Increasing Learner's Experience trough Power-Based Adaptation of Educational Content Selection and Delivery

Arghir-Nicolae Moldovan and Cristina Hava Muntean
School of Computing
National College of Ireland
Mayor Street, IFSC, Dublin 1, Ireland
E-mail: amoldovan@student.ncirl.ie, cmuntean@ncirl.ie

Abstract—**Since battery still represent a constraint resource for mobile devices, mobile learning users are often forced to interrupt their learning activity because of low power situations. This paper analyses for the first time the need for a power saving solution in adaptive m-learning systems. Testing results show that battery life can be extended by varying some of the parameters of a video clip, such as encoding scheme, resolution, frame rate and bitrate. Preliminary subjective tests assess the effect of these variations on learner's Quality of Experience.**

Keywords—**mobile learning, power save, content adaptation**

Paper Type—**Research**

1 Introduction

The latest improvements in the areas of information and communication technologies have contributed significantly to the appearance and development of new ways in which people learn. E-learning has brought revolutionary changes in education when it first introduced technology-enhanced distance learning.

Since educational content is often a rich mixture of media that includes video, audio, images, animations and/or text, its delivery and displaying requires significant resources such as network bandwidth and client-side processing power. Additionally the increase in the number of wireless broadband networks deployed and the improvements in mobile devices performance make possible for the learners to access rich multimedia educational content using their everyday mobile devices such as laptops, smart phones or PDAs almost anywhere and anytime.

However mobile devices rely on portable power source, such as batteries, whose improvement did not follow the exponential trend of other mobile device components. An e-learning activity can drain serious amount of battery power, especially when video streaming is involved. Running out of battery before finishing a learning activity (such as watching an educational multimedia clip or listening an educational podcast) due to low power situations can impact negatively the users' satisfaction with the mobile learning system but also may reduce significantly their learning outcome.

Solutions like carrying a backup battery or opting for a higher battery capacity are not welcomed by everybody, because they add extra cost and weight in a context characterised by the trend of miniaturisation.

This paper describes a new challenge for mobile learning and presents the results of a study that was conducted in order to find out what factors have a high impact on battery consumption and could be used as part of a solution to this challenge. This solution could prevent an interruption of the learning activity due to low battery levels and allow learners to complete their current lesson or task by managing the available power resources.

Experimental tests were conducted in order to find out which factors have higher impact on battery consumption. As multimedia content (video in particular) puts the highest pressure on battery level, these tests focused on finding how much power save can be achieved by modifying some characteristics of a video file. Preliminary subjective tests were also conducted in order to investigate how learners perceive the modifications performed on these video clips and how much they were affected by them.

The remainder of the paper is structured as follows. In section two, research efforts in the area of power saving are listed. Section three presents the tests performed, the results obtained and a discussion about them, whereas at the end conclusions are drawn and future work directions are indicated.

2 Related Work

Mobile learning (m-learning) came along with many advantages for the learners who have now more control on their learning schedule and on their learning environment. At the same time many technological but also educational challenges had to be faced. Personalisation of educational content came as a solution to improve the flexibility, the feedback and the evaluation of adaptive m-learning systems (Sharples 2007).

Much research has been conducted in the area of adaptive mobile learning and various solutions were proposed for educational content personalisation. Different learner characteristics were considered as important input in the personalisation process. Some of these characteristics are user preferences, goals (Clifford 2000), but also their knowledge level (De Bra et al. 2003), skills, culture and other educational contextual learning parameters (Sampson & Karagiannidis 2002).

Another research (Muntean & McManis 2006) has shown that by extending the standard educational Adaptive Hypermedia Systems to consider user Quality of Experience, significant improvements can be achieved in terms of learning performance but also in terms of learning task execution time.

Delivering learning content to mobile devices requires m-learning applications to be able to run efficiently on a multitude of platforms that can differ in terms of screen size, processing power or operating system. Device characteristics were also addressed in the personalisation process along with learners' characteristics (Meawad & Stubbs 2008; Zhao & Okamoto 2008).

Although much research was performed in personalised learning and there is a clear evidence that mobile device battery power plays a key role in m-learning, no study has assessed how device battery affects the learner in a low power condition and did not consider the learner device battery level in the personalisation process.

On the other hand battery still represents a constrained resource for mobile devices. This combined with complex multimedia tasks that use at the same time components like screen, speakers, CPU, memory and Wireless Network Interface Card (WNIC), can drain very quickly the power from the battery.

Due to this limitations power saving solutions in wireless networks have become a necessity and much research has been done in this area. In addition to the energy conservation techniques which are largely considered in the hardware design of mobile devices and their components, power save can be obtained by incorporating low-power strategies into the design of network protocols used for data communications (Jones et al. 2001) or by coordinating the adaptation of system layers like CPU hardware, operating system scheduling, and multimedia applications quality based on user preferences (Yuan et al. 2006).

Various power saving techniques were proposed for the particular case of multimedia streaming to mobile devices over IEEE 802.11 Wireless LANs. These solutions concentrate on particular aspects such as on the WNIC (Wei et al. 2006), on the encoding scheme (Zhao et al. 2006) or on the mobile device screen (Pasricha et al. 2003). Another solution goes further and combines specific power save mechanisms for all three stages of the multimedia streaming process: reception, decoding and playing into an algorithm with significant increase in battery lifetime (Adams & Muntean 2007a, b).

Even if most of the techniques have good results in terms of power saving, they did not consider how learners perceive the modifications in the delivered material, a very important aspect from a learning perspective.

Unlike them, this paper bridges two well researched areas: personalised m-learning and power saving in mobile devices. It looks at some possibilities of saving battery power but also how a learner perceives the low power situations and the modifications in the quality of the learning material.

3 Power Saving Effect of Different Video Characteristics

3.1 Test Setup

Video playback is a more energy intensive task in comparison with other media types. A number of experimental tests were run in order to determine how different parameters of a video influence the battery consumption. A Dell Axim PDA with 520 MHz processor and Windows Mobile operating system was used to play multiple versions of an educational video clips. These versions were encoded with different encoding schemes, using the 'AVS Video Converter' (n.d.) software.

The following video clip parameters were considered:

- format type (including video and audio compression);
- resolution;
- frame rate;
- average bit rate.

In all test situations the screen brightness and sound volume (both of the device and of the media player) were set to 100%. The sound was encoded stereo, with a sample rate of 48 KHz, a sample size of 16 bit and a bit rate of 48 kbps.

If no otherwise specified, the video clips used had the following characteristics: format – mp4, video compression – H.264, resolution - 320x240, frame rate – 25 fps and average video bit rate – 720 kbps.

Each version of the video was played for 31 min 45 sec. During playback, battery-related information, such as current and voltage were saved every 1 sec. Te information gathered was processed offline and analysed later on.

3.2 Scenarios and Results

A first set of tests were carried out in order to see which one of some common video formats and encoding schemes is the most energy efficient. The original video was converted in five other video formats which differ by file type and/or video compression technique, as presented in Table 1. The results show that for example using the *MPEG4* video compression instead of *H.264* video compression, an increase of approximately 28% in battery life, or 8.83 minutes extra playing time, can be achieved in given testing conditions. Results also show that battery consumption is also impacted by the container used to encapsulate the audio-video sequence. For example in case of H.264 video compression, there is a slightly improvement of 3.5%, or 1.11 minutes in playing time, if the *mp4* container is used as opposed to *mov* container.

Table 1. Video format energy efficiency

Video Format	Avg. Current Drain [mA]	Battery Power Save [%]	Time Improvement [mins]
avi (MPEG4)	268	27.8	8.83
flv (H.263)	306	17.5	5.56
wmv (VMV9)	340	8.4	2.67
mp4 (H.264)	358	3.5	1.11
mov (H.264)	371	0.0	0.00

Battery life can be also improved by decreasing other parameters like: video resolution, frame rate or average bit rate. Testing scenarios two, three and four considered these parameters and have assessed the effect of battery life span when different values of these parameters were used. The results of the tests corresponding to these scenarios are summarised in Table 2, Table 3 and Table 4, respectively. Changes in average bit rate has significantly lower impact on battery life comparing with changes in video resolution or frame rate. However in all situations, modifications of video clip parameters had impacted the battery power life.

Table 2. Video resolution effect on power consumption

Resolution [pixel x pixel]	Avg. Current Drain [mA]	Battery Power Save [%]	Time Improvement [mins]
240x180	301	25.7	8.15
320x240	334	17.6	5.58
480x360	405	0.0	0.00

Table 3. Frame rate effect on power consumption

Frame Rate [fps]	Avg. Current Drain [mA]	Battery Power Save [%]	Time Improvement [mins]
15	274	22.2	7.05
20	316	10.4	3.29
25	353	0.0	0.00

Table 4. Average video bit rate effect on power consumption

Bit Rate [kbps]	Avg. Current Drain [mA]	Battery Power Save [%]	Time Improvement [mins]
180	312	12.2	3.89
360	336	5.3	1.69
720	355	0.0	0.00

3.3 Preliminary Subjective Tests

In order to see how learners perceive the effect of modifications in some video parameters, preliminary subjective tests were conducted on a small group of participants. Four video sets were prepared; in each set the videos had one of their parameters varied such as video encoding, resolution, frame rate or bit rate, whereas the other ones were maintained constant. After watching the videos the participants were asked to rate their perceived quality on the 1 to 5 Likert scale (i.e. 1 -Poor, 5 -Excellent.) Preliminary results have shown that some of the solutions which could provide the highest energy saving correspond to lower video quality which affects learner quality of experience and may not be suitable in a learning environment. For example for the video clips encoded at a resolution of 240x180 which brings a battery saving of approximately 26%, the average user perceived quality as graded by learners was 2.17 on the 1-5 scale, whereas for the 320x240 was 4.17 and provided a good battery saving of almost 18%. Similar results were obtained when varying the bitrate, frame rate and encoding scheme. Detailed results of the subjective tests will be presented in another paper.

4 Conclusions and Future Work

This paper investigates power saving in mobile devices used by m-learners. Starting from the premise that video playback is one of the most intensive energy tasks that can occur during a mobile learning session, the paper shows that battery life can be extended by varying some of the video parameters such as encoding scheme, resolution, frame rate and bitrate.

Preliminary subjective tests were run in order to investigate learners' perception of video clip quality when various modifications in video parameters are employed.

Future work will extend the analysis of possible power saving techniques for the case when videos with different properties are streamed to the device over the wireless network.

The research goal is to devise a power saving algorithm that will complement the functionality of already existing adaptive mobile learning systems and will assist learners engaged in a learning activity in case of low power situations.

Acknowledgements

The support of Science Foundation Ireland is gratefully acknowledged.

References

Adams, J. & Muntean, G., 2007a. Adaptive-Buffer Power Save Mechanism for Mobile Multimedia Streaming. In *Communications, 2007. ICC '07. IEEE International Conference on*. pp. 4548-4553.

Adams, J. & Muntean, G., 2007b. Power Save Adaptation Algorithm for Multimedia Streaming to Mobile Devices. In *Portable Information Devices, 2007. PORTABLE07. IEEE International Conference on*. pp. 1-5.

Clifford, R., 2000. Adaptive Hypermedia for Music Instruction. In *7th International Technological Directions in Music Learning Conference*.

De Bra, P., Aerts, A., Berden, B., De Lange, B., Rousseau, B., Santic, T., Smits, D. & Stash, N., 2003. AHA! The adaptive hypermedia architecture. In *Proceedings of the fourteenth ACM conference on Hypertext and hypermedia*. ACM Press New York, NY, USA, pp. 81-84.

Jones, C.E., Sivalingam, K.M., Agrawal, P. & Chen, J.C., 2001. A Survey of Energy Efficient Network Protocols for Wireless Networks. *Wireless Networks*, 7(4), 343-358.

Meawad, F. & Stubbs, G., 2008. A framework for enabling on-demand personalised mobile learning. *International Journal of Mobile Learning and Organisation*, 2(2), 133-148.

Muntean, C.H. & McManis, J., 2006. End-User Quality of Experience Oriented Adaptive E-learning System. *Journal of Digital Information*, 7(1).

Pasricha, S., Mohapatra, S., Luthra, M. & Dutt, N., 2003. Reducing backlight power consumption for streaming video applications on mobile handheld devices. *ESTIMedia, CODES-ISSS*.

Sampson, D. & Karagiannidis, C., 2002. Personalised Learning: Educational, Technological and Standardisation Perspective. *Interactive Educational Multimedia*, 4.

Sharples, M., 2007. Big Issues in Mobile Learning: Report of a workshop by the Kaleidoscope Network of Excellence Mobile Learning Initiative. *Learning Sciences Research Institute, University of Nottingham*.

Wei, Y., Bhandarkar, S.M. & Chandra, S., 2006. A Client-Side Statistical Prediction Scheme for Energy Aware Multimedia Data Streaming. *IEEE TRANSACTIONS ON MULTIMEDIA*, 8(4), 866-874.

Yuan, W., Nahrstedh, K., Adve, S.V., Jones, D.L. & Kravets, R.H., 2006. GRACE-1: Cross-Layer Adaptation for Multimedia Quality and Battery Energy. *IEEE TRANSACTIONS ON MOBILE COMPUTING*, 799-815.

Zhao, X. & Okamoto, T., 2008. A Device-Independent System Architecture for Adaptive Mobile Learning. In *Advanced Learning Technologies, 2008. ICALT '08. Eighth IEEE International Conference on*. pp. 23-25.

Zhao, X., Tao, P. & Yang, S., 2006. The Analysis of Offloading H.264 Video Encoder on Mobile Devices for Energy Saving. In *Systems, Man and Cybernetics, 2006. SMC '06. IEEE International Conference on*. pp. 4315-4320.

'AVS Video Converter' - a universal AVI to MPEG Converter, AVI to DVD Converter n.d., Available at: http://www.avs4you.com/AVS-Video-Converter.aspx [Accessed April 27, 2009].