Learner-Battery Interaction in Energy-Aware Learning Multimedia Systems

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ABSTRACT
Using online multimedia content on mobile devices is a power hungry activity and drains battery power very quickly. This poses a big challenge in using mobile devices with limited battery power for learning purposes using online educational multimedia. Multimedia adaptation techniques have been developed that preserve battery power by lowering multimedia quality. These adaptation techniques do not provide users with any power-saving options and the adaptation is done automatically without involvement of users. In this paper, we propose a Learner-Battery Interaction model that suggests involving learners in the adaptation process. The idea is to provide learners with power-saving options and relevant feedback about the form of adapted multimedia in advance. This will help leaners in making informed power-saving decisions for adaptation. We implemented the model in a prototype system and conducted an evaluation in the form of a user study.

Categories and Subject Descriptors
H.5.2 **[User Interfaces]**: *Interaction styles.* I.3.6: **[Methodology and Techniques]**: *Interaction Techniques*

General Terms
Human Factors, Design, Standardization, Theory

Keywords
Energy-Efficiency, Power-Saving, Multimedia Adaptation, Battery-Efficient Mobile Learning, Power-Saving Interfaces.

1. INTRODUCTION
Mobile devices now come with increased processing and storage capabilities, bigger screens and the ability to communicate with the Internet at higher data rates. These improvements enable mobile users to watch online multimedia in a higher quality. In the era of mobile learning, learners can now afford to use high-quality multimedia learning resources on mobile devices, enabling them to learn anytime and anywhere [1]. Using high-quality multimedia learning resources, however, is a very power hungry activity that drains battery power quickly [14; 15]. Battery lifetime is becoming a major usability concern to mobile phone users. To address the issue of battery efficiency in streaming multimedia applications, many power-saving multimedia adaptation techniques have been proposed [4; 5]. These application layer techniques reduce power consumption by lowering the presentation quality of multimedia [5; 10; 15], changing modality and skipping some less important information contents. All these changes are aimed at reducing the overall data size of multimedia. This helps in reducing power consumption in wireless data transfer and processing. These adaptations may have negative impacts on user experience and on learning activity [8]. It is, therefore, necessary that learners must be given control of the adaptation process and allowed to make informed decisions about battery saving. A learner will know best about their own battery-saving needs. A lower battery status does not necessarily mean that a learner will be out of charge soon, and the current learning activity will be abandoned. Automation in such situations, for example, by degrading the multimedia quality without learner's consent does not provide a better experience. To address these issues, we introduce the concept of Learner-Battery Interaction (LBI) that allows learners to take control of the power-saving adaptation. This means learners are provided with options to select an adapted version based on the feedback provided by the system. This feedback consists of the expected characteristics and compromises of the adapted multimedia and its possible impacts on user experience and learning. In this paper, we first provide some related research work in section 2. We discuss the proposed concept of Learning-Battery Interaction in section 3 and discuss a prototype implementation in section 4. In section 5, we discuss a case study that we conducted to evaluate the prototype system.

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2. RESEARCH BACKGROUND
It is found from the study of the relevant literature of multimedia adaptation techniques [4-6; 11; 17; 18] that they lack options for users to control the adaptation process regarding choosing any acceptable trade-off. Furthermore, there is also lack of feedback to inform the users about the form and characteristics of the adapted multimedia in advance. Without these control options and information, users' satisfaction is not guaranteed. A higher user satisfaction may be achieved if some control is given to users and they decide themselves about either accepting the extent resulting compromise or aborting an activity completely.

Research efforts have been done to enhance battery efficiency, however little has been done regarding how human users deal with limited battery power [2]. A survey in [13] shows that 80% of mobile phone users took various measures to increase their battery lifetime. Rahmati et al. in [12; 13] proposed Human-Battery Interaction (HBI) , which is the study and understanding of users' charging behaviour, battery-indicators, user-interfaces for power-saving settings, user knowledge, and user reactions. A conceptual model of the Human-Battery Interaction is presented in [12]. This explains that the user reads the battery-indicator and assesses the situation using knowledge they have about system power characteristics and their goal in using the device. Based on their knowledge the user interacts with the mobile device's power settings in the hope to meet the goal. Study results in [12] suggest that mobile phone users often have inadequate knowledge on the power characteristics of mobile devices and exposed the inadequacy of state-of-the-art battery interfaces. Heikkinen et al. in [3] also conducted a user survey to understand the user behaviours and expectation about battery management. Their results confirmed the findings of Rahmati et al in [12; 13]. Ferreira et al. in [2] developed an Interactive Battery Interface (IBI) to provide user information about the impact of each running application on battery life and allowed them to abort any application if they wished based on the extent of battery power being consumed by each application and how much they can extend battery-life by aborting any application. Truong et.al in [16] discusses a Task-Centred Battery Interface that provides user information about how different applications affect battery usage and for how long a combination or individual tasks with several applications can be performed.

3. LEARNER-BATTERY INTERACTION

The study of Human-Battery Interaction (HBI) has been limited to the interfaces provided by mobile operating systems and applications that allow information about the battery consumption of all running applications. Furthermore, the only application level options in HBI that allowed interaction were of aborting an application completely, discussed in [2]. HBI does not suggest any options within application about battery savings. We extend the concept of Human-Battery Interaction to include user interaction for power-saving at within applications level, that we call Application-Level Human-Battery Interaction (A-HBI). A-HBI includes understanding and the study of user interaction with power-saving interfaces and information provided in an application that increase user understanding about battery-consumption and to enable them in making informed power-saving decisions. This concept applies to those applications that perform power-saving adaptation by modifying certain aspects of behaviour, output or the way of interaction. These include changing backlight, colours, extent of interactivity, modality and quality of multimedia content and omitting irrelevant or less important details from information, etc.

This paper is focused on a specific application of A-HBI in the domain of educational multimedia adaptation for mobile devices and proposes Learner-Battery Interaction (LBI). The learner has to deal with learning applications. Therefore, in Learner-Battery Interaction (LBI), we consider both the educational and the energy-efficiency aspects. Multimedia learning resources are very costly in terms of battery-power consumption. Energy-Saving multimedia adaptation techniques are based on reducing multimedia presentation quality. As discussed in section 2 little has been done to involve users in the battery-efficient multimedia adaptation process. Adaptation decisions like decreasing quality or reducing information contents are done without involvement of users. LBI proposes that learners must be provided enough information that enables them to make informed decisions regarding power-saving choices. Power-saving settings results in some trade-offs. Learners must be made aware of the extents of these trade-offs and the compromises they would face for each available option. This will enable learners to choose a compromised experience by themselves, based on their goals. This can offer a satisfying learning experience. In figure 2, we describe the Learner-Battery Interaction Model. We discuss learner interaction with power-saving settings in learning multimedia mobile applications. We also focus on what information should be provided to learners to help them make informed battery-saving decisions in order to achieve immediate goals.

In Learner-Battery Interaction a *Power-Saving Interface (PSI)* provides interaction options for battery power saving. The goal of the PSI is to enable informed selection of options by providing a detailed feedback about each available option.

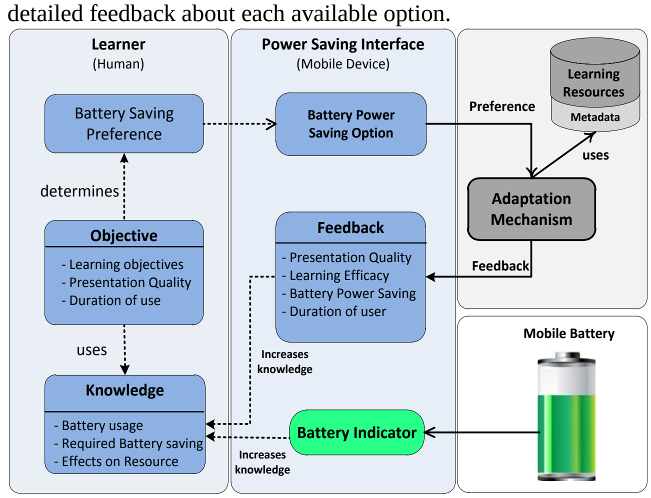

Figure 1: Learner-Battery Interaction Model

A learner chooses a particular power-saving option based on the *Objective* of the learner and the *Knowledge* the learner has about the power-saving options. The first piece of *Knowledge* the learner gets is from the current *Battery-Indicator*. *Knowledge* means the information a learner currently has about different aspects of battery. It includes battery charge status, consumption by running applications and opportunities for power-savings. Importance of such knowledge has been identified in the Human Battery Interaction studies [2; 3; 12]. *Battery-Indicator* gives the learner an idea if they need any power-saving plan for the learning activity. The second factor that contributes in decision making is the *Objective* of the learner. The *Objective* of a learner in simple terms is the goal of the learner for the learning activity. It includes the learning objective, preferences for presentation quality of the learning material, approximate duration of learning, etc.

A learner then wishes to select a *Battery-Power Saving Option* from the Learner-Battery Interface (LBI). LBI provides *Feedback* about each power-saving option to update the learner's *Knowledge* about consequences of each choice he would make. Based on the updated *Knowledge* from the *Feedback*, the learner may alter their *Objective* (and preferences) about the intended learning activity. The learner may decide to select a compromise on quality of presentation, change learning objective for the present time or opt to choose a learning activity of a reduced duration. Some aspects of information that a learner may be interested to get from feedbacks are given below.

- Which option will help most in completing the learning activity?
- How will any option affect presentation quality?
- How much battery saving can be achieved with each option?
- How much will any option extend the battery life?
- Will any option result in negative impact on the learning process?

An appropriate way for conveying this information can be developed that could convey the resulting compromises and benefits. The feedback is the main source of updating learners' knowledge about battery consumption and possible savings. Each power-saving option results in some trade-offs in certain aspects of the application and learning activity. For example, it may result in reduction in presentation quality, modality, duration of learning activity, skipping of certain information, etc. All options must be clearly made available to learners with appropriate descriptions of resulting output. *Power-Saving Preference* represents the option that a learner has currently selected from the set of options. Based on the feedback and goal, the learner may try another option before committing to one final option. The *Adaptation Mechanism* takes power-saving preferences, accesses metadata and provides feedback about the resulting adapted content. In order to have better feedback a detailed and suitable metadata is required [9]. Metadata can, for example, describe which sections of learning contents are less important and can be skipped for a particular learner and which sections can be delivered in alternative modalities etc.

4. PROTOTYPE SYSTEM

We developed a proof-of-concept prototype interface in MoBELearn (Mobile Battery Efficient Learning) system [7]. MoBELearn is an adaptive mobile multimedia learning system that implements our developed Content-Aware Power Saving Multimedia Adaptation (CAPSEMA) [9] approach. The interface in MoBELearn implements the Learner-Battery Interaction Model for learning multimedia application. Screenshots of our prototype MoBELearn application are given in Figure 3. In the system a learner can select their desire level of battery-efficiency based on immediate feedback for each option. Feedback includes the extent of battery-saving to be achieved, change in structure and presentation quality of the adapted multimedia. The battery-saving percentage values given in the figure are not real-time accurate values. The values are displayed in the system for evaluation purposes to convey the way the proposed system would work. In complete applications these values can be calculated with the help of reliable battery consumption model and metadata. Once a learner is happy with any power-saving option, they can go ahead with and start learning from resultant adapted multimedia resource. We designed an experimental study to evaluate the MoBELearn interface that implemented the Learner-Battery Interaction model.

5. EVALUATION

A case study was designed for evaluating the system and the proposed Learner-Battery Interaction concept. For this purpose we recruited 15 volunteers from the Electronics and Computer Science at the University of Southampton. All participants were PhD students with experience of using smart phones. We asked participants to interact with the MoBELearn system, using the interface and then report their experience and opinion using a questionnaire. The questionnaire was designed in a way to understand the participants' perception about different aspects of usability, usefulness and importance of the feedback in LBI. Only one participant was used at a time and all participants were provided the same Samsung Galaxy Note 2 mobile device. The questionnaire consisted of 15 statements about different aspects of the system. Responses were recorded in the form of 5 point Likert scale with Strongly Disagree (1) to Strongly Agree (5). We noted from the results that participants' opinions were positive. Results of the user study are given Table 1. We report responses of 'Strongly Agree' and 'Agree' as positive responses while 'Disagree' and 'Strongly Disagree' as negative responses. To assess the novelty of the mechanism used in the system, we enquired participants in statement S1 if they have used similar systems before. All participants responded with disagreement. This supports the novelty of the concept.

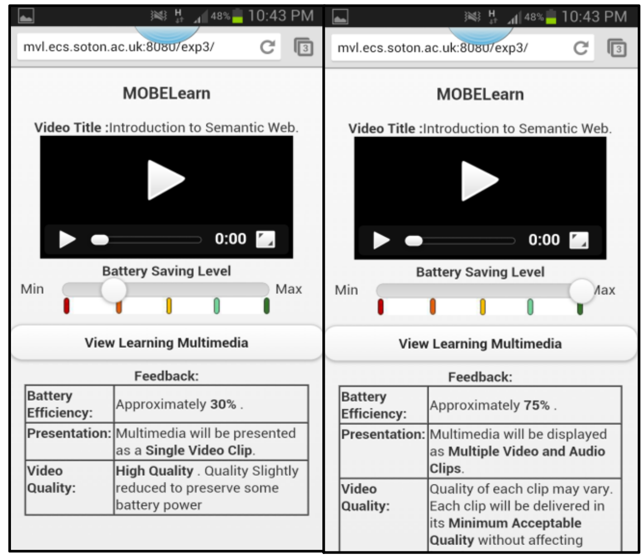

Figure 2: Screen shots from MoBELearn System

In statements S3 to S6 we asked participants to report their views regarding usability and understanding the purpose of the application. All participants responded positively with only one participant responding in neutral for one statement (S5). In statements S7 to S10 we enquired about participants' perceptions about usefulness of the system. Results show that all participants were positive about the usefulness of the system for multimedia learning application. 80% responded positively when asked if they think such systems should be integrated in mobile learning application and 20% responded with neutral responses. Similarly 93.3% responded that they would use such a system in the future if they needed battery saving in such learning scenarios. Statements S11 to S15 evaluated the feedback aspect of the LBI provided by the system. We enquired if they thought they needed more information in the feedback. 86.7% (14) agreed that the feedback provided by the system was easy to understand while 2 participants (13.3%) responded with neutral opinions. For statement S12 about the importance of knowing the impact of battery-saving choices on adapted multimedia, 93.3% (14 participants) agreed. When specifically asked in S13 about if the feedback provided by our system is helpful in selecting a battery-saving option, 86.6% were positive, 14 participants responded positively while 1 responded with a neutral answer. A total of 5 participants (33.3%) agreed in S15 that they needed more information. 3 (20%) participants did not think they needed any further information in the feedback while 7 (46.7%) neither agreed nor disagreed. Based on the results of the study we can conclude that participants were having a favourable opinion about the system and the proposed idea. We also asked participants some optional open questions. Most participants thought the information in the feedback was enough; however, some participants raised important issues. For example, some participants asked for a preview of quality for each option, some preferred to have encoding parameters in the feedback and some asked to know about the resulting extension in battery-life in terms of amount of time duration for each power-saving option.

6. CONLUSION

In this paper, we propose the concept of the Learner Battery Interaction (LBI). LBI extends the concept of Human-Battery Interaction to application level. It proposes a way of interaction and providing power-saving options to users in an adaptive power-saving multimedia learning application. LBI suggests providing learners with information about expected changes in the behaviour of the system for each power-saving option. This enables mobile learners to make informed power-saving choices to increase user satisfaction. We implemented this concept in a prototype mobile multimedia learning system (MoBELearn) and evaluated using a case study.

Table 1: Evaluation results

	Statement	Strongly Disagree 1	Disagree 2	Neutral 3	Agree 4	Strongly Agree 5	Mean	Std Div.
S1	I have used similar systems before	9 60%	6 40%	0	0	0	1.4	.57
S2	I am aware of other methods that can help me save battery power in mobile multimedia streaming applications.	6 40%	5 33.3	0	2 13.3%	2 13.3%	2.27	1.486
S3	I understand the overall purpose of this application	0	0	0	5 33.3%	10 66.7%	4.67	.488
S4	This application is easy to understand.	0	0	0	7 46.7%	8 53.6%	4.53	.516
S5	This application is easy to use on touch screen mobile devices.	0	0	1 6.7%	7 46.7%	7 46.7%	4.4	.632
S6	I am comfortable with use of the Slider Control for selecting battery saving options	0	0	0	9 60%	6 40%	4.4	.507
S7	This application is useful for preserving mobile battery-power in multimedia learning	0	0	0	8 53.3%	7 46.7%	4.47	.516
S8	I agree to the way this system addresses the problem of battery consumption in learning multimedia	0	0	2 13.3%	10 66.7%	3 20.0%	4.07	.594
S9	Such application should be integrated in mobile learning systems.	0	0	3 20.0%	8 53.3%	4 26.7%	4.07	.704
S10	I would use such a system in situations where I need to save battery power.	0	0	1 6.7%	9 60.0%	5 33.3%	4.27	.594
S11	The feedback provided is easy to understand	0	0	2 13.3	9 60.0%	4 26.7%	4.13	.640
S12	Knowing the impact of battery saving choices on multimedia through feedback is important	0	0	1 6.7%	10 66.7%	4 26.7%	4.13	.743
S13	The feedback provided is helpful in making informed decision about battery saving choices	0	0	2 13.3%	8 53.3%	5 33.3%	4.20	.676
S14	I am satisfied with the feedback provided by the system	0	0	1 6.7%	11 73.3%	3 20%	4.13	.516
S15	I need more information in the feedback	2 13.3%	1 6.7%	7 46.7%	5 33.3%	0	3.00	1.00

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