eLSaaS: A FRAMEWORK FOR MOBILE LEARNING CONTENT ADAPTATION

Ivan Madjarov and Omar Boucelma
Aix-Marseille Univ, LSIS, Avenue Escadrille Normandie-Niemen, 13397 Marseille, France

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Abstract: As a typical Internet application, an m-learning system is an innovative approach for delivering well-designed, learner-centred, interactive and facilitated learning environments to anyone, anywhere at any time. Cloud computing is a technology and a business model that allows access to an extensible set of storage and computing facilities with a provision and pay as you go model. This position paper discusses the problem of content adaptation for mobile devices in a cloud context. A device independent model is presented in order to achieve automatic adaptation of the content based on its semantics and the capabilities of the target device. An m-learning software as a service cloud framework is presented for adapting, displaying and manipulating learning documents on smart devices. Some aspects of services integration in the cloud for m-learning are also discussed.

1 INTRODUCTION

Cloud computing is a technology and business model that follows a provision/pay-as-you go model for the delivery of computing resources. With the vast amount of available resources (data and services), the cloud paradigm together with mobile computing enables services that are scalable on demand and implemented on virtualized resources over the Internet (Keng, 2011). Software-as-a-Service (SaaS) is cloud service layer which delivers a single application through the Web browser to thousands of desktop or mobile learners. Mobile learning (m-learning) is a time constrained activity performed usually on-the-fly. Mobile technologies tent to restrict significantly presentation features.

Most learning resources already in use in desktop-based learning course management systems (LCMS) cannot be simply ported to mobile devices. Hence, this necessary to develop context-aware learning tools for mobile environments. In this paper, we advocate an e-learning-software-as-a-service (eLSaaS) model to handle scalability over distributed learning content. The objective is to provide accessibility over a wide variety of mobile devices.

We believe that a new cloud-based e-learning system should comprise a set of independent but cooperating non-monolithic Web services-based applications that integrate pedagogical data between common LCMS. For instance, in opposition to the restricted LMS learner's access, a content adaptation method can be developed for cloud users. Our claim is to make a device-independent m-learning SaaS gateway between different mobile devices and the plethora of learning objects (LOs) (LOM, 2002) that are available on various LCMS.

The rest of this paper is organized as follows. Section 2 surveys some related work, and in Section 3 the cloud-based approach for m-learning systems is discussed. Section 4 details our SaaS solution for m-learning as well as design issues and implementation details. Conclusion and future work are presented in Section 5.

2 RELATED WORK

Currently there are on-going projects that propose the usage of cloud computing as a basis for modern e-learning applications and systems. As an example, the CloudIA project (Doelitzscher, 2011) demonstrates the feasibility of a private cloud infrastructure for e-learning. This project addresses functionalities for enabling an e-learning system in the cloud, such as authentication and integration with existing IT infrastructures, and the creation of customized on-demand virtual machines. The authors make a choice for private resources. However, their choice is not compared

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with the features and capabilities of those available in the public domain.

A similar architectural system has been adopted in BlueSky (Dong, 2009). This cloud framework enables physical machines to be virtualized and allocated on demand for e-learning systems. However, the security layer for this cloud-based framework is not addressed.

In Casquero (2008) and Al-Zoube (2009) similar cloud frameworks, based on iGoogle with gadgets related to Google Apps infrastructure for the development of a corporative e-learning network, are presented. The authors discuss the integration of institutional and external services in order to provide a personalized support. Google App Engine provides a Java Web framework (Jetty), a servlet container, and BigTable for data storage. However, the process of data and application integration with Google Apps is not covered by the authors.

In Madjarov (2010) features of a personalized m-learning approach are presented including context-based adaptation and portability of LOs on several mobile Web browsers. Also discussed are the hierarchical display of multimedia units with index extraction and content summarization.

Finally, in Madjarov (2011), a service-based solution is described that overcomes the limitations of mobile devices in combining textual content adaptation with alternate audio transcoding to better fulfil student needs.

3 CLOUD-BASED e-LEARNING

3.1 Cloud Computing Architecture

The cloud can be seen as a unique access point for all the requests coming from the world wide spread clients. Cloud computing provides dynamically scalable infrastructure supplying computation, storage and communication capabilities as services (Hossain, 2011). In this infrastructure the coupling between resources and applications is facilitated. Cloud computing is the promising infrastructure which can provide information and application interoperability to e-learning systems. Figure 1 shows how to build e-learning systems through cloud services in a simple way.

Cloud computing comprises three layers as presented in Figure 2 (Creeger, 2009):

1. Infrastructure as a Service (IaaS);
2. Platform as a Service (PaaS);
3. Software as a Service (SaaS).

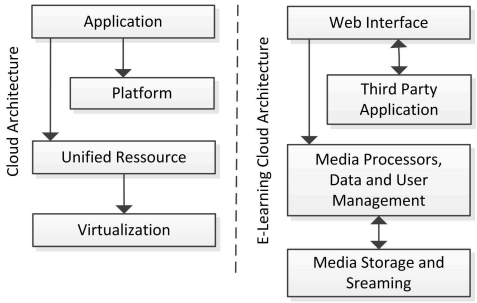

Figure 1: Cloud computing and e-learning cloud-based architecture.

Figure 2: e-Learning cloud architecture layers.

3.1.1 Infrastructure as a Service (IaaS)

IT infrastructure is deployed in a provider's data centre as virtual machines, i.e., the virtualized hardware resources are deployed as a service. IaaS comprises the layer of storage, hardware, servers and networking components. Architecture scalability is achieved through virtualization, such that multiple systems or

operating systems can be run at the same time on a virtual machine or across multiple machines. A user can access the server, network and storage equipment, only through Internet. Also, he or she can install one's own application system.

3.1.2 Platform as a Service (PaaS)

The concept of PaaS remains invisible to the user as it provides the necessary operating platforms for the virtually provided applications (hardware and software as service). It offers an application platform for the Internet programming interface and the operating environment, in which users can structure and deploy the domain specific applications. PaaS allows software and service development without downloading tools and software to client machines. Using the PaaS concept, large and complicated software packages can be developed, tested and disseminated. Thus, the PaaS concept supports virtualization and scalability.

3.1.3 Software as a Service (SaaS)

This is a software delivery model in which software and its associated data are hosted centrally and are accessed by users using a Web browser over the Internet. Web 2.0 is the main technology behind the realization of SaaS (Cortez, 2010). SaaS has become a common delivery model for most business applications, including accounting, customer relationship management (CRM), enterprise resource planning (ERP), and recently e-learning LCMS. Clients access software services such as email, word processing, spreadsheets, quizzes, exercises, simulations, etc. from the cloud instead of running these applications directly on their client computers.

3.2 Cloud e-Learning

There is a growing interest in cloud computing for e-learning practitioners. Greater connectivity between centralized cloud-side applications, in combination with low cost, and low processor capacity of mobile devices could provide better access, more control, and greater freedom for mobile learners. At the same time, mobile devices significantly differ from each other in their characteristics. An ultimate challenge facing m-learning is the creation of pedagogical learning models to handle the specificity of mobile pedagogical processes and the inherent constraints of mobile devices (Keng, 2011). To overcome the limitations of lightweight devices, distributed client-server architecture using Web services can be employed. To handle scalability over large-sized learning content sources, and also to provide accessibility over wide variety of mobile devices, a SaaS m-learning model can be deployed. In a cloud infrastructure, Web pages are generally designed for desktop screens making it difficult to visualize on mobile phones. To overcome this constraint a scalable adaptation process for a wide variety of mobile units is needed.

The SaaS approach is perfect for e-learning and m-learning because it can be implemented quickly and it is easy to maintain. Thus, clients can receive the latest updates and features without any extra financial obligation. Another advantage with SaaS is that it helps authors to share pedagogical resources with a simple "click", using Web 2.0 technology. All aspects of an e-learning or m-learning solution can be delivered using the SaaS model, including LMS, LCMS, courseware content, authoring tools, and synchronous collaboration tools like webcasting and white boarding (Basal, 2010). To visualize this relationship, refer to the service layer in Figure 2.

4 e-LEARNING SOFTWARE AS A SERVICE (eLSaaS)

This section presents a solution for building a virtual and personalized learning environment which utilizes a cloud-based technology to create a service-oriented model for m-learning application service providers and learners. The concept of eLSaaS has introduced as a software distribution model in which applications are hosted by a service provider and distributed via the Web. Our contribution is as follows:

- demonstration of a Web service-based architecture to an integrated Web-based learning and m-learning environment;
- design of a service-based framework, as part of an e-learning SaaS cloud, that uses hierarchical displaying multimedia units with index extraction and content summarization;
- description of a SaaS-based e-learning system architecture to provide a flexible integration model in which all the learning components and applications are well defined and loosely connected;
- deployment of multimedia services and especially the presentation of multimedia content on mobile environments.

One major drawback of existing e-learning systems is that they are content-centric. Many course authors simply move all their learning materials to the LMS. The pedagogical materials are presented uniformly to all learners regardless of their background, learning styles and preferences. In the same time,

some efforts of content providers and course instructors in pedagogical content organization in function of LMS's branching capabilities helps to overcome partially these constraints. Despite all this nowadays, we need a suitable context-aware pedagogical content adapted to learning preferences, profiles and requirements, i.e., a learner-centric content.

In the proposed eLSaaS environment we can easily combine semi-structured data, stored in a Native XML Database (NXDB), with structured data stored in a Relational Database (RDB) through Web services (WS). The objective is to provide direct data and application integration, located at distributed sites in order to improve the achievement of learning outcomes. This approach promotes a device-independent m-learning gateway between different mobile units and the huge number of learning resources available on a plethora of LMSs. It becomes possible by combining our Web-based Open Semantic Editor Suite (WOSES) (Madjarov, 2010) with a set of additional services to allow different mobile units a direct access to LOs customarily designed for desktop Web browsers. A semantic content adaptation service is plugged for content standardization. This tool uses templates to automatically and efficiently adapt content for mobile Web browsers. An alternative service is available for a speech solution, which allows learners to turn any written text into natural speech files, when using standard voices. This approach allows the generation and the progressive downloading of text and audio based learning material dynamically for m-learning and ubiquitous access.

4.1 m-Learning Content Model

4.1.1 m-Learning Advantages and Challenges

M-Learning focuses on the mobility of the learner, interacting with portable technologies, and presents several advantages:

- Ability to access learning everywhere and anytime e.g. down time can be leveraged for learning;
- Ability to access learning at the point of need;
- Flexibility for mobile development as video, presentations, podcasts, and quizzes are all potential outputs to mobile devices;
- Creativity with a huge potential for location-based and context-based learning.

At the same time, we can list several challenges (disadvantages) of m-learning delivery and development:

- The choice of a mobile device which can technologically meet learners needs best is often difficult and expensive;
- The course interface size and richness seems critical to the engagement factor of a learner in a learning;
- Mobile device potentially is never disconnected and ensures permanent access to an abundance of information that requires time for incubation, critical thinking, and reflection for learning. This can be critical for the learner's success due to the "fast" (mobile) learning;
- Challenges of initial cost threshold of mobile applications development.

As SaaS is delivered over the Internet through Web browsers, in our approach to overcome some m-learning disadvantages and to produce device-independent Web-accessible information that can be browsed in a readable and effective way on different smart devices and software platforms we use mobile Web browser and methods for effective mobile device recognition, and mobile Web browsers functionalities identification.

4.1.2 m-Learning Multimodal Portability

For an effective Mobile Device Recognition Method (MDRM) we use the header field in the HTTP protocol. To prove the multimodal portability on mobile browsers we conducted a series of tests that represent some of the common design types that are in use, and like most real Web pages, not all of them are designed to work with small screens. We tested several mobile Web browsers on different models of PDAs, smartphones and cell phones in order to identify their compatibility with desktop Web browsers. Analysis of the test results (Madjarov 2010) showed that multimedia pedagogical content is suitable for mobile Web browsers such as Opera Mobile, Safari, and Firefox Mobile. The main problem to address is to how to tailor the multimedia presentation for the small-screen of a mobile devices. Thus, the main problem is not focused on the complexity of pedagogical hypermedia content.

4.1.3 m-Learning Mash-up

Another way to mitigate the previously cited disadvantages consists of a flexible architecture enabling learners to mash-up heterogeneous set of services that support different learning activities such as production, distribution, reflection, and discussion. A mash-up is an application that uses, combines and aggregates data or functionality from more than one source

to create a new service. The idea is that combining various applications into one will help to present data in a more useful way to meet the m-learning specific needs. These applications are usually hosted in the cloud and diffused as Web services. Mash-ups can be a very effective approach to overcome challenges of distributed services and to solve problems related to devices heterogeneity. Using mash-ups in an m-learning environment can help to connect resources and applications in one environment customized to the needs of suitable Web service-based content-adaptation technique that we developed (Madjarov, 2011). On the other hand, application mash-ups can be achieved by implementing the applications as widgets (Al-Zoube, 2009). This portable application is typically implemented using HTML 5.0, JavaScript and CSS3, and can be run on a wide range of platforms and recent versions of mobile Web browsers as showed by our tests. A widget performs a specific function, usually obtaining content from one website and displays it on another website (W3C, 2011). In this case, we suggest the use of Web services technologies that can be involved through the Ajax technique to manage the client-server communication asynchronously. In our concept, we recommend the use of a thin mobile client instead of heavy clients installed in smart devices for client-to-cloud communication.

4.1.4 m-Learning Content Presentation

The device context presents a decisive factor for appropriate presentation of multimedia learning content in connection with m-learning. Besides the choice of learning content and appropriate methods of interaction, the input-output modality plays a central role for optimal use of m-learning in different context, scenarios and situations. M-learning content can be given in the form of a visual presentation as text, pictures, and tables or can be given as sound data in the form of an acoustic presentation. The speech synthesis or text-to-speech (TTS) combines previously-recorded words, or produced synthetically by linking the smallest linguistic units. In order to create a naturally-sounding result, one must consider the length and tone of the individual components. To build the speech-production service in our eLSaaS framework, we invoked the proper SOAP methods that will enable the Web service to send text and generate speech files on the Cloud server.

4.2 Implementation Scenario

Figure 3 highlights the WOSES cloud-based application integration with a Web-based LCMS. The interconnection is carried out by a Web Services Management System (WSMS). As illustrated, the learning-centric data and the management-centric data are clearly separated. Pedagogical documents are developed in the WOSES section of the eLSaaS-based Xesop system and thereafter are stored in a NXDB. The information relevant to learner personal data, learner profiles, course maps, LOs sequencing, data presentation and general user data is stored in the RDB of LCMS. The publication process of learning content is carried out by WSMS. This allows integration into existing LCMS systems as a cloud-based service. In the discussed case, Web service-based content modules make the bridge from e-learning to m-learning system in a simple and effective way through Apache Libcloud (Apache, 2011), an open source library that provides a system-neutral interface to cloud provider APIs. The Java version supports Amazon EC2.

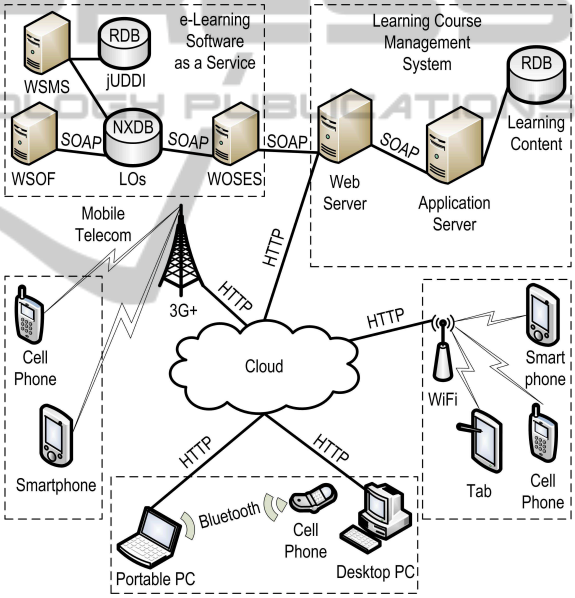

Figure 3: e-Learning software as a service solution.

For system deployment, we used eCUME (Moodle-based) e-Learning system deployed at Aix-Marseille University (eCUME, 2012). Our system is based on the Apache containers suite for data storage and service management. We integrated the PHP-based LCMS interface via Web services. For services deployment we used Apache Axis. For storing and managing LOs, we used eXist (Native XML database) running in the Apache Tomcat Servlet engine as a Web application and invoked via REST-style Web services API. To integrate with other e-learning and/or m-learning systems we implemented an Apache jUDDI registry.

5 CONCLUSIONS

In this paper, we advocate and illustrate a cloud-based m-learning solution that may leverage both existing e-learning services, cloud computing provision/pay-as-you-go models and mobile devices. This solution is clearly needed because:

- Many mobile applications are based on cloud services such as location service and messaging service;
- Cloud services promote the use of mobile Web browsers instead of mobile applications since the cell phones are not powerful or fast enough;
- SaaS enables a speech-production service where a method sends a text and generates speech files on the speech cloud server.

The solution we propose shows clearly how to combine existing individual systems into a virtual one, available as a SaaS unit. We received positive initial feedback from users who tested our system. Our approach is consistent with cloud-based solutions that are being proposed for LMS such as Moodle.

For future work, we plan to use mash-ups in a context-aware content adapted interface to connect resources and applications that are customized to the needs of individual users. We also plan to work on different scenarios where it will be possible to exchange both data and applications among different systems.

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