PERFORMANCE AWARE AND COST ORIENTED ADAPTIVE E-LEARNING FRAMEWORK

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ABSTRACT

Nowadays learners have access to multiple wireless networks from the same hand held device challenging them to choose the best network in terms of cost and performance. However, the Internet billing plans are still difficult to understand, predict and control by most users. This paper presents a user oriented adaptive e-learning framework which takes into consideration: (i) the learner profile when content adaptation is done, (ii) user device that can have multiple wireless connections with different characteristics, (iii) how much the learner is willing to pay, and (iv) the network delivery performance. The goal is to ensure that the learner gets educational content that best suits his/her profile and that content will be delivered over the network which assures the best delivery performance, maintaining also a small price for getting the requested information.

KEYWORDS

Adaptive and personalised e-learning, wireless connectivity, budget, framework, user modelling

1. INTRODUCTION

The amount of information which we need to process in everyday life has increased tremendously over the past years. However the time we have at our disposal to handle this information has remained the same. As a result, having the right information at the right time as quickly as possible becomes a necessity. Two main directions make this possible: AH (Adaptive Hypermedia), which allows content personalisation and adaptation to the learners needs, and technological innovation which brings to market new and powerful mobile devices with low prices and provide support for access to multiple wireless networks that may be enabled.

Hand held wireless devices make information easier to access. Their popularity is also increasing; studies showing that in some countries, for example in Australia, they surpass the number of desktop computers (Al-khamayseh & Lawrence 2005). Today, more than half of the world population has a mobile device (Shuler 2009). Mobile phones are becoming ubiquitous for the younger generations, the children under 12 being the fastest growing segment of population who owns a mobile device (Shuler 2009). A study performed in 2006 at Australian universities has shown that 96.4% of the students have unlimited access to mobile devices (Kennedy 2008). Therefore, because of their widespread existence and with the development of newer wireless protocols and technologies, mobile devices can assure ubiquitous access to information.

Unfortunately, most of the information we receive through web pages is created following the "one size fits all" approach which makes desired pieces of information more difficult to find and most of the time not presented in a manner which suits the current learner. AH researches responses to this problem by trying to offer personalised information to each learner and guiding him to the information he is looking for. It has

been shown that by following different strategies, that involve adaptation and personalisation, the time required for a user to find certain information decreases (Kaplan 1993). Also adapting the content to the user prerequisites makes it easier for him to understand the provided information.

Different AHS (Adaptive Hypermedia Systems) have been developed so far, mostly in the field of education. These systems take into account different aspects related to the user such as: knowledge (Yudelson et al. 2008), goal (Karampiperis & Sampson 2005), learning styles (Brown et al. 2006), learner device (Brady et al. 2004), prerequisites and experience (De Bra et al. 2006), network conditions (Muntean 2008), etc during the adaptation process. All these systems were developed with the goal of increasing the learning outcome and improving the learner QoE (Quality of Experience). However, none of these systems have taken into account the cost the learner has to pay for the network access, neither do they take into account the possibility for the learner to have multiple connectivity to different wireless networks.

2. COST AND QUALITY OF EXPERIENCE

An increasing number of modern mobile devices allow users to connect to multiple wireless networks, through various technologies. Examples of such devices are:

- PDA O2 XDA Zinc has access to 3G, WiFi and GPRS;
- HTC TyTN II has access to HSDPA/UMTS, WiFi, GSM, EDGE and GPRS;
- HTC P3300 has access to GSM/GPRS/EDGE and WiFi;
- Mobile Pocket PC-i-mate Jasjar has access to GPRS, WiFi, etc.

From the multiple networks that learners have access to they need to choose the one which best suits their goals (Figure 1). The diversity of billing plans does not make this task easier. In the best case the learner has access to a free AP (Access Point) to which s/he can connect. Another good connection option is when the learner has a monthly flat plan for a cellular network. However, the billing plans on mobile devices are usually based on the duration of the connection, the quantity of information uploaded or downloaded or sometimes even a combination of all these. These billing profiles could vary also based on the network performance, one factor being the connection speed. Even though a monthly flat rate for access to the Internet is quite common for wired LANs, the most common pricing scheme for wireless communications is flat rate bundle (Telecoms Pricing 2008). Wireless networks still have stringent limitations on resources; mobile carriers being sceptical about a flat plan when it comes to mobile data traffic because the networks can become quickly congested (Roto et al. 2006).

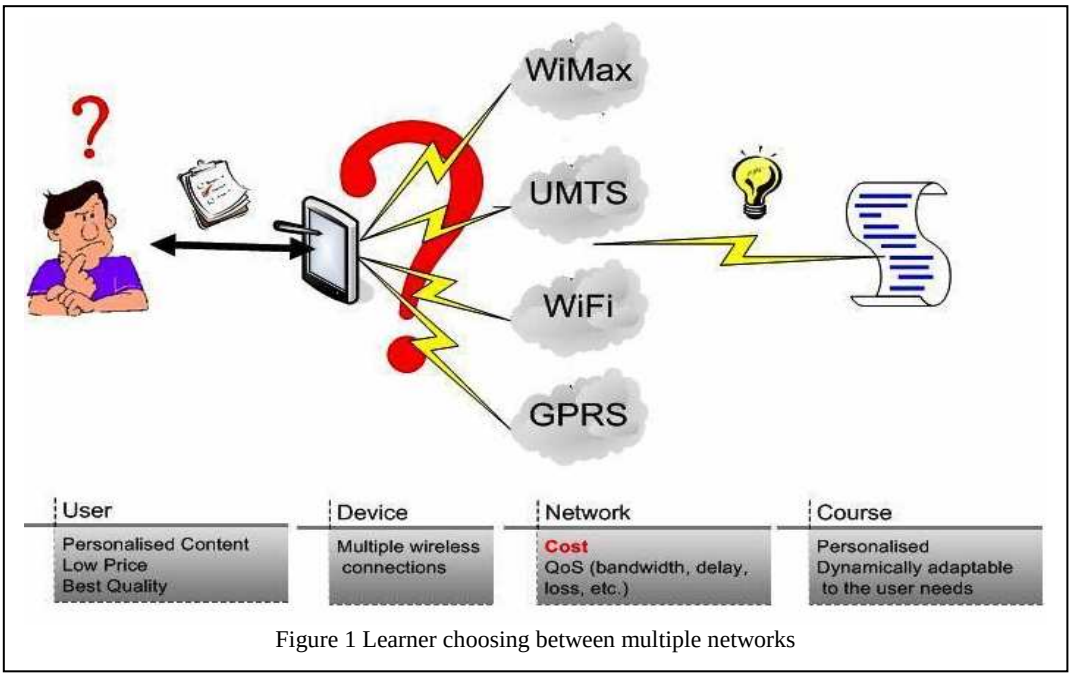

Figure 1 Learner choosing between multiple networks

Outside the learning arena there are many research efforts that study the effect of Internet billing on user satisfaction (Altmann & Varaiya 2001; Hinman et al. 2008; Shenker et al. 1996). In general, people try to estimate how much they spend based on previous experiences; leading to wrong estimations on the amount of money they currently owe (Roto et al. 2006; Isomursu et al. 2007).

The diversity of billing schemes for mobile data access, concerns about cost transparency, and difficulty to estimate how much a learner spent when using the Internet make the cost estimation a challenge for most users. Unfortunately, taking into account just the price needed to pay for delivery of the educational content is not enough in choosing a network. Wireless networks have different characteristics such as: bandwidth, latency, coverage area, QoS, etc that change dynamically. What has been a network over which the educational content can easily be transported can quickly become a congested network, which causes delays and affects the integrity of the educational content. Choosing the right network involves most of the time, engineering knowledge and this effort is time consuming for the learner. Therefore there is a need for an automatic mechanism that assesses the learner billing plan, and examines the features of the enabled networks for accessing the content.

3. PERFORMANCE AWARE AND COST ORIENTED E-LEARNING FRAMEWORK

In order to increase user satisfaction four approaches have been taken into consideration for the PACO-eLF (Performance Aware and Cost Oriented e-Learning Framework):

- personalisation based on the learner profile;
- personalisation based on learner device;
- content adaptation according to the network conditions ;
- the amount of money the learner is willing to spend in order to retrieve the educational content by the e-learning system.

The goal is to select educational content that best suits learner profile and device and to deliver it over a network that achieves the best trade-off between cost and performance. This addresses mainly the learners who have a device that can connect to multiple networks. It also aims at helping the user to decide which network would offer satisfactory performance for retrieving the educational content without affecting the learning process, maintaining at the same time the cost under a threshold imposed by the user. It also tracks the network conditions and when the network performance is too poor to support the transmission, it helps the user in deciding which network is the best one to switch over to. Next the proposed framework is presented.

Even though there is no standardised architecture, most adaptive e-Learning systems have the following three components: DM (Domain Model), UM (User Model) and AM (Adaptation Model). This classic architecture has been enhanced with the PM (Performance Model) (Muntean 2008; Muntean & McManis 2006), that aims to address network delivery performance issues. The proposed PACO-eLF (Figure 2) adds a CM (Cost Model) that models the pricing profiles the learner has for the networks s/he has access to. It also monitors the enabled network to see whether there are changes in the billing plan the learner has to pay in order to retrieve the educational content. In order to allow for the manipulation of multiple networks and for the different cost associated with them, changes were required also to the other components such as UM, AM, PM.

CM, UM, DM, AM and PM are divided between the *Client Application (*CA*)* and *Server Application (*SA*)*. The *Client Application* maintains information about the billing plans of the networks the device has connectivity to (CM) as well as information related to network performances (PM). It monitors and triggers events that account for changes in the network conditions that could affect the amount the user is spending for retrieving the course when this change is greater than the threshold imposed by the user. If this happens, based on the characteristics of the other networks the user has access to, the cost of the networks the user has available is computed. Then it requests from the SA information related to the educational content. The SA decides which educational content is suitable for the learner based on his profile and the network characteristics obtained from CA. A ranking of the networks based on the educational content that needs to be sent to the learner, the network performances and the price for retrieving the educational content is given. The decision of which network to be chosen belongs to the learner.

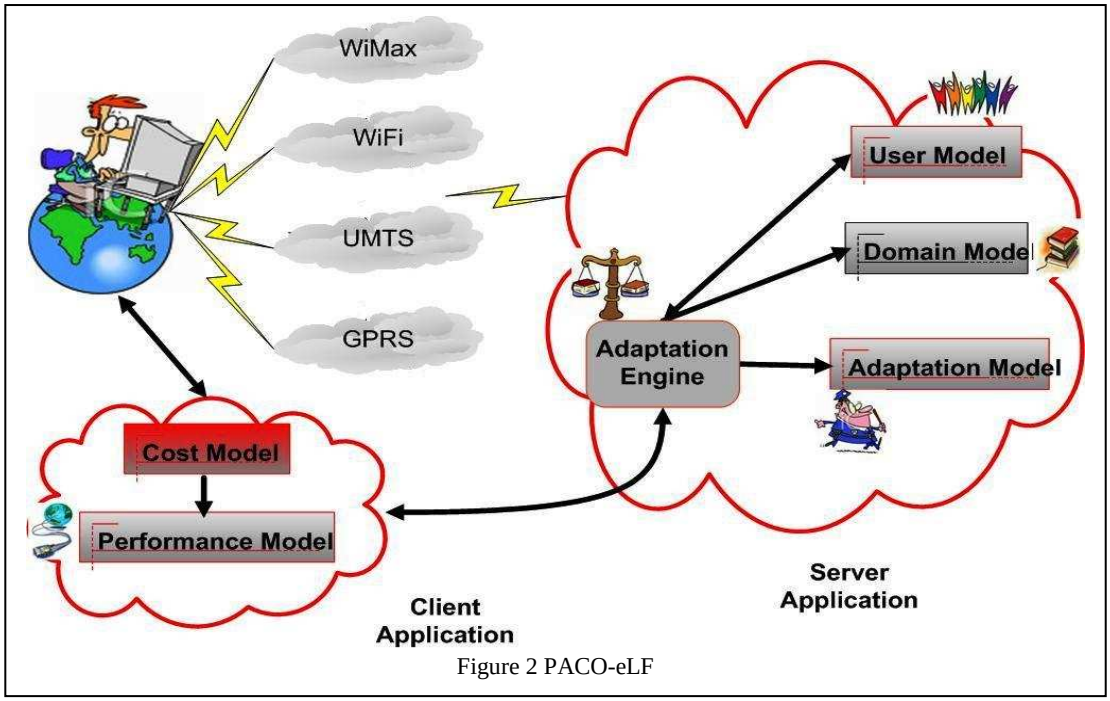

Figure 2 PACO-eLF

3.1 User Model

The UM (User Model) maintains data about the user. This could be Domain Dependent Data (DDD) or Domain Independent Data (DID) (Martins et al. 2008). The DDD contains information about the user related to the topics defined in DM (Domain Model) such as the knowledge the learner has acquired during the usage of the system, the learner navigation history etc.

DID contains general information and/or psychological information about the learner (Kobsa 2001). The general profile contains demographic data (e.g. age), personal information (e.g. name, password), whereas in the psychological profile we would have information such as learning styles, cognitive capacities, etc. It also contains learner's device related information such as:

- *Screen size*: width and height in pixels;
- *Screen colour depth*: bits/pixel;
- *Screen mode*: it refers to whether the screen has portrait or landscape mode and if it supports switching between them;
- *Capabilities*: whether the device is capable of displaying video, audio or images, etc;
- *Supported mark-up or scripting language*: e.g. not all mobile devices support all JavaScript functions;
- *Memory:* capacity.

DID has been enhanced in order to contain the maximum budget the user is willing to spend for getting the course over the network, and a list with the IDs of all enabled networks the learner's device has access to. The learner may connect from his device to multiple networks each of them with different characteristics.

The information related to the user is obtained both through registration (such as the personal data about the user, the budget he is willing to spend, etc) and through online forms or questionnaires (e.g. user budget modifications, etc) or by monitoring the user behaviour (e.g. the pages the user has visited).

3.2 Domain Model

The DM (Domain Model) represents the knowledge of the system. It maintains fragments of information, called LO (Learning Objects) and the relationships which exist between them. The types of relationships considered are:

- *Link*: indicates that between those fragments navigation can be done.
- *Prerequisites*: describes that there is an order in which the fragments should be delivered to the learner (e.g. a learner should not read about a certain concept if s/he has no knowledge or if h/she didn't read first about the *prerequisite* concept).
- *Inhibitor:* suggests fragments which should not be sent to this particular learner.

Fragments can be grouped together in order to form complex concepts, which can be grouped again in even more complex concepts. A fragment has associated metadata which describes different characteristics of the LO such as the topic or information related to the quality and the type of information associated with the learning object. The LO may also contain information related to the price the user may need to pay for that learning object. During content creation time, different versions of the same fragment are made, differentiated by the metadata associated with each of them. Different versions may be necessary when the network performance of the learner is so poor that transmitting the educational content over it could cause major delays, and/or also the integrity of the content can be affected. In these cases, a version with a lower quality but which does not affect the learning process, may be sent to the learner. It has been shown that slightly changing the video quality does not affect the learning process (Ghinea & Chen 2006). Different attributes are maintained for each fragment based on the fragment type (a video will have different metadata associated with it than a piece of text). Three types of data are considered:

- *Text* files metadata*: size* (kilobytes), *length* (number of words), *format* (e.g. plain text).
- *Image* files metadata: *size* (kilobytes), format (e.g. jpg), resolution (pixels).
- *Video* files metadata: *bitrate* (megabits per second), *framerate* (frames per second), *resolution* (pixels), *colours* (number of colours represented in bits required for encoding), *encoding* (encoding scheme: e.g. MPEG4).

3.3 Adaptation Model

The main function of the AM (Adaptation Model) is to hold adaptation rules that establish the most suitable content to be delivered to the learner. The AM has been enhanced by allowing rules which permit a content adaptation based also on the budget the user is willing to spend on that specific course. The AM rules, make references to the content maintained in UM, DM and PM. These rules are interpreted by the AE and the content which satisfies these rules is sent to the learner. A simple rule on how the DM performance oriented metadata is used in the adaptation process is presented. Information about the network performance is kept in the PM and provides information on both the minimum size (*PM.size.minValue*) and the maximum size (*PM.size.maxValue*) of the suitable file. The rule contained in the AM would be: *IF (DM.polymorphism_video_Version2.size > PM.size.minValue && DM.polymorphism_video_Version2.size < PM.size.maxValue) THEN {DM. computer_science.polymorphism_video_Version2}.*

3.4 Performance Model

The PM (Performance Model) contains suggestions on how the content should be adapted in order to address the changes in the network performances. The performance of the enabled networks are continuously monitored and based on the current conditions; a set of suggestions is given. A suggestion includes how many objects can be on a page, what size they may have, etc. Because the network conditions could cause delay and compromise the educational material, sending the user a material with lower quality could be desirable. The idea is to provide the user with the best educational content that the network conditions allow.

3.5 Cost Model

The cost model functionality is two folded: to maintain the billing plans the learner has for different networks and to manage the network price variations. The billing plans the user has for a given network may vary over a time period. For example, if a user has a time based plan, the price may vary during the same day. It could be more expensive during the working hours and less expensive during the night. It can also vary based on the day of the week, being less expensive during the weekend than during the working days.

The information about the networks the user has access to and their corresponding billing policy can be modified at different points. During the registration process the learner may introduce the plans for the networks s/he has access to. Modifications in the Internet networks structure and plans can be made at any time, from the PACO-eLF system.

The cost for every network is calculated for the first time when the application starts. Based on the network conditions and on the billing policy, the learner is provided with the cost required to retrieve the educational content for every network s/he has access to and a ranking based on the suitability, on the network conditions and cost. The learner has the final decision on the network that is to be chosen. However, the learner may be asked to reconsider his/her decision in two cases: when due to the network performance the price may increase over the limit imposed or the network performance is too poor for the educational content to be transmitted over it.

3.6 Adaptation Engine

The AE (Adaptation Engine), based on the rules from the AM, selects the content tailored to the learner interest, network performance and device. The adaptation rules are based on the information contained in the UM, DM, PM and CM.

The adaptation is done in three steps:

- the educational content the user will be provided with is chosen based on learner profile stored in UM (e.g. the learner goal, the knowledge s/he has about the subject willing to be studied, etc.)
- the LO referring to the educational content chosen in the first step is adapted for the learner device. If there is no LO version which exactly matches the learner device, the most appropriate one is chosen (for example, a content which is suitable to a PDA, can also be seen on a tablet PC, even if it is not desirable).
- the versions of the LO chosen in the second step are verified for suitability of transport over the network the learner is currently connected to. The selection is based on the suggestions made by the PM.

4. EXEMPLIFICATION

A learner having a PDA O2 XDA Zinc has access to 3G, GPRS or WiFi. S/he uses PACO-eLF application with the aim of improving his/her French Vocabulary. The lesson s/he is about to study: *Travel and Directions* contains html pages and a video which gives a real example about how the expressions and explanations introduced in the first part of the lesson may be used. The size of the lesson is 3 MB.

The learner is in the coverage area of the following operators (Figure 3): *O2* (3G), *Meteor* (GPRS), *Vodafone* (3G), *Three (3G).*

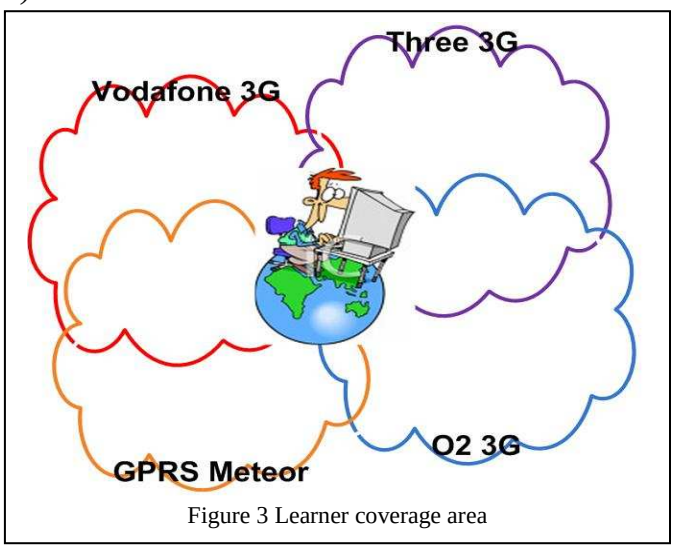

Figure 3 Learner coverage area

The billing plans s/he can choose from are described in Table 1. These are the plans currently in use by Irish mobile operators.

Table 1 Learner Internet tariffs

Operator	Time bundle	Allowance	Price	Out of the bundle cost
Three	day	500MB	5€	49c/MB
	week	2GB	10€	
	30 days	10GB	25€	
Meteor	day	50MB	99c	2c/kb
Vodafone	day	50MB	99c	2c/kb
O2	30 days	5GB	30€	2c/MB

The learner has fixed the threshold for the price s/he wants to spend for retrieving the course at 10€ and s/he already chosen *Three* network for personal uses. Assuming that the educational content has already been personalised to best fit learner profile, the scope of the application is to help the user to choose the best network based on the price and the network delivery performance.

The first step is to compute the price the user has to pay, based on the plans s/he has. The application calculates the following prices:

- *Three:*
  - 5€ for the daily
  - 1.47€ (because the learner has already exceed the 2GB allowance for the current week)
  - 25€ for the 30 days
- *Meteor:* 0.99€
- *Vodafone:* 0.99€
- *O2:* 30€ for 30 days

In the next step, networks' performance is analysed, and a decision on whether the networks are suitable for transmitting the educational content is made. Network characteristics are known, because the network is continuously monitored. The Performance Monitor suggests that for the selected educational content to be transmitted over the network, at least a bandwidth of 200 Kbits/s is required. The networks that satisfy this condition are the *Vodafone*, *Three* and *O2* networks. The *Meteor* network cannot be used because the GPRS supports data transfer rates of 56-114 Kbit/s. Based on the computed prices and on the network conditions, a ranking of the networks is done:

- *Vodafone*: 0.99€ daily packet
- *Three:* 1.47€ by using the week packet
- *Three:* 5€ for the daily packet

The learner also gets to see the networks which did not satisfy the conditions, and the reason why they were rejected.

5. CONCLUSION

This paper presented the PACO-eLF, a framework that aims at taking into account the tradeoffs involved between the educational content, user device and network conditions when the content personalisation is done. Also the price the learner needs to pay when retrieving the educational content is taken into consideration. By considering the fact that the learner may have access from the same device to multiple wireless networks, PACO-eLF detects which is the best network in terms of price and performance. In the same time it continuously checks whether modifications in the price may occur due to the network conditions, and notifies the learner when this value increases over a certain threshold imposed by her/him.

The framework may be improved by taking into consideration not just the price the user has to pay for accessing the network, but also the price s/he is willing to pay for the educational content. A trade-off between the learner expectations, the device s/he posses, network performance and his budget has to be derived. We need to determine how these characteristics are influencing the QoE in order to associate them with different weights during the adaptation process.

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