collection

In the initial data collection, the first step is the setup of the experiment and the instrument for device testing as well as measurement apparatus setup. In this phase, instruments and devices such as multimeter and smartphone is being chosen for the experiment. There are several early testing has been conducted to find the energy testing on a certain device. Next, a metadata from content and device capability constraints data are collected from the establish repository server. The server setup is using established streaming server placement. For this research, Wowza Server.com has been used for content repository. There are other early testing on another server, such as Android Developer Server Side, however the content (video) have so much limitation on duration restriction. One free server for streaming video content, GitHub.com that using Google Development infrastructure, have some video size constraint and it is not recommended to use this server. Content is described as an extracted metadata from video content for the experimental purpose. Content metadata will be extracted using a hybrid energy-aware profiler. Before the experiments, the video content from has to be configured to tailor certain attributes in order to start capturing initial results. Next, is the device capability constraints and data features are collected together with QoS.

2.3 Baseline Data Processing

In this phase, experimentation preliminary work and baseline of energy consumption are conducted. Before the actual testing on the smartphone device, reliability testing is necessary to be conducted. The explanation of preliminary experiment is presented in the subchapter. In this phase, the development of generic profiler has been established as well. The development used Android development tool (Eclipse) software.

There are many more Android development software tools can be used, for instance Netbeens Android developer and JQuery mobile development. Eclipse has been chosen for development platform because of the frequent update of Software Development Kit (SDK). The SDK relies on recent mobile device operating system. Some Android OS need SDK update for development propose such as Kit Kat Android OS (Android 19) that needs to update on devices streaming orientation often to run video on devices. Netbeens, JQuery and other platform lack of SDK features makes Eclipse more compatible for mobile application development. Furthermore, baseline of energy consumption is conducted after setup is completed by determining the threshold of energy usage in mobile device before experiment testing is executed. Then, baseline energy consumption experiment is executed for energy model of both smartphone devices, in order to get the basic energy threshold of mobile devices.

In this paper, we will make experiments based on two aspect of energy savings from hybrid energy-aware profiler (QoS) and take into account the preferences of the subjective user survey (QoE). The first step is to make a comparison in terms of realibility testing to measure the energy used by smartphones. Then, by developing a hybrid energy-aware profiler and generic video streaming application both energy result will be compared.

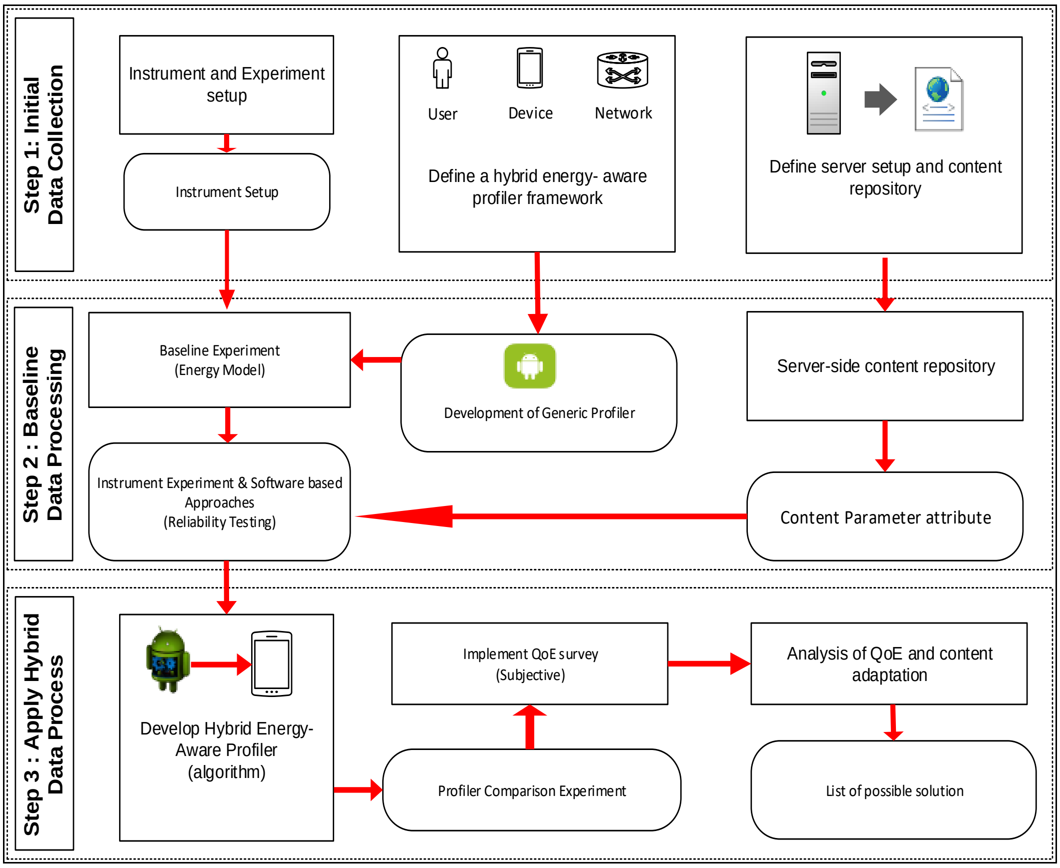

Figure 2. Step-by-step process

Getting stable and valid measurement is essential. Measurement stability and test result reproducibility: Different measurement of energy consumed by a component of a smartphone or by the device itself can vary from test to test [2], [4]. Many factors had introduced certain levels of variability even in controlled lab environments [14]. If the sample or tester has admitted to a high sampling frequency measurement tools, a stable result for a test case can be achieved

faster and by a smaller number of runs [9]. Content parameter attribute is basically an adapted content from the server and through the reliability testing in the experiment later.
Secondly, by using energy models that have been provided in the baseline testing will be used to measure the energy consumption of video content adaptation.application is developed as the baseline for experimentation and comparison purpose Next, the subjective surveys using the Mean Opinion Score (MOS) will be carried out where it will determine the outcome of the user QoE. Finally, after both result finding acquired a result from both QoE and QoS are compared where QoE is the minimal satisfaction from user and energy is the maximum criteria to get the list of possible solutions.

4. Experiment Setup

Before running an experiment to measure energy consumption, firstly a proper devices must be choose. This experiment need a two different smartphone device with a specific characteristic. Both of the devices running on Android platform and have a dissimilar capability in term of processor speed, network capability, battery capacity and screen resolution [16]. As explained, within this experiment, there are several type of mobile device that have been used. Samsung Galaxy S2 and LG Nexus 5 are suitable devices for the experiment. However, several experiments have been conducted on HTC One X, Lenovo S930 and Motorola DROID Maxx that have similar attributes with LG Nexus 5 but the main concern of heating problem vary in these smartphones.
Other experiment has been conducted is using Alcatel Idol 2, LG Spectrum II 4G VS930, and Sony Xperia ion that have similar specification with Samsung Galaxy S2 and the biggest problem is wireless connection (Wi-Fi) strengths is quite low. This kind of weakness give the low result on QoE satisfaction. Another problem arise on certain devices the lag while streaming video The testing on BlackBerry Torch 9850, ZTE Blade, Samsung S3650 Corby, LG Optimus One P500, BlackBerry Curve 9360 and HTC Desire clearly having the lag problem. These characteristics are taken into the account on choosing the good device platform, otherwise the problem will delayed the experiment later.
Experiment setup using instrument by initial a jumper cable to the positive and negative terminal of all smartphones battery. This method technique use a real instrument instead of fake battery [14] the jumper connection setup of hardware between both terminals in a smartphone device is crucial because one mistake connection will create a circumstance where smartphone device automatically shut down immediately. This process cause battery to wear of and broken. Figure 3 shows the experiment setup.

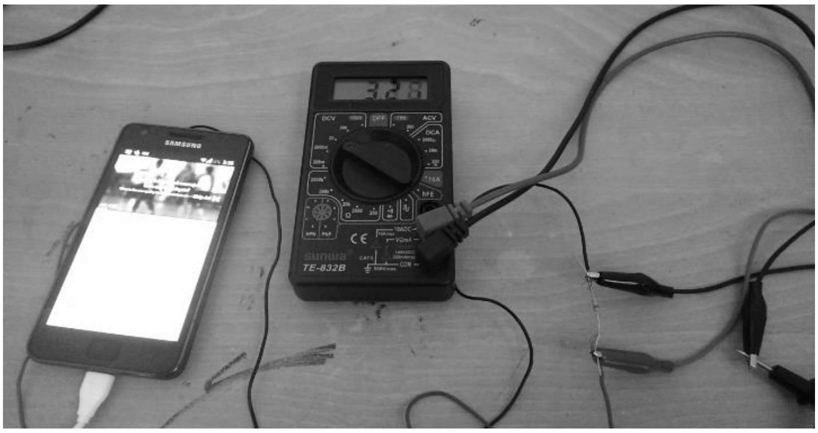

Figure 3. Experiment setup between multimeter and Samsung Galaxy S2 smartphone devices

Next is after the setup of experiment is initiate, the realibility testing needs to be conducted. Reliability testing aim is to compare energy usage percentage between instrument method and software approaches in smartphone. The instrument method generally by using a apparatus measurement tool to examine an energy consumption in the smartphone devices. Nevertheless, before start measuring a basic equation needs to be determined for the energy calculation later. The basic electrical equation describes as follows:

$$P = I \times V \quad (1)$$

P = power consumption,
I = current (ampere Ω),
V = voltage

This basic of electrical equation obligate to be implemented in the instrument method equation.

$$RTI = \sum_{P=(V\ x\ \Omega)}^{TAI} (Pe - Ps) \quad (2)$$

RTI = relibility test instrument,
T_{AI} = Total average energy instrument,
$P=(V x Ω)$ = basic electrical equation
Pe = energy at end experiment
Ps = energy at start experiment

Then, it will be compared with software approach using PowerTutor 1.4 smartphone profiler application. This profiling software measure any application power consumption usage. Equation 3 shows the software approaches equation.

$$RTP = \sum_{n=PPs}^{TAP} (\mathrm{PPe} - n) \quad (3)$$

RTP = relibility testing PowerTutor,
T_{AP} = total average energy PowerTutor,
$n=PPs$ = energy at start experiment
PPe = energy at end experiment

Energy consumption for reliability testing using PowerTutor (*RTP*) tool is 149.1 mW, meanwhile the result of energy consumption from instrument method (*RTI*) is 148.9 mW. Result from PowerTutor approaches is deducted with the energy consumption from the instrument method. The difference between these two experiments is 0.2 mW. This show the relevance of both method and approaches since the difference is less than 5% and the accuracy is definite and reliable [18]. Hybrid energy-aware profiler consider developing an algorithm for pre-experimenting involving the model parameters based on collected dataset. In this algorithm, there are several steps of processes and parameters related to energy.

These steps are included during the hybrid energy-aware application development. It shows the algorithm of hybrid energy-aware profiler video application.

Algorithm 2 displays the input elements. *Tot_CPUcore* is the total number of smartphone cpu core. Nowadays, the smartphone CPU core is increasing and relatively the energy consumption also rising [19]. By controlling the CPU load, it can reduce energy consumption in the smartphone device [17].

Algorithm 2: Hybrid Energy-Aware Profiler for video application

```
INPUT: Tot_CPUcore,σ, En, Br;
OUTPUT:content adaptation video streaming
BEGIN
Initialization (QoS_prof)
Device_capbility// check smartphone preference. (e.g.
        orientation, brightness)
 { IF ((En < Min (En)) THEN  // if energy minimum then CPU,
        sensor is
    Disable Tot_CPUcore, σ, Min Br; // disable and brightness
        is minimum
        ELSE IF ((En = Med (En)) THEN // if energy half then CPU,
        brightness
Tot_CPUcore/half + Br/half + Disable σ;  //divide into half,
        sensor is disable.
        ELSE IF ((En > Med (En) &&En< Max (En)) THEN  // if
        energy maximum,
    Enable Tot_CPUcore, σ, Max Br;    //enable all.
  END IF (En = 0)
}
        // Retrieve video service//
FOR
Retrieve_service= True;  // connection establish for video
        stream
        Access = Res_vid, fps_vid, dur_vid, est_En_vid;
Stream_update
    IF (Retrieve_service = null AND (Access = empty))THEN
Terminate Streaming;  // if content not available, video is not
        stream
Else
Stream content_adapt_vid;   // play video streaming
END FOR(end_stream);     // stop video streaming if finish
RETURN
END
```

Next, σ is the available sensors in smartphone devices. *En,* define as the energy while *Br* stands for brightness in the smartphone devices. *Tot_CPUcore*, σ, and *Br* divided into three constraints. First if energy < energy minimum (*(Min) En*) *Tot_CPUcore* and σ is disable completely and brightness level is set to minimum. Then, if energy = energy medium (*(Med)En*) then *Tot_CPUcore* will divided into half of CPU cores. If the smartphone device has 4 core of CPU running, then it will used only half of the total CPU core to save energy. In this condition, σ is disable completely and brightness level in medium. The final constraint is energy which is set to more than medium and may reach to maximum (*(Max) En*) for all the *Tot_CPUcore* and σ is enable and brightness is set to maximum value.

To retrieve the media content from repository server, the hybrid energy aware profiler algorithm retrieves it from the broadcast services and it must be enabled. Next, the video content adaptation attribute is checked before the steaming session. Streaming process is executed if retrieving media content return to NULL, and if content is empty, then video streaming is terminated.

4.1 Baseline Power Consumption

Before actual prediction of power consumption of any usage in mobile device activities, first, defining the based line of energy threshold in any different type of condition on mobile phone. Baseline for power consumption is the benchmark of energy usage on any smartphone devices before determine the actual energy usage of certain application or energy bug [18].

Table 1 indicates the energy model baseline setup and energy result for Samsung Galaxy S2 using the hybrid energy-aware profiler application.

Table 1. Energy model for Samsung Galaxy S2

Power Consumption Setup Criteria	Energy Model	Average Power
Baseline (Dim Screen + Cellular +Services + Audio)	$\beta base_{\_S2} + Aud$	305 mW
(Baseline with Wi-Fi active)	$\beta base_{\_S} + WiFi_{\_S2}$	305 + 32 = 337 mW
(Baseline + Min Screen Brightness)	$\beta base_{\_S} + Br_{Min\_2S}$	305 + 116 = 421 mW
Baseline + Half Screen Brightness	$\beta base_{\_S} + Br_{Med\_S2}$	305 + 479 = 784 mW
Baseline + Max Screen Brightness	$\beta base_{\_S} + Br_{Max\_S2}$	305 + 915 = 1220 mW
Baseline Power Consumption	$[(\beta base_{\_S2} + Aud) + WiFi_{\_S2} + (Br_{Min\_S2}, \ldots Br_{Med\_S2}, \ldots Br_{Max\_S2})]$	

Table 1 displays the energy model for Samsung Galaxy S2 and the setup criteria with the energy model notation and the average power consumption on each of energy model. After the baseline was setup we proceed to the QoE subjective survey to determine the requirement for user QoE preferences.

4.2 QoE Subjective Experiment

In this experiment we choose the subjective approaches for QoE measurement [13]. Research by [5] describe most of the objective quality models rely on subjective test results to train model parameters, therefore these models cannot be widely applied due to limitations of the subjective test. Since the implementation not only on QoS alone, QoE prediction is not the real-environment-situation to capture user QoE.

Table 2. Demographic and Experimental Condition of Three QoE Enviroment

	Study Section A (Brightness)	Study Section B (Resolution)	Study Section C (Frame Rate)
Number of Subject	45	41	48
Age of Subject	Mean = 34.45	Mean = 29.38	30.61
Gender (Male/Female)	F:22 / M:23	F:19 / M:22	F:26 / M:22
MOS Score (Mean)	3.2	3.6	3.3

In Table 2 shows the demographic of respondents on the survey experiments. We follow the standardization bodies (e.g. ITU-T) recommendation Mean Opinion Score (MOS) for determining the user QoE result. The MOS score from 1 (Very Annoying), 2 (Annoying), 3 (Slightly Annoying), 4 (Perceptible but not annoying) and 5 (Imperceptible). Survey setup for determining a respondents result a based from [12]. In the survey, the setup is to determine QoE from smartphone user via content adaptation. The setup is using a smartphone devices (Samsung Galaxy S2) and installed with modify video streaming application. First is generic profiler and second is hybrid energy-aware profiler application. Result from user QoE is divided into three variable; Brightness, Resolution and Frame rate from user preferences. The acceptable value of brightness in percentage between (38 % – 52%). In order to set variant of brightness percentage value, three variable from this survey to define energy acceptable value from brightness. First is 50% for the maximum acceptable value and second is 40% the lowest acceptable value. This values will be used in determine a list of possible solution later.

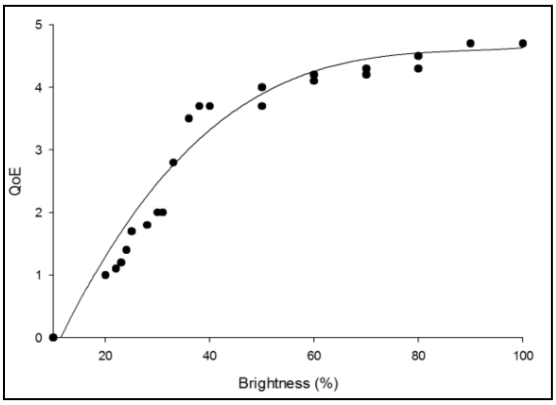

Figure 4. QoE versus Brightness (%) level in MOS

Figure 4 shows the relationship between QoE versus brightness (%) within MOS measurement. From this figure, x-axis displays the percentage of the smartphone device brightness level while y-axis shows the MOS sample from selected users. The graph result starts from 10% of brightness and 1 for MOS (Very Annoying) and highest result is 4.7 (Imperceptible) for 100% of brightness.

The mean score for brightness level is 3.2 and it shows 46% of users selected MOS less than 3 values and the rest 54% choose MOS score 3 and higher. The percentage for the brightness from users QoE is 52% to the lowest value 38%. The acceptable value of brightness in percentage is between (38 % – 52%).

In order to set variant of brightness percentage value, three variables from this survey to define energy acceptable value from brightness. First value is 50% brightness and second value is 40% brightness of the lowest acceptable value. It represents the user QoE toward brightness. It also will be used to determine the list of possible video variation. Figure 4 defines MOS versus resolution in QoE survey measurement.

Figure 5 illustrates the relationship between QoE versus resolution within MOS measurement. X-axis displays the percentage of the smartphone device resolution while y-axis shows the MOS sample from selected users. The resolution in pixels are the standard video streaming available in the mobile device [11], [14]. The respondent for this survey is 41 test subjects.

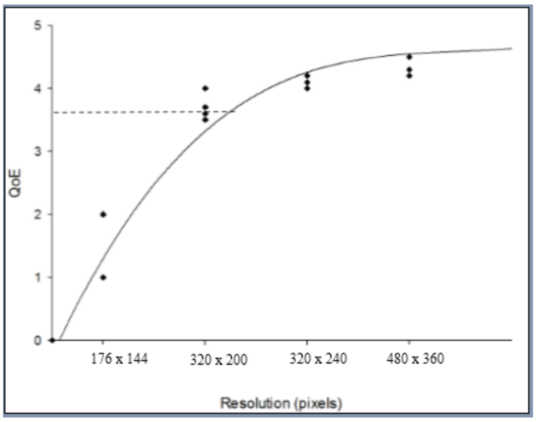

Figure 5. QoE versus Resolution (Pixels) level in MOS measurement

The graph outcome start from 1 for MOS (Very Annoying) and the highest result is 4.5 (Imperceptible) for resolution selected. The mean score for resolution is 3.6. The 320 x 200 pixels resolution is the minimum QoE from user's acceptance and this result will be used to find the possible video variation.

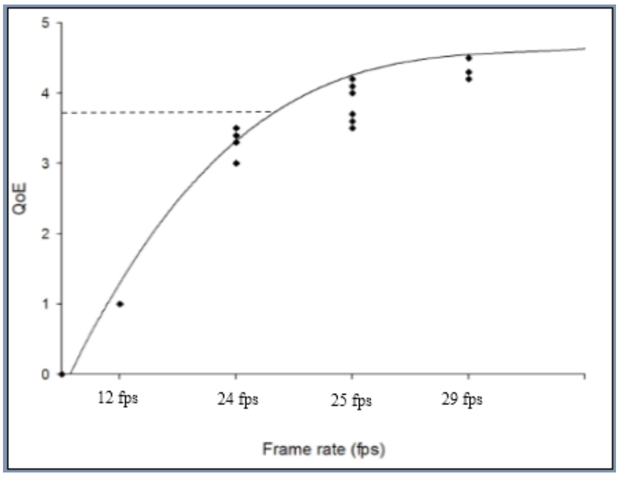

Figure 6. QoE versus Frame rate (fps) level in MOS

Figure 6 describes the relationship between QoE versus frame rates within MOS measurement. X-axis displays the common frame rates available in the video format while y-axis shows the MOS sample from selected users. The frame per second (FPS) value is a video broadcast system standard. 24fps represents the Phase Alternate Line (PAL) video frequency while 25fps and 29fps related to National Television System Committee (NTSC) video broadcasting standard (ITU, 2008). These video broadcast systems later adapted in the mobile device for video streaming propose. The respondent for this survey are 48 test subjects.

The graph outcome starts from 1 for MOS (Very Annoying) and highest result is 4.5 (Imperceptible) for frame rates. The mean score for frame rates is 3.6. The 24 fps frame rate is the minimum QoE from user's acceptance and this result will be used to find the possible solution of video variation.

5. Results and Analysis

5.1 Energy Consumption and QoE Effect on Video Attribute

Another possible variable that affecting energy in mobile devices is the video attributes (e.g. resolution, frame rate etc.). The video quality is certainly influenced by this attribute specifically. In this experiment, the main purpose is to identify the adaptation for video attribute whether it affecting the energy usage in smartphone devices using hybrid energy-aware profiler. In table 4 illustrate a video attribute for content adaptation experiment sampling.

Table 3. Video attribute for adaptation experiments samples

Video Attribute	Low Quality (QCIF)	Average Quality (CGA)	Average Quality (QVGA)	Medium Quality
Video Resolution	176 x 144 pixel	320 x 200 pixel	320 x 240 pixel	480 x 360 pixel
Video frame rate	12 fps	24 fps	25 fps	29 fps
Audio Codec	AAC-LC	AAC-LC	AAC-LC	AAC-LC
Audio Channel	1 (Mono)	2(Stereo)	2(Stereo)	2(Stereo)

The video attribute must be determined with the baseline energy model setup. The result show for the acceptable resolution is 320 x 200 pixel, 320 x 240 pixel, and 480 x 360 pixel. Next is the Frame rate, the minimum accepted list of possible solution is 24 fps, and 25 fps. From the experiment a user's point of view the selected fps relatively higher more than 25 fps. However, in term of energy usage the acceptable fps is not more than 25 fps. The result of

29 fps shows the energy affecting by the content adaptation is high. The constraints for video experiment proposes definitely contribute to the huge power-hungry for the running video streaming application. For example, the duration for the video experiment adjusted to 150 seconds per video (2 minutes and 30 seconds), generic profiler and 24 frame rate cause the energy usage only 55 mW for Samsung Galaxys S2. Imagine the duration of the video for 10 minute. It will cause more energy consumption both of a smartphone devices. Nevertheless, this experiment proves that by applying a simple QoE element (e.g. frame rate) for content adaptation, the energy usage is reduce significantly.

5.2 List of Possible Solution

After defining the variation of energy usage and content adaptation along with user QoE, next step is to determine the list of possible solution. It describe from after profiling energy usage, QoS and QoE, the entire set of possible solution can be listed down. To define all the combination of possible solution, paths' score tree generation proposition is used (Fudzee & Abawajy, 2010). To calculate the proposition the following steps must be followed:

Proposition 1: The maximum number of available paths P(m) to be generated is bounded by equation (4), where n is a number of possible solution available for a particular task, and m is a number of tasks for a particular n.

$$P(m) = 1^{m_1} \times \dots \times (n-1)^{m_{n-1}} \times n^{m_n} \quad (4)$$

Next steps is to determine the list of possible solution using the paths' score tree. From semantic values there have a 3 possible solution from resolution, 2 possible solution from frame rates and 2 possible solution from brightness. As Proposition 1 equation 4.5,

$$P(0) = 1^{0_1} \times \dots \times (3-1)^{0_{3-1}} \times 3^{0_3}\,.$$

$$P(0) = 1 \times (2)^2 \times 3^1 = 12\,possible\ solution$$

From experiments, the final possible solution can be defined as follow:

Resolution = {320x200, 320x240, 480x360}
Frame rates = {24 fps, 25 fps}
QoE energy = {40%, 50%}

Convert the value to semantic values for determine list of possible solution using the paths' score tree, then in figure 5 illustrates the result list of possible solution.

Resolution = {R1, R2, R3}
Frame rates = {F1, F2}
QoE energy = {B1, B2}

The final result after using equation 4 is 12 possible video variation available. From these list of video variation attributes, it is possible to use any of these 12 possible video variation in order to streaming video online. Basically, within the developer perspective, these possible video variation can be used in the server for user to stream video directly without any user device optimization. In the user viewpoint, the possible video variation could be improve in term of software or application used. However, the final result simulated within control environments and scenarios and also using wireless connection. In real situation, it may cause more energy usage while streaming services is running.The focus of this paper was to develop a hybrid energy-aware profiler to obtain a possible solution of suitable video streaming attribute along with the user QoE concern. It also has shown that the hybrid energy-aware profiler indeed can reduce energy usage in the smartphone devices for video streaming tool. In addition, as part of the experimental propose the software measurements tool (*PowerTutor*) is proven useful in accurate for detecting energy usage in the smartphone devices. Furthermore, the contribution on list of possible solution for video attribute can be used for the media content developer to organize proper content or to a user in determining suitable video streaming variation in the future.

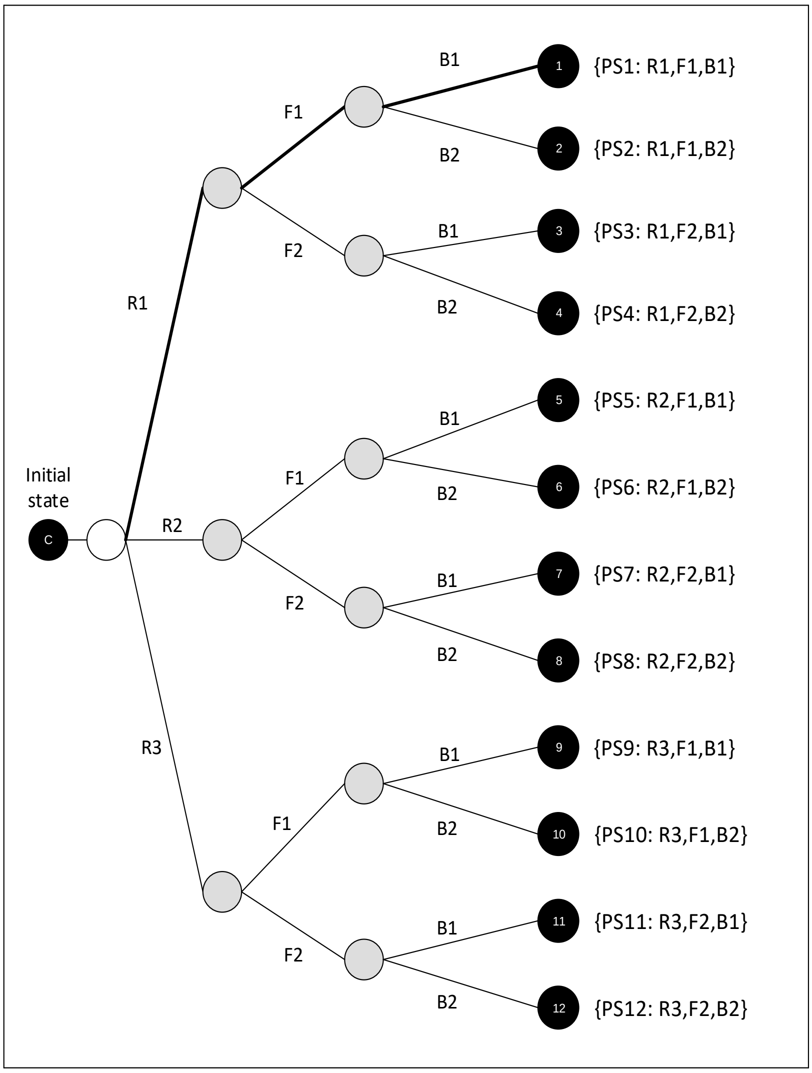

Figure 7. Paths' score tree to determine list of possible solution

4. Conclusion

The experiments evaluate the energy-aware framework with algorithm and hybrid energy-aware profiler application. Content adaptation video attribute and hybrid energy-aware profiler significantly reducing energy usage in video streaming in smartphone devices.

Developing a hybrid energy-aware profiler and implement technique that require an energy awareness for QoE using content adaptation within video streaming. This technique provides an analytical result of what constitutes video quality and how it can be interpreted and measured. It introduces a specific demand on video streaming to satisfy users needed. Next is a list of possible solution via adaptation strategy regarding energy consumption on video streaming. Define the list of possible solution that help to minimize the solution space for content adaptation possibility.

In the future work, the QoE objective model that can predict the user behaviour and determine the best solution towards energy management and user preferences. The model ought to estimate the user desire in order to give the best outcome for their video streaming that satisfy both QoE and energy in the smartphone device.

Remote content adaptation engine that provide read-time choice measurement for media prediction in video streaming. In order to find the best solution for video attribute it has to be triggered automatically to find good video attributes being implemented in the server.

Acknowledgement

The authors would like to thank for the support given to this research by Ministry of Higher Education (MOHE) for the Research Grant FRGS Vot 1238 and UTHM Contract Grant Vot U559. Also, we acknowledge Gates IT Solution for their publication grant.

References

[1] Ardito. L. *Energy Aware Self-Adaptation in Mobile Systems*. Proceeding 35th International Conference on Software Engineering, 2013, pp 1435-1437.

[2] Balasubramanian. N., Balasubramanian. A., Venkataramani. A. *Energy consumption in mobile phones: a measurement study and implications for network applications*. Proceedings of the 9th ACM SIGCOMM conference on Internet measurement conference. Mobile connectivity 8. 2009; 280-293.

[3] Bernal. J. F. M., Ardito. L., Morisio. M., Falcarin. F. *Towards an Efficient Context-Aware System: Problems and Suggestions to Reduce Energy Consumption in Mobile Devices*. Mobile Business and 2010 Ninth Global Mobility Roundtable (ICMB-GMR), 2010 Ninth International Conference. Athens. . 2010; 510-514..

[4] Chen. H., Luo. B., Shi. W. *Anole: A Case for Energy-Aware Mobile Application Design.* Parallel Processing Workshops (ICPPW), 2012 41st International Conference. 2012; 232-238.

[5] Chen. Y., Wu. K., Zhang, Q. From QoS to QoE: A Tutorial on Video Quality Assessment. *Communications Surveys & Tutorials*, *IEEE*. 2015; 17(2): 1126 – 1165.

[6] Chang. H., C., Agrawal. A., Cameron. K. *Energy-Aware Computing for Android Platforms*. International Conference Energy Aware Computing (ICEAC). Istanbul. 2011: 1-4.

[7] Chung. Y. F., Lin. C. Y., King. C. T. *ANEPROF: Energy Profiling for Android Java Virtual Machine and Applications*. International Conference on Parallel and Distributed Systems. Tainan. 2011; 372-379.

[8] *Devlic. A., Lungaro. P., Kamaraju. P., Segall. Z., Tollmar. K. Energy consumption reduction via context-aware mobile video pre-fetching, Multimedia (ISM).* 2012 IEEE International Symposium. 2012; 261-265.

[9] Hoque. M. A., Siekkinen. M., Nurminen. J. K., Aalto. A. *World of Wireless, Mobile and Multimedia Networks (WoWMoM)*, 2013 IEEE 14th International Symposium and Workshops. 2013; 1-11.

[10] Fudzee. M. F., Abawajy. A., Deris. M. M. *Multi-criteria Content Adaptation Service Selection Broker. Cluster, Cloud and Grid Computing (CCGrid)*, 2010 10th IEEE/ACM International Conference. 2010; 721-726.

[11] *I*nternational Telecommunication Union. *Vocabulary and effects of transmission parameters on customer opinion of transmission quality, amendment 2.* ITU-T Recommendation P.10/G.100, 2006.

[12] Ickin. S., Wac. K., Fiedler. M. *QoE-Based Energy Reduction by Controlling the 3G Cellular Data Traffic on the Smartphone*. Energy Efficient and Green Networking (SSEEGN), 2013 22nd ITC Specialist Seminar. 2013; 13-18.

[13] Mitra, K. Zaslavsky, A. Åhlund, C. Context-Aware QoE Modelling, Measurement, and Prediction in Mobile Computing Systems. *Mobile Computing. IEEE Transactions.* 2015; 14 (5): 920 – 936.

[14] Tarkoma. S., Sikkinen. M., Lagerspetz. E., Xiao. Y. *Smartphone Energy Consumption: Modeling and Optimization*. University Printing House Cambridge. 2014.

[15] Peltonen. E., Lagerspetz. E., Nurmi. P., Tarkoma. *Energy Modeling of System Settings: A Crowdsourced Approach*, In Proceedings of the IEEE International Conference on Pervasive Computing and Communications. 2015.

[16] Thiagarajan. N., Aggarwal. G., Nicoara. A. *Who Killed My Battery: Analyzing Mobile Browser Energy Consumption*. Proceedings of the 21st international conference on World Wide Web. 2012; 41-50.

[17] Carroll. A., Heiser. G. *An Analysis of Power Consumption in a Smartphone*. Proceedings of the 2010 USENIX conference on USENIX annual technical conference. USENIX Association Berkeley, CA, USA. 2010; 21-21.

[18] Lide. Z., Tiwana. B., Dick. R. P., Qian. Z.. *Accurate online power estimation and automatic battery behavior based power model generation for smartphones*. International Conference on Hardware/Software Codesign and System Synthesis (CODES+ISSS). Scottsdale, AZ. 2010; 105 – 114.

[19] Zhu. Y., Halpern. M., Reddi. V. J. The Role of the CPU in Energy-Efficient Mobile Web Browsing. *Micro, IEEE 35 (1)*. 2015. 26 – 33.