Cost–Oriented Selection and Delivery of e-Content over Various Wireless Networks

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Abstract

As wireless technologies are competing with wired solutions in delivering information, there is a clear shift of e-learning towards mobile learning (m-learning). M-learning, which involves both wireless communications and mobile computing, provides learning opportunities to people without wire-based Internet infrastructure or that are continually on the move. At the same time, a large number of educational e-content providers produce and distribute materials that cover a wide range of topics (very often different providers may cover the same topic), differ in quality or presentation format and have different cost.

In this context this paper presents a COST-efficient PERsonalised Wireless based E-LEARNing Service (Cost/We-Learn) that provides support for the selection and distribution of personalised educational rich media content (e.g. multimedia, pictures, graphics and text) that best suits user goals, device and cost constraints. Assuming that the user has simultaneous access to multiple wireless networks, Cost/We-Learn enables the selection of that access network over which the selected personalised content will be delivered such as the overall cost matches user budget constraints. This overall cost includes both the price paid for the selected educational material and the delivery cost.

I. Introduction

The rapid growth of information and communication technologies and the increase in the number of people that have computer-based knowledge make possible appearance of new educational forms. The first stage in the computer-based training involved CDs and content delivered over local area networks. Later on, due to the enormous growth and development of the Internet and increase in use of WWW as a medium for distribution of educational material, e-learning emerged as a new educational concept. Since then e-learning was accepted globally as a standard mode for distance education by most educational institutions.

As wireless technologies are complementing wired delivery solutions, there is a clear increase of interest in mobile learning or m-learning in the e-learning community. M-learning involves a combination of e-learning concepts, wireless technologies and mobile computing, unlike e-learning term that currently mostly refers to distance education by PC users using fixed wireline access to the Internet. In the context of the latest technological advancements m-learning is becoming more feasible now. M-learning brings a new evolution stage of the e-learning that makes learning more widely available and provides learning opportunities to people without wire-based Internet infrastructure (e.g. rural and isolated learners) or continually on the move. M-learning environments are based on the use of mobile devices that must support wireless technology, have a possibility to present educational materials and to allow bilateral information exchange between the learners and the teacher.

Traditional educational e-content providers are becoming more interested in the delivery of media-rich content over a variety of networks. Wider access to high-speed broadband wireless technologies such as WiFi and 3G is making e-learning area more attractive to the users offering access to educational e-content *anytime* and *anywhere*. At the same time, based on the latest development of wireless technologies and the deployment of a large number of mobile devices, an increasing number of e-learners prefer to have access to e-learning services from *any device* (e.g. desktop, laptop, tabletPC, PDA, smart phone, wide screen TV, etc.), becoming m-learners. Users with the latest devices (e.g. Mobile Pocket PC- i-mate Jasjar) have already access to multiple networks at the same time (Figure 1). For example, i-mate Jasjar offers multiple connectivity options that include GPRS, Wi-Fi (Wireless LAN) and Bluetooth. These solutions enable access to networks that differ in characteristics such as bandwidth, level of congestion, mobility support and cost of transmission.

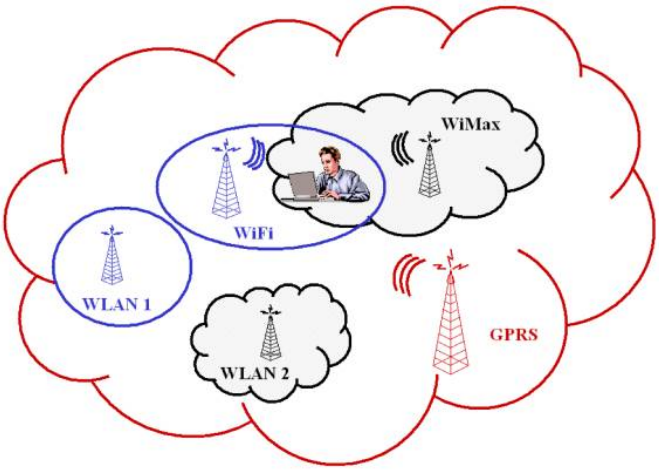

Figure 1. User Choice Between Multiple Access Networks

This paper introduces a COST-efficient PERsonalised Wireless based E-LEARNing Service (Cost/We-Learn) that allows for the selection and distribution of educational content based on user goals, device, delivery performance and budget. This service will enable efficient delivery of high quality content such as the overall cost that consists of price paid for the selected educational material and the delivery cost matches user budget. Section 2 briefly presents the high potential of the proposed service in the m-learning market, while Section 3 introduces some of the well-known adaptive e-learning systems from both industry and academia that provide personalised e-content. Section 4 presents the block-level architecture of the Cost/We-Learn service as well as the algorithms for content and network selection when the user device has access to multiple wireless networks at the same time. The last section draws the conclusions of the work presented in this paper.

II. M-learning Development Potential

The potential of m-learning development is supported by a strong already existing e-learning market and by statistical information regarding the growth in number of mobile devices used and the high increase in number of users of both mobile communications and e-learning services. Next are some statements that demonstrate this trend:

- Josh Bersin, president of Bersin & Associates [1] said that "the rapid e-learning market is explosive, growing at about 40% a year".
- KMWorld [2] believes that distance education will account for 50% of all post-secondary learning by 2010 and Internet delivered courses will be playing a more central role in distance education or in supporting conventional delivery methods.
- Bersin [3] estimated that 20% or more of corporate training is now being conducted online.
- By 2005 the number of multi-purpose handheld mobile devices sold will exceed the number of personal computers sold [4].
- By 2007 over 31 million people will routinely connect to the Internet via Wi-Fi in public places. Gartner [5] believes that the number of Wi-Fi hotspots will grow from 20,000 worldwide, in 2003, to 120,000 by 2007.
- The worldwide wireless Internet users will grow from 102 millions in 2001, to 810 millions in 2007 [6].

The success of m-learning/e-learning does not solely depend on the technological developments and the possibilities they provide. The ability to design and develop m-learning/e-learning environments that offer great learning experience by delivering personalised educational content tailored to individuals or groups based on personal characteristics such as skills, goals, knowledge and preferences is also imperative. IDC has indicated that the level of customisation of content is the most important factor that determines the value of the e-learning for an organisation and there is a strong trend towards customising content. Nearly 80% of all companies and nearly 90% of organisations with more then ten thousands employees are either currently creating e-learning objects that would allow for customised material delivery or are planning to do so [7].

Since more and more companies and educational institutes have started to produce educational e-content and to provide online personalised learning solutions, it is likely that an oversupply of information will occur. As it is expected that information will differ in terms of formatting, size, cost, etc., it will be very difficult for e-learners to select the e-learning service that best matches their interest, cost budget as well as their network connection and device (display size, processing power, battery life). Therefore, there is a need for a service such as Cost/We-Learn.

III. Adaptive E-learning Solutions

Researchers from both industry and academia were interested in finding solutions to deliver personalised educational content tailored to individuals or groups based on user characteristics (e.g. skills, goals, knowledge) in order to improve the e-learners' overall learning outcome and their performance. The adaptive e-learning approach involves gathering some initial information about the user, monitoring user interactions with the system, building a user profile and adapting the delivered content to this profile. Among research-proposed adaptive e-learning systems are AHA! [8, 9, 10], ISIS-Tutor [11], ELM-ART II [12], JointZone [13] and ApeLS [14]. These systems build a model of the goals, knowledge and preferences of each individual person and use this model throughout the interaction with the user in order to propose content and link adaptations that would best suit e-learners. Lately, researchers started to integrate learning styles in the design of the adaptive e-learning systems along with the classic learner features. Several systems providing adaptation to users' learning styles have been created such as INSPIRE [15] and AES-CS [16].

Tracking the user behaviour in real time in order to retrieve an appropriate and fine-grained user profile, as well as to provide personalised learning content, represents a challenging task for adaptive e-learning research. Apart of navigational behaviour and page scrolling, real time eye-tracking and content-tracking techniques have been recently introduced and applied within the AdeLE [17] project. These techniques help to identify areas of understanding difficulty and to provide selective additional information or explanation. The main goal is to observe users' learning activities in real-time by monitoring a number of behavioural aspects and personal traits such as objects and areas of focus, time

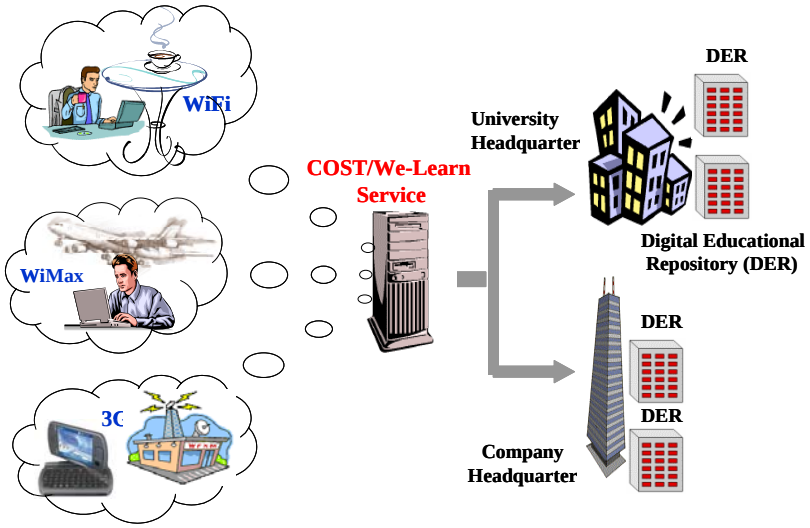

Figure 2. Access of the e-learning content through Cost/We-Learn service using various high speed broadband wireless networks (e.g. WiFi, WiMax, 3G) available in cafes, airports and other public areas

spent on objects, the sequence in which the e-content is processed and momentary states (e.g. tiredness) [18].

In parallel with the academic research that led to an important number of adaptive e-learning systems, many companies have started to produce and commercialise similar systems. IBM has launched the Workplace Collaborative Learning v. 2.5 [19] that recommends specific training for a student based on profiles, skills and competencies. Companies such as Skillsoft [20], Ossidian [21], Pulse Learning [22] and Interactive Services [23] are already developing e-learning systems that deliver content tailored to either user interests or devices over wired and wireless networks.

However, the advantages brought by these systems are lost when the users' operational environment, the network or device through which they access the selected content, cannot support the delivery of the personalised e-learning material. Moreover, if the e-learner does not want to pay for a whole course or a large material, the effort of the personalisation process is not appreciated. In consequence, the selection of the educational material should be based not only on users' characteristics but also on the connectivity type and cost properties in order to allow for a cost-efficient fast transfer from the source to user's terminal.

IV. COST-efficient PERsonalised Wireless based E-LEARNing Service (Cost/We-Learn)

The main purpose of the COST-efficient PERsonalised Wireless based E-LEARNing Service (Cost/We-Learn) is to allow for the selection and distribution of personalised educational rich media content (e.g. multimedia, pictures, graphics and text) that best suits user interests and goals, device, and access network type and load while taking into consideration user budget limitations.

As the user device has access to multiple wireless networks at the same time, Cost/We-Learn selects the access network over which the content will be delivered efficiently such as high quality information is provided, and the overall cost matches user budget constraints. The overall cost includes both the price paid for the selected educational material and the delivery cost.

Shortly Cost/We-Learn provides the meeting place between companies and organisations that offer personalised e-learning content and e-learners that can receive efficiently high quality e-content according to their budget (Figure 2).

Figure 3 presents the Cost/We-Learn block-level architecture. It consists of three main components:

- Distributed Digital Educational Repositories (DERs)
- Cost/We-Learn Management System (Cost/We-LearnMS)
- Client Application (CA)

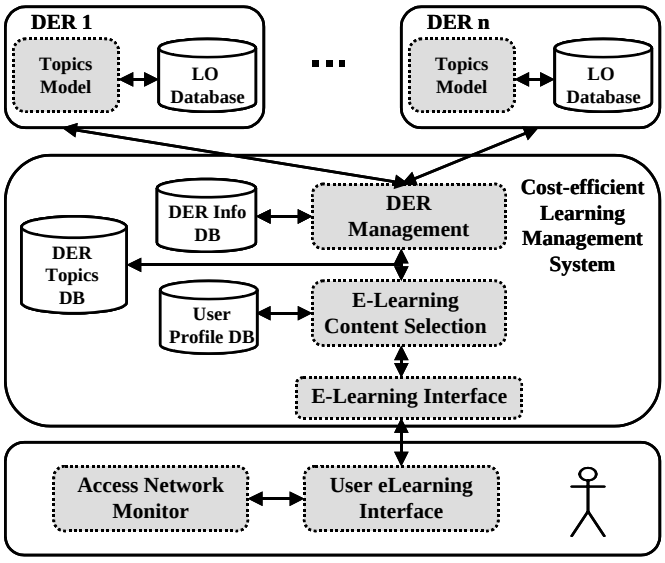

Figure 3. Cost/We-Learn Block-level Architecture

A. Distributed Digital Educational Repositories (DERs)

Each DER stores educational content represented as a collection of Learning Objects (LOs). An LO is a self-contained reusable digital resource that represents a small unit of learning material that supports a more complex learning activity [24]. Each LO is tagged with metadata that describes its topic, quality, formatting and cost-related information. In general DERs belong to certain content providers that manage them completely.

The educational material is selected and personalised for each individual person according to his/her personal characteristics and then delivered by a Learning Management System (LMS). A company or organisation that provides e-learning services runs the LMS.

DER also includes a *Topics Model* (TM) that describes hierarchically the relationship between topics and LOs. A topic may represent a chapter or sub-chapter, part of a course. The types of relations that may exist between topics or LO include:

- *Link* – suggests a navigational link. For example from LO1 one can navigate to LO2.
- *Prerequisite* – indicates a certain desirable reading order between LOs or topics. For example LO1 should be studied before LO2.
- *Inhibitor* – describes an unusual type of desirable reading order. For example after studying LO1 it is no longer desirable to read LO2.

In this context, TM is used to determine the next content to be delivered during a learning session or the work–flow of the topic or course studied. DER's topics are registered with Cost/We-LearnMS in order to enable their cost-based intelligent selection.

B. Cost/We-Learn Management System

Cost/We-LearnMS, deployed on a server and accessible by e-learners, represents the brains of the system. It has a three-tier architecture:

- *E-learning Interface* that focuses on user interaction and protects Cost/We-LearnMS from potential harmful contacts is the outermost tier.
- *E-learning Content Selection* that implements the proposed cost-efficient content selection and delivery algorithm and *DER Management module* -that manages registered DERs and DER-related activities are part of the middle-tier.
- *A set of databases* that support information storage for the Cost/We-LearnMS modules is the innermost-tier.

In particular, *DER Info Database* stores information (e.g. localisation and ownership) about each DER registered with Cost/We-LearnMS. *DER Topics Database* helps in Topics search and localization. *User Profile Database* stores user-related information, including budget, access network(s) and device and is automatically updated after each user access based on the information gathered during the delivery of learning material.

C. Client Application

CA includes a *User eLearning Interface* that supports both selected information display on the user device and user interaction. The *Access Network Monitor* permanently watches for the availability of all wireless networks that are enabled on the device, monitors their performance, sends updates to the Cost/We-LearnMS and performs network switch when is required.

V. E-learning Content Selection Principle

The E-learning Content Selection module implements the proposed cost-efficient selection and delivery of distributed e-learning content mechanism. When provided with a learner goal or interest, the main purpose of the mechanism is to process the information stored in Cost/We-LearnMS databases, to select the topic(s) available in the distributed DERs that best matches user profile, budget, connectivity and device properties. It also determines and selects the wireless access network (when multiple wireless access networks are accessible from the user device) that provides high content delivery performance at low cost. The proposed cost-based mechanism bases its functionality mainly on the user goal and on the user profile that includes budget and available access networks as well as their price-plan and their current traffic status. Therefore maintaining an accurate user profile is very important and is performed in two phases: during the registration phase CA gathers info about user device, available access networks and the user enters other characteristics that cannot be automatically discovered. Then, CA monitors continually these networks and, if changes occur in their characteristics (e.g. changes into the transfer rate, cost changes due to different tariff periods), it informs the Cost/We-LearnMS that updates the user profile. Also each DER informs Cost/We-LearnMS if any changes (e.g. cost) related to their topics or LOs have occurred.

Figure 4 presents the algorithm for the selection of the candidate topics that match user goals, device, budget and network characteristics. First all the topics from *DER Topics Database* stored by the Cost/We-LearnMS that match user goals are selected. Then, a Grade of Match to the user topic (GoM_Topic) is computed for each selected topic based on: device compatibility (considering user device type and the type of device(s) the educational material that presents the selected topic was designed for); the price paid for the getting access to the educational material, the characteristics of the current user access network (e.g. bandwidth, delay, connectivity cost for downloading data) and the user budget.

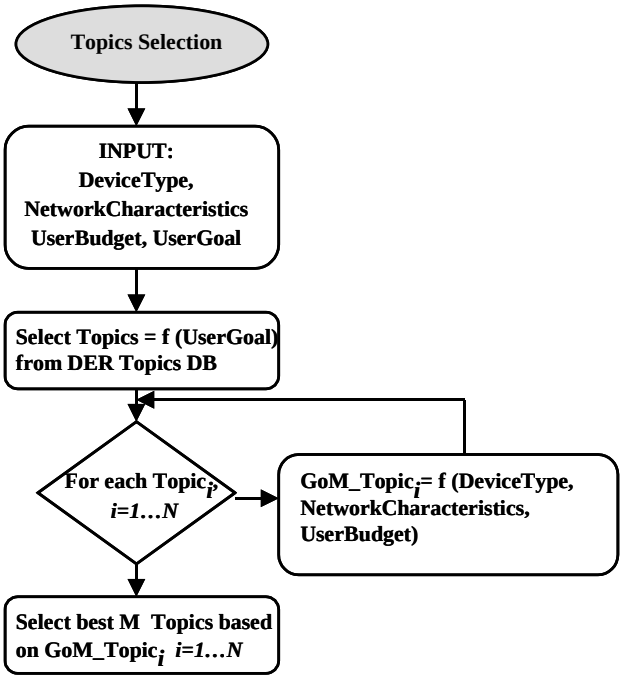

Figure 4. Topics selection algorithm

Three categories of user devices are considered and they are presented in the order of their complexity: smart phones, Pocket PC/PDA and laptop/desktop. If the educational material was designed for a device that matches user device type, the highest score is awarded in relation to the device compatibility. If there is no perfect match, but the user device may be used to display the content, a lower mark is given. (e.g. if the educational content was designed for PDA, the content can be displayed if user has a laptop.) If the user device cannot display in a proper manner the content, the lowest mark is given on the device compatibility. (e.g. the user has a smart phone and the content was designed for a desktop terminal).

In computing the GOM_Topic, the topic selection algorithm grades the cost of the content relative to the overall user budget and considering the cost of the delivery constant for all the topics over the network the user is currently connected to.

After a GoM_Topic was computed for each selected topic the algorithm provides to the user a list of M topics that received the highest grades and asks for explicit selection. A value of M=5 is considered average in terms of both selection complexity and freedom of choice.

Apart from topic selection, the Cost/We-LearnMS is also in charge with the determination of the most cost-effective wireless access network trough which to download the selected data. The main idea is to select the network which will minimise the delivery cost while maintaining good user perceived delivery performance. Figure 5 illustrates the network selection algorithm. This algorithm takes into consideration network service provider cost per accessing data, average bit rate

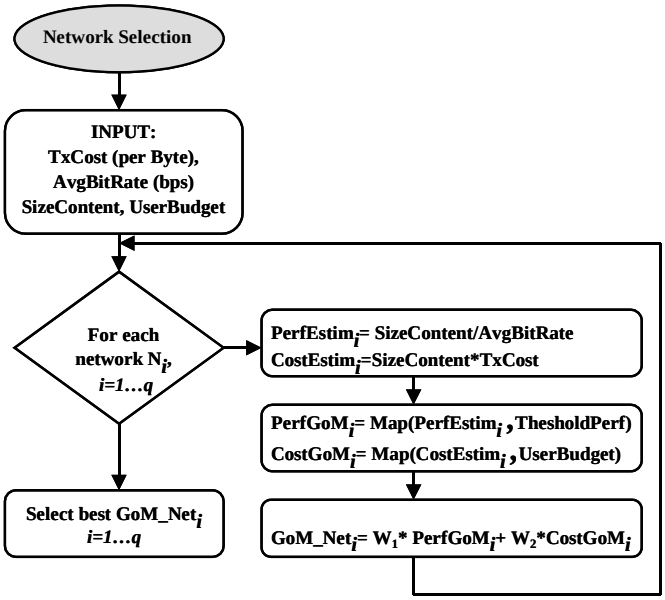

Figure 5. Network selection algorithm

provided by the wireless network and the size of the educational content that has to be transferred to the user device. For each accessible network from the user device a network Grade of Match (GoM_Net) is computed based on cost estimation for downloading the content and on estimated user perceived performance measured in terms of the download time. The estimated performance is mapped into a zone that describes certain level of user tolerance to delay. Based on a survey of the current research into user tolerance to delay [25], three zones were considered, representing how users feel in relation to download time: satisfaction, tolerance and frustration. Results of studies [26, 27] were used to map the estimated download time over each available network into one of these zones and compute network performance-based Grade of Match (PerfGoM) scores. Similarly delivery costs on different networks relative to user budget were considered and network cost-based Grade of Match (CostGoM) scores were computed. The final GoM_Net is computed by combining with equal weights the two components: delivery performance and transmission cost. However the users may be allowed to increase the importance of one or the other of these scores in the final grade.

By assessing GoM_Net grades for all the networks the user device has access to Cost/We-LearnMS suggests the most cost-efficient network for the content delivery.

VI. Conclusions

This paper presents a COST-efficient PERsonalised Wireless based E-LEARNing Service (Cost/We-Learn) that allows for the selection and distribution of educational content based on user goals, device and available wireless networks. Cost/We-Learn considers both delivery performance relative to users expectations and overall cost associated with accessing an e-learning service (that includes wireless network delivery cost and

price paid for the learning content) in relation to user budget. The paper also presents two algorithms for topic and network selection respectively that are involved in the cost-efficient performance-aware selection and delivery of personalised content via various networks.

Cost/We-Learn as novel e-learning platform provides a very efficient meeting place between content providers, organisations and companies that offer e-learning-related services on one hand and e-learners that want great learning experience and to improve their knowledge at low cost on the other hand.

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