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Article · January 2009

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The Architecture of an "Ultimate" e-Assessment System

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Abstract. In the past two decades the area of e-learning was dominated by monolithic application silos. Modern Learning Management Systems (LMS) are facing the challenges for greater interoperability, flexibility, reusability, accessibility and manageability, as well as for sharing learning resources and components. Extensive research has been done in the field of sharing learning content and resources, but there is lack of theoretical and practical examples of systems sharing components and their functionality.

Assessment is an important integral part of every learning process. A lot of software packages exist in the market to realize automated assessment, but most of them are stand alone applications without possibilities for interoperability, adaptability according to learner characteristics and possibilities for content and functionalities reuse.

In this paper we present the architecture of an "ultimate" e-Assessment System. This System should be able to work as a standalone e-assessment application, be able to use and exchange content and components with other e-assessment systems, and at the same time it should be easily attachable to any existing applications in educational and business environments.

Keywords: e-Assessment, Service Oriented Architecture, e-Learning

1 Introduction

The ability to innovate and create new knowledge has always been a main tool for creating well-being. In an increasingly global economy where the capacity to use information in the right time and on right place gives advances on the market, knowledge has become the key resource.

The emerging knowledge society and the Knowledge-based Economy signify a new era for education and training. Learning becomes a continuous process over lifetime [1]. Workers in the 21st century knowledge society will need to be lifelong learners, adapting continuously to changed opportunities, work practices, business models and forms of economic and social organization.

High education institutions have the main role in the process of redefining the models for acquiring knowledge and skills. Technology is more often used in learning as a tool for lectures, delivery of materials, and assessment of student knowledge.

Although technology has the potential to extend and improve educational and training activities, opposite results can be achieved "not because it (technology) wasn't effective, but because it … did not adapt to the way people wanted to learn." [2]. The potential of the technology can only be fully realized if the activities are built upon a stable and coherent technical infrastructure, and with existence of appropriate widely accepted standards.

The vast majority of the currently used web-based educational systems are powerful integrated systems, like Blackboard [3] or WebCT [4] that provide a large variety of support services to both learners and teachers, but lack adaptability, personalized training schemes tailored to the learner's objectives, background, style and needs; flexible access to lifelong learning as a continual process; just-in-time training delivery; new learning models for efficient integration of training on workplaces. The variety of the platforms and approaches used in these LMSs makes it difficult to exchange information between them, the thing that makes some of them obsolete and dedicated for specific institutions.

Assessment takes central place in the learning process, and most LMS have tools for assessing learner knowledge. Although there are several comprehensive systems for automatic assessment, most of them are independent software packages for computer based assessment, web based assessment or electronic assessment without possibilities for interoperability, adaptability according to learner characteristics and possibilities for content reuse [5] [6] [7].

Significant research exists in designing e-assessment systems which will be able to respond to the market needs, but there is no single standardized and widely adopted system for e-assessment yet. Modern e-assessment systems have to be modular, interoperable, adaptable, reusable systems which are capable for exchange of content and components both with other e-assessment systems as well as with other applications like LMS or any business applications installed in working environments.

In this paper we present the overall architecture of an "ultimate" assessment system. We will try to give answers to the following questions: What is an "ultimate" assessment engine? What architectural style should be used for design of the "ultimate" assessment engine? What is the overall architecture of an "ultimate" assessment engine?

2 Modern e-Learning system architectures

In [8], Dagger analyses the evolution of e-learning platforms regarding their interoperability. Three generation of e-learning platforms are identified where the last generation is the current one, which should offer complete federated exchange among services (information and control), various levels of interoperability (intradomain and interdomain), and service composition (orchestration and choreography).

The first generation of e-learning platforms provided black-box solutions. In terms of e-learning evolution, they provided a shift toward modular architectural designs

and recognized a need for semantic exchange. The second generation separates content from tools, and the learner information became more distinguished.

The next (third) generation will no longer be monolithic, one-size fits- all solutions, but rather interoperable platforms and a range of e-learning services, letting consumers choose the right combination of services for their requirements.

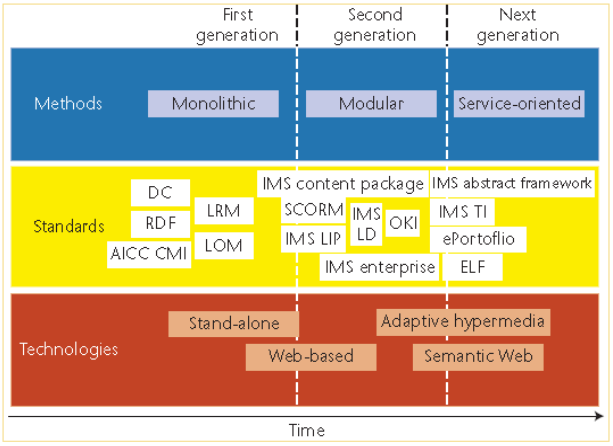

Figure 1: Evolution of e-Learning platforms [8]

Future framework of Learning Management Systems (LMS) will allow the exchange of the learner profile and learning resources with other legacy systems over the Internet. This will lead to the true individualization of media content to provide the next generation of personalized learning environments.

In the past few years, world leading organizations in the e-learning community were focused on creating a joint vision for common technical framework in e-learning area, and in defining international learning technology standards and specifications, in order to allow systems to "support organisational and cross-organisational processes for enabling effective e-learning" [9]. These standards and specifications are supposed to promote interoperability, flexibility and pedagogic diversity in the e-learning process.

As a result of those activities few detailed frameworks were developed. Some of the most successful and comprehensive are:

- JISC e-Learning Technical Framework (ELF) [10]
- IMS Abstract Framework (IAF) [11]
- Open Knowledge Initiative (O.K.I.) [12]
- LeAPP Learning Architecture Project [13]

One common structural issue for which these organizations reached a consensus was the adoption of Service Oriented Architecture (SOA).

The potential of service-oriented software architectures had been recognized previously. Back in history of distributed communication, standards such as DCOM, CORBA or RPC existed, so service-orientation is not a new architectural pattern in itself [14].

Still, the literature shows several differences between Component-oriented architectures (COA) and SOAs. Component-oriented architectures are more finely grained and tightly coupled than SOAs. Changes to individual components typically impact the software those components access, making COAs less flexible and extensible than SOAs.

3 SOA

Service-Oriented Computing is shift from a vision of a web based on the presentation of information to a vision of the web as computational infrastructure, where systems and services can interact in order to fulfil users' requests programmatic view. [15]

The Service-Oriented Computing (SOC) paradigm refers to the set of concepts, principles, and methods that represent computing in Service-Oriented Architecture (SOA) in which software applications are constructed based on independent component services with standard interfaces.

European initiatives such as i2010: European Information Society 2010, supports the implementation of Service Oriented Computing. Also, all of DoD's major IT initiatives in the past years are based on the SOC paradigm, including the Army's FCS, the Navy's FORCEnet, the Air Force's JBI, and the OSD's NCES and GIG-ES. [16]

Although there are lots of definitions for SOA we will define it as "An approach for building distributed computing systems based on encapsulating business functions as services that can be easily accessed in a loosely coupled fashion." [17]. SOA has many advantages, like reusability and flexibility of implementation, higher compatibility with the Grid, "lower overall costs, protection of legacy investment, lower cost of entry, rapid development, potential for business processes to drive technology" [18].

From an institutional point of view it enables collaboration between institutions, faster deployment of new functionality, and support for pedagogic diversity, and avoids lock in to single vendor solutions with the possible attendant costs. From a technical point of view the open interfaces of the components make it relatively simple to connect components in novel and custom ways, encourage interoperability, and facilitate replacing one service with another to provide the same functionality in different ways.

In [19], Willson discusses the pedagogical aspects of SOA e-learning system analyzing 6 pedagogical choices in e-learning, and concludes that "'Brave New World' of web-service driven environments" offers much greater pedagogical diversity than the monolithic systems.

The comparison of abovementioned frameworks shows that they all have layered architecture consisting of a set of services which can be used in e-learning context and collectively realize required business objective.

A Service Orientated Architecture (SOA) is capable of facilitating rapid development of highly customizable systems that can be optimized towards a specific goal or pedagogical requirement. This framework also makes it easy to plug in extra components or combine services in novel ways to evaluate their effectiveness.

4 e-Assessment

Assessment takes central place in the learning process. The assessment nature have deep impact on the way people learn, defining the contents they will assume as important and defining the way they will spend their time [20].

Assessment is a process in which examples of person's attitude are taken at particular time and they are evaluated. According to the evaluation of these examples, conclusions are made for the person's achievement, potential, intelligence, attitude or motivation. Different forms of assessment exist and each of them has different use. Besides the traditional summative and formative assessment, in the past several years newer types of assessment are becoming more popular, such as competence assessment, performance assessment, portfolio assessment and peer assessment [21]. Compared to the traditional ones, they are more integrated and embedded in the learning context which requires higher level of student involvement in the assessment process. These types of assessments try to give an adequate answer to the ideas of a learning process where teaching, learning and assessment interact. In the new learning approach, assessment is integrated in learning and instruction and addresses the complex characteristics of the learner.

The broadest term which is used in literature when discussing assessment automation is computer assisted assessment. This term cover any use of computers in the process of assessing knowledge, skills and abilities of individuals [22].

There are several systems for automatic assessment on the market, mainly as part of distance learning systems. However, there are independent software packages for computer based assessment, web based assessment or electronic assessment. Many of these systems are very comprehensive but most of them are stand alone applications without possibilities for interoperability, adaptability according to learner characteristics and possibilities for content reuse [5] [6] [7].

Interoperability can be defined as capability of software systems to use the same formats for storing and retrieving information and to provide the same service on different hardware and software platforms [21]. Dagger [8] discusses two levels of interoperability between LMS and its tools: interoperability of content and interoperability of tools. Vossen and Westercamp [23] identified one more level of interoperability in exchanging user data.

The interoperability of content was main focus of research in the past several years. Extensive research has been done, resulting with several published standards SCORM [24], IMS Content Packaging [25] and IMS Learning Design [25]. Separating content from tools and moving towards modular architectures opens up the possibility for exchange of tools, functionalities, semantics and control in a seamless and dynamic fashion.

Analyzing the current trends in the e-Learning and e-Assessment domain, where lots of emphasis is given to the level of interoperability between systems, exchange of content, functionalities and data not depending on the platform they work on, by using widely adopted standards, increasing system flexibility and pedagogical diversities supported, the new modern e-Assessment systems should be build with Service Oriented Architecture, based on encapsulating existing business functions as loosely coupled, reusable, platform-independent services which collectively realize required business objective.

4.1 Requirements of an "Ultimate" e-Assessment System

In [26] Sclater and Howie introduced the term "ultimate" online assessment engine analyzing it from user perspective and defining all types of users which exist in that system. Several approximations and assumptions regarding the internal data structures and data flows of the engine are taken into consideration, identifying the following purposes and possible uses of the system [26]:

- credit bearing tests which may be either formal examinations or continuous assessment;
- self assessment which may be authenticated self-assessment or anonymous self-assessment
- diagnostic tests enabling a student and/or tutor to evaluate the student's knowledge by pretesting before the course is commenced or post-testing in order to evaluate the effectiveness of the learning.

We will extend the definition of the "ultimate" e-assessment system with the following additional possible functionalities

- the assessment engine should support the "new" types of assessment: competence assessment, performance assessment, portfolio assessment and peer assessment
- the assessment engine should support all types of test delivery models (linear tests, dynamic linear, testlets, mastery models and adaptive tests) as defined in [27]

From architectural point of view the system should be able to

- work as a standalone e-assessment system
- exchange content, user data and components with other existing e-assessment systems
- be pluggable to any existing e-Learning LMS.
- be pluggable to any other application in business environment (Security, Library, HR, Financial etc)

The "ultimate" e-assessment system should also be compliant with the requirements that any complete conceptual model should in the long run comply to [28]:

- Flexibility: The assessment model can describe assessments that are based on different theories and models:
- Formalization: The assessment model describes assessments and its processes in such a formal way that it is machine-readable and automatic processing is possible. The formalization gives the possibility to extend the model if new developments in assessment arise.
- Reusability: The assessment model supports identification, isolation, decontextualization and exchange of useful objects (e.g. items, assessment units, competencies, assessment plans) and their re-use in other contexts.
- Interoperability and sustainability: The assessment model distinguishes the description standards from the interpretation techniques, thus making the model resistant to technical changes and conversion problems.
- Completeness: The assessment model covers the whole assessment process, including all the typed objects, the relations between the objects and the workflow.

- Explicitly typed objects: The assessment model expresses the semantic meaning of different objects within the context of an assessment.
- Reproducibility: The assessment model describes assessments in such a way that replicated execution is possible.
- Medium neutrality: The educational model for assessment, where possible, supports the use of different media, in different (publication) formats, such as computerized assessments on the web or paper and pencil tests.
- Compatibility: The assessment model matches available standards and specifications.

4.2 SOA in e-Assessment

Although Assessment is present as one of the main services in all mentioned frameworks, JISC [11] as organization developing the E-Learning Framework (ELF), has made significant steps forward in definition of the Assessment domain.

Following its strategy for creation of Reference Models for number of domains and identification of sub services in each domain, identified as one of the 5 prioritized domains in ELF, Assessment is extensively a subject of research in the past few years. Numbers of projects have been funded [29], among which FREMA (Framework Reference Model for Assessment) is the most comprehensive and is concerned with the definition of assessment domain.

The project gave definition of the domain creating “map of resource types that are considered important within the assessment domain, and … concept map of the common processes” [30], identified common usage patterns, developed use cases and defined Web Services in the domain. As a result of the project, these Core Services where identified: Assign, Author item, Author assessment, Validate assessment, Take assessment, Mark assessment, Moderate assessment, Grade Assessment and also 4 Supporting Services: Schedule, Notify, Track, Authorise and Authenticate. [31]

Besides these frameworks which intention is to define the e-learning domain at whole, another project whose main objective is “provide a technical and organizational Infrastructure that can be used by any citizen, team or organization to develop competences” [32] have identified assessment as a main tool for achieving its goal and have intention to develop new assessment model. Analyzing this model we have concluded that the model they have developed consists of these services: Assessment Design, Item Construction, Assessment Construction, Assessment Delivery, Response Evaluation, and Decision Making. During the development of this model no supporting services where identified. [33].

5. Modelling a common architecture

The lack of standardized and widely adopted architecture of e-Assessment systems, as well as valuable experience from practical realization and implementation of the existing architectures or parts of them, results with little experience about the real use of service oriented architecture in the design of e-Assessment systems and the influence it has on the assessment and learning process. Because of that, research on

standards and development work is underway in order to see what will be results from the implementation of the proposed models. A number of projects based on web services were funded in this domain in order to develop services or set of services.

Comprehensive overview of assessment projects is given in [34]. Most of them give practical realization of particular service identified by the FREMA, and propose extensions to (or verify) already existing standards. Some projects are more comprehensive, demonstrating the use of multiple services in SOA (ASSIS [35]).

The both architectures identified in 4.2 modularize the architecture of e-assessment systems in set of services which collectively can realize the required functionality that any "ultimate" e-assessment system should have. Still, both architectures concentrate on the architecture of e-assessment system as standalone application does not providing details of possible interaction between several e-assessment systems having the same architecture. Most of their research is concentrated on exchange of assessment content and little attention is paid to the exchange of services and functionality between systems.

The concept of pluggability is also not discussed and there are no examples how systems can interact or be pluggable to other systems both in educational or business environments.

In the process of designing the architecture of an "ultimate" e-assessment system we started from the point that any functionality that system has, should be implemented as a service. The whole system itself also should be considered as a service, realizing the global idea that it can be plugged to any LMS or other types of systems which would like to use some of its functionalities. These systems will use the system as a service.

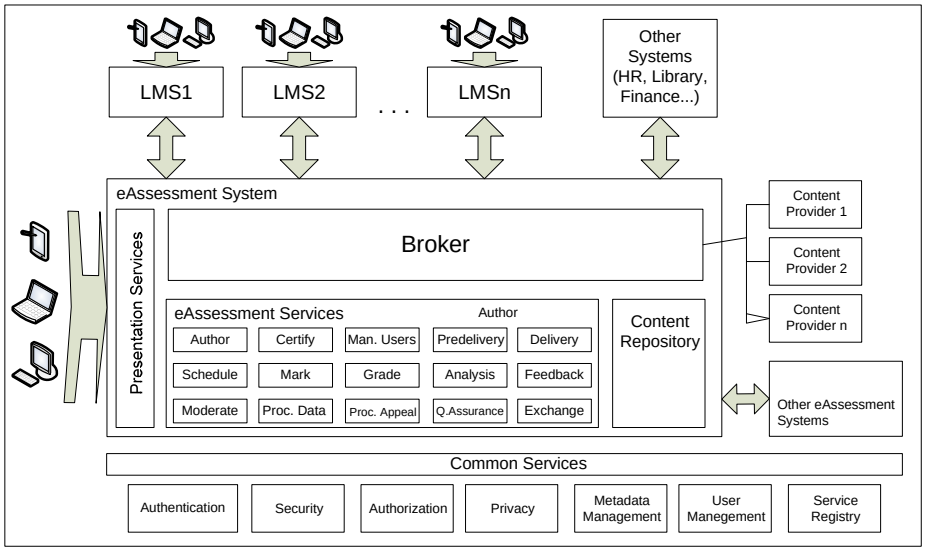

Figure 2: Architecture of an "ultimate" e-Assessment System

Figure 2 presents the high level abstraction architecture of the e-assessment system with its intradomain and interdomain interoperability links. As can be seen from the figure, the e-Assessment system can be used as a standalone system directly accessed by its users from different devices. The system is also accessible through any LMS system which can consume it as a service using widely accepted standards for content, user data and components interoperability.

Standards used for communication between LMSs and the eAssessment engine are IMS LIP and PAPI Learner for user modelling and personalization, IMS QTI for exchange of content and IEEE LOM or Dublin Core Metadata for exchange of metadata.

Internal architecture of the "ultimate" eAssessment System is also presented. The system has layered architecture and consists of presentation layer, common services layer, e-Assessment services layer and composite services layer (Broker). The services in e-Assessment layer and in common services layer are those identified in FREMA project mentioned above.

Presentation layer service components are primarily responsible for interacting with end-users and for transforming the actions of the end-user into calls against the available services. These services are operational only in cases when this e-Assessment system is used as standalone application.

In cases when the system is used by external LMSs or other systems (HR, Library, Finance etc), those systems communicate with Broker service which is capable to coordinate other services from lower layers in order to fulfil the request. The Broker service can orchestrate existing services from the e-Assessment Services layer or it can search for other specific services using the Service Registry. Service Registry is a UDDI like registry where description about available services is stored as well as information how these services can be invoked.

Another function of Broker service is to look for specific content in the local content repository or in other available repositories available. These external repositories can be part of other existing e-Assessment systems, or can be just offered by third parties as standalone services.

6 Conclusion

In this paper we have presented high level abstraction architecture of an "ultimate" e-Assessment system. It is designed using service oriented architecture where existing business functions are encapsulated as loosely coupled, reusable, platform-independent services which collectively realize required business objective. This architecture fulfills the requirements of an "ultimate" e-Assessment system defined. The system can be used as standalone application for e-Assessment both as compact application as well as application which can use its own services and services from other e-Assessment systems. Also, the system at whole can be used as a service and can be plugged to any existing Learning Management System, as well as other systems using existing standards for exchange of content, user data and metadata about the services which needs to be used. Further detailed specification is needed for the Broker Service which is capable of orchestrating and coordinating existing web

services registered in the service registry. Extension of the system can also be the addition of functionality for the Broker Service in order to make it capable of exchanging semantic information between systems.

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